The Consequences of Minimum Wage Laws: Some Theoretical Ideas Revisited

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Abstract

We develop an efficiency wages model, to study the effects of the imposition of a higher minimum wage on employment of heterogeneous workers, when employers use the wage and monitoring intensity to induce motivation. It is shown that when effort is adjusted to exogenous shocks then the wage and supervision, and employment and supervision can be either strategic complements or strategic substitutes. This finding provides a theoretical explanation of why the results of studies that try to identify the wage-supervision trade-off(Neal 1993, Kruse 1992, Leonard 1987), and do not control for effort may be hindered by omitted variable bias and thus are misleading. The total effect of a higher minimum wage on employment can be decomposed into two distinct effects; the 'partial' wage effect and the 'supervision' effect. We show that, when the wage and supervision are complements in providing incentives then employment and supervision are strategic complements, the supervision and the wage effect are counteractive and the total employment effect of a higher minimum wage is ambiguous. On the other hand if there is a trade-off between

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wage and supervision and complementarity between employment and supervision, then both employment and supervision fall, as a result of a higher minimum wage. Employment again falls, if the wage and supervision and employment and supervision are substitutes. In general, the magnitude of the positive employment effect of a higher minimum wage and the range up to which, one can increase the wage and increase employment are exaggerated if supervisory resources are fixed. Our analysis reveals that theoretical work on the efficiency wage approach of the minimum wage seems incomplete as the predictions of the seminal models(Calvo-Wellisz 1979, Rebitzer and Taylor 1995) in the field hinge on a number of simplified assumptions. Finally, our theoretical predictions reconcile with recent findings that point towards a zero, or small negative or positive minimum wage employment elasticity(Card and Krueger 1995, Brown 1999). Moreover, the fact that our model can provide a theoretical explanation of the recent findings from the fast food studies (Card and Krueger 1994, Katz and Krueger 1992), enhances the validity of our predictions.

1 Introduction

The minimum wage is a highly controversial policy issue among economists, policy makers and even social activists. On the one hand supporters argue that minimum wages consist an antipoverty device that combat exploitation and contribute to a more"egalitarian"distribution of income by bringing the living of the working poor in a minimum acceptable standard. On the other hand opponents argue that minimum wages are not so effective in reducing poverty, because most poor people are not in the labour market, and that a higher minimum wage will decrease employment of those that is initially aiming to benefit. Recent evidence suggest that an increase in the minimum wage compresses the wage distribution (Dickens et al. 1999), and that the majority of minimum wage earners tend to be at the bottom of the earnings distribution (Dolado et al. 1997, Card and Krueger 1995) and thus there is a positive relationship between poverty and low wages. Given these findings it is easy to understand why the employment effect of the minimum wage has concentrated so much attention, as it is the key hypothesis for investigation that could shed light to whether or not the minimum wage policy is beneficial for low-paid people. Until the late 1980s there was a consensus on the effects of the minimum wage on employment. According to the dominant competitive model of the labour market, a binding minimum wage will decrease employment of covered workers. Time series evidence (Brown et al. 1982) supported this prediction and any other theoretical model that predicted other than a negative effect (Jones 1987) it was viewed as an exception that proves the rule. In the late 1980s, and beginning of 1990s, some changes in the state and federal minimum wage laws in the US generated a good opportunity for further testing of the prediction of the negative employment effects of a minimum wage on employment. Card (1992a, 1992b), Card-Krueger (1994, 1995) and Katz-Krueger (1992) conducted a number of case studies and after reexamining past time-series studies with new data sets as well, concluded that an increase in the minimum wage may have positive or no-effect on the employment of covered workers. Card and Krueger (1995) tried to give an ex post rationalization of their findings by suggesting that their results may be driven because of the presence of monopsony in the low-wage labour market. Although in economics it takes a theory to kill a theory and facts can only dent a theorist's hide (Paul Samuelson's adage quoted in Card-Krueger 1995). Thus, there was a need for an alternative theoretical explanation of the non-negative effect of a minimum wage increase on employment of affected workers. As we noted above, the static monopsony model (Robinson 1933, Charles 1974) is widely presented in economics textbooks as a case where the neoclassical's model prediction of the effects of the minimum wage on employment is reversed. Although, the static monopsony model has been criticized as quite unrealistic, because low-wage labour markets are characterized by a large number of employers. In general, any environment that could give rise to an upward sloping labour supply at the firm level, can generate the monopsony result. Wage setting power and thus a finite elasticity of labor supply at the firm level may also stem from the existence of labour market frictions. Models accounting for search and recruiting frictions such that presented by Burdett and Mortensen(1989), Lang and Dickens (1993) and Manning (1993) provide a satisfactory theoretical explanation of the recent empirical findings of a positive or zero employment effect of a higher minimum wage. However wage-setting power may also arise by asymmetric information in the labour market. An asymmetric information environment may arise when employees action or type is imperfectly observable by the employer which in turn may be a reason for efficiency wages considerations. In efficiency wages models, in contrast with the neoclassical model of the labour market, worker's productivity depends on the wage, and thus under some cases an increase in the wage may increase employment (Manning 1995). There is a considerable amount of evidence, confirming the efficiency wages story, in low-wage industries. Krueger and Summers (1988), conducted an empirical investigation of the efficiency wages hypothesis by trying to explain the wage differences across industries and they concluded that interindustry wage differentials cannot be solely explained by the traditional neoclassical reasoning of differences in ability and working conditions, which implies that employers, also in some low-wage industries may pay efficiency wages. Moreover, there is evidence that larger in size establishments, pay higher wages (Lester 1967, Masters 1969, Mellow 1982, and Brown and Medoff 1989), suggesting that a potential reason for this observation may be efficiency wages arising from imperfect monitoring and shirking problems on the job. There is additional evidence(Groshen-Krueger 1990, Krueger 1991, Rebitzer 1995) supporting the shirking version of the efficiency wages theory, which also predicts that, at a given level of effort, an increase in the wage will decrease supervision, suggesting a wage-supervision trade-off. The above evidence are concerned also with some low-wage industries, as the restaurant, the hotel, the gasoline service and retail trade industries, where supervision also seems to be an important aspect of production. As suggested by the evidence and observations presented above, a shirking efficiency wages environment could possibly provide a fruitful basis to generate predictions on the employment effects of a higher minimum wage, in low-wage industries, where the minimum wage is particularly binding. In particular, a revised shirking model of Shapiro-Stiglitz (1984) as proposed by Rebitzer and Taylor (1995) generates a positive effect of a minimum wage on employment, even when the number of firms in the industry is large. Rebitzer-Taylor analysis has been cited in all reviews in the topic of the minimum wage as one of the alternative theoretical explanation of the increasing employment effect of a higher minimum wage. Although, some researchers believe that predictions generated by Rebitzer-Taylor model hinge heavily on a number of simplified assumptions. Chung-Cheng Lin(1999) extended Rebitzer-Taylor work to allow for workers heterogeneity and conclude that, after this assumption is relaxed, employment decreases as a result of the imposition of a binding minimum wage. Consequently they suggest that Rebitzer-Taylor result is driven because of worker's homogeneity. Moreover, Chung-Cheng Lin suggested that if in Rebitzer and Taylor model supervisory resources are unfixed then again their result breaks down. Furthermore, a model that it seems curiously neglected in the literature is presented by Calvo-Wellisz (1979). Calvo-Wellisz examined labor allocation and wage scale, for a competitive hierarchic firm, in a more general environment, than those presented by Rebitzer- Taylor and Lin. Their major result is that a binding minimum wage increases the quantity and quality of covered workers and decreases the quantity, quality and the wage of supervisors. Finally, Manning (1995) has been also concerned with the efficiency wage explanation of involuntary unemployment, but also examined the effects of a minimum wage increase under different efficiency wage environment. Manning presented a combined monopsony-shirking model, where workers differ in their valuation of leisure and firm has some ex ante ability to identify workers who are more likely to shirk and concludes that under this kind of environment an increase in the minimum wage will increase employment and may also decrease unemployment. However, the existing seminal models seem to have some limitations and we also suspect that may be their results are driven by some of their specific assumption that may not capture some of the true features of the low-wage labour markets. In contrast with Rebitzer and Taylor and Lin where supervisory resources are assumed to be exogenous, Groshen-Krueger (1990) suggest that empirical investigations of the wage -supervision trade-off which include supervision proxies as an explanatory variable are hindered by endogeneity bias as most of the times supervision consists a choice of the firm. Furthermore, as Rebitzer(1995) argues efficiency wage models apply only where employee actions or type is difficult to observe and thus we also believe that it is often the case that the employer cannot observe or imperfectly observes worker's type (in contrast with Manning's assumption) especially in cases where the type is determined by the employee's innate characteristic, such as the innate inclination to shirk. Finally, in Calvo-Wellisz, it may be the case that their main predictions hinge on the hierarchic structure of the firm or previous results on labor allocation and wage scale that stem from this setting. Particularly, Calvo-Wellisz present different variants of their model but they devote a minor part of their analysis on the effects of minimum wages on employment of production workers, and thus they do not show how and why results are changing, when slight alterations in the environment are made. Our aim is to develop a generalized efficiency wages environment that also allows for features that are not accounted by the existing seminal models in this theoretical approach of the minimum wage, and may be critical for the production of different predictions. Our model captures, explains and improves the results generated by the existing models in the efficiency wages approach of the minimum wage, but also allows for other predictions. Specifically, we show that under workers' heterogeneity the wage and supervision may not only be substitutes, as the efficiency wage theory predicts, but they may also be complements in providing incentives. Additionally, employment and supervision can be strategic substitutes and not only complements as the standard shirking efficiency wage model predicts. This may not be surprising, but it is a result that hasn't been produced by models of similar flavor (Calvo-Wellisz 1979). In particular, this result provides a theoretical explanation of why empirical investigations (Leonard 1987, Kruse 1992, Neal 1993) that attempted to estimate the wage-supervision trade-off and do not control for determinants of employee's perfomance, rendered inconclusive. Determinants of employees'perfomance (training etc.) are correlated with supervision and wages, creating a bias to the estimate of the wage-supervision trade-off. Under a shirking model with endogenous determination of supervision the employment effect of a binding minimum wage can be decomposed into two distinct effects; The 'partial' or direct wage effect and the 'supervision' effect. The sign(direction) of the 'partial' wage effect of an increase in the minimum wage depends on the sign of the partial elasticity of employment w.r.t the wage, whereas the sign(direction) of the 'supervision' effect depends on the sign of the product of the partial elasticity of employment w.r.t the quantity of supervisory resources and the partial elasticity of supervision w.r.t the wage. It is shown that the 'partial' wage effect, which is equal to the partial elasticity of employment w.r.t the wage, is always negative, if workers are heterogeneous, but it is positive, under homogeneous workforce. When workers are heterogeneous, if the wage and supervision are complements in providing incentives(the partial elasticity of supervision w.r.t the wage is positive) then employment and supervision are strategic complements(the partial elasticity of employment w.r.t supervision is positive) , the 'partial' wage and the 'supervision' effect are counteractive and thus an increase in the minimum wage has an ambiguous effect on employment of covered workers. If certain conditions hold for the partial elasticity of employment w.r.t supervision and the wage respectively and the partial elasticity of supervision w.r.t the wage, then it is possible for both employment and supervision to rise, after an increase in the minimum wage. The wage and 'supervision' effect are also counteractive, under substitutability between wage and supervision and employment and supervision. However, under this case employment falls but supervision is possible to rise reflecting a substitution of supervisors for workers. Finally, when there is a trade-off between wage and supervision and complementarity of employment and supervision as the efficiency wages models predict then both employment and supervision fall. When workers are homogeneous and supervision is endogenous, the partial wage effect is exactly offset by the 'supervision' effect, and thus employment remains unchanged, while supervision falls, after the imposition of a binding minimum wage. In general, another implication of the decomposition of the minimum wage effect on employment into the partial wage and the 'supervision' effect is that the minimum wage employment elasticity (whatever its sign) is more pronounced under fixed than under endogenous supervisory resources[1]. Moreover, the range up to which, one can increase the wage and increase employment is smaller, when the supervision is determined endogenously. Therefore, given this last finding and the fact that in Rebitzer and Taylor model, supervisory resources are assumed to be fixed, it is clear that

[1]The only case, where this doesn't hold is under case 2 in the following sections

Rebitzer and Taylor exaggerate the positive minimum wage employment elasticity and the range up to which an increase in the wage will increase employment. Rebitzer and Taylor result, is sustained, for a just binding minimum wage, under endogenous supervision, only if supervisors decide between shirking or working as well as workers and technology exhibits constant returns to scale into efficient labour units. It is also shown that, in Calvo-Wellisz the assumption of constant returns to scale in efficient labour units is critical for their result that up to a point an increase in the minimum wage increases the employment of workers and decreases that of supervisors. Our predictions reconcile with recent evidence(Card-Krueger 1995, Brown 1999) of the estimated minimum wage employment elasticity, which point towards a small negative, positive or even a zero effect of a higher minimum wage on the employment of covered workers. In particular, our model may provide an alternative theoretical explanation of the employment gains reported in the popular fast food case studies conducted by Card and Krueger (1994) and Katz and Krueger (1992) which suggest that after the minimum wage increase, employment increased in low-wage, more affected restaurants, relative to high-wage, less affected restaurants.

2 The Worker

Consider a competitive industry, with a large number of identical firms, where the representative firm recruits a number of low-skilled, low-wage workers to produce a single product. Workers are heterogeneous, infinitely lived and risk neutral with instantaneous utility function given by

$$U(w, e; \theta) = w - \theta e, (1)$$

where θ is the parameter of heterogeneity and denotes the marginal disutility of effort, which will assume that it is uniformly distributed between zero and one. The higher the θ the more the worker dislikes to put forth effort. Moreover, a worker of type θ enjoys spending wage w and dislikes putting forth effort e. We will assume that the firm cannot observe the worker's characteristic, because of asymmetric information and thus it cannot screen the workers with higher θ[2]. A worker is hired at the beginning of each year and then he or she must decide whether he or she will work or shirk. If the worker shirks then he/she contributes

[2] If θ is observable then the model becomes similar to Manning.

zero effort and if he or she works then he or she contributes a positive level of effort which for simplicity we will assume it is equal to one. The employer cannot perfectly observe employees' effort, even though he employs supervisors who monitor workers and try to detect shirkers. We will assume that dismissal threats, is the only device available to employers to prevent shirking and thus there is no other way to solve the problem of asymmetric information(bonding or entry fee). On the other hand supervisors are employed from a pool, homogeneous, non-shirking workers, and their price is given and independent of the wage of workers[3]. The instantaneous probability of detection of a shirker is given by:

$$P = Min\{\frac{N}{L}, 1\}, (2)$$

,where $N$and L is the quantity of supervisors and workers respectively employed by the firm[4]. We will assume that 1 in equation (2) is never binding[5], which holds as long as the cost of supervision is increasing sufficiently fast with the number of supervisors. Furthermore, detection is taking place at the beginning of each period and workers who are caught shirking flow to unemployment and receive an unemployment benefit μ. The instantaneous probability that a worker will be separated from his or her job due to exogenous reasons is q. Let r represent the discount rate and s to be the exogenous probability that an unemployed worker will find a job. The present discounted value(p.d.v) of expected lifetime utility of a worker of type θ, when he or she is not shirking, V^w can then be written as:

$$V^w = w - \theta e + \frac{(1-q)V^w + qV^u}{(1+r)}, (3)$$

[3]This assumption is made to simplify our analysis by reducing the margins along which employers adjust. We could also think supervisory resources as based solely on capital services (cameras for example), fact which could justify the exogenous price of supervision. However, in one of the following sections we relax this assumption in order to check if it is critical for our results.

[4]The choice of this probability of detection seems reasonable under the assumption that supervision is based on labour services, but it can be also used in the case where supervision is based on capital services denoting the capital per supervisee ratio. As it is suggested by Odiorne (1963) the supervisory resources-to-staff ratio is likely to be highly correlated with the extent of employee monitoring. In our case the probability of detection and the degree of monitoring intensity are tautosimous.

[5]If one in equation (1) was binding then the model specializes to the standard one in the theory of the firm.

where V^u is the p.d.v of expected lifetime utility of an unemployed worker. Similarly, the p.d.v of expected lifetime utility of a shirker $V^s$is given by:

$$V^s = w + \frac{(1-P)(1-q)V^s + [1-(1-P)(1-q)]V^u}{(1+r)}, \quad (4)$$

Finally, the p.d.v of expected lifetime utility of an unemployed worker V^u, is given by the following equation:

$$V^u = \mu + \frac{sV^w + (1-s)V^u}{(1+r)}, \quad (5)$$

We are assuming that once a worker chooses to shirk he will always shirk, and if an unemployed worker finds a job he will work rather than shirk. A type θ worker will shirk unless the p.d.v of expected lifetime utility of being a shirker is less than or equal to that of being a worker. This is expressed by the following equation[6]:

$$V^w \geq V^s, \quad (6)$$

Combining (3), (4), (5)and (6)we obtain equation (7)

$$w \geq \mu + \theta e + \frac{\theta e(r+s+q)}{P(1-q)}, \quad (7)$$

Equation (7) is known as the non-shirking condition (NSC), and expresses the set of all wages that prevent shirking for any given level of e, μ, θ, r, s, q and P. The firm will be willing to pay the lowest possible wage associated with non-shirking of a worker of type θ. We will assume that in case of indifference workers will choose to work rather than shirk. Therefore, the NSC holds with equality. It is intuitive that the non-shirking wage w will be higher, the higher the unemployment benefit μ, the interest rate r, the rehiring rate s, the quit rate q, the more onerous the worker finds putting forth effort (the higher θ) and the lower the probability of detection P. When workers are homogeneous the NSC is used to determine the lower wage bound that prevents shirking (see following section). In this case workers are heterogeneous and

[6]In fact there is a continuum of such equations, arising by the continuity of the parameter θ.

we will assume that the employer pays a uniform wage[7]. Therefore, the NSC cannot determine the lower wage that prevents shirking for each worker, but instead of that it determines the marginal type of worker who is indifferent between shirking and non-shirking, at a given wage, employment and supervision. Additionally, using equation (2), (7)and the fact that each worker contributes one unit of effort when he or she works, we obtain equation (8):

$$\theta^* = \frac{N(1-q)(w-\mu)}{N(1-q)+(r+s+q)L}, \quad (8)$$

Equation (8)expresses the marginal type of worker θ^*who will be indifferent between shirking and working, at any different value of wage, employment and supervision. It is rather intuitive that workers with θ less than θ^*will choose to work. Because of our prior assumption that θ is uniformly distributed between 0 and 1, the cumulative density function of θ^*will be $F(\theta^*) = \theta^*$. Using this property of the uniform distribution, θ^*determines the proportion of non-shirkers in the workforce. Because we have assumed that a non-shirker's effort is 1, θ^*denotes also average effort. According to (8) the proportion of non-shirkers is increasing in the wage and supervision and decreasing in the number of employees. In other words, average effort is positively related to the wage and monitoring intensity expressed by the probability of detection. Thus the marginal type of non-shirker, or average effort or the proportion of non-shirkers can be expressed as a function of the wage and monitoring intensity. Hence (8)becomes :

$$\begin{aligned} \theta^* &= \theta^*(w, L, N), \text{ (9), with } \theta^*_w > 0,\ \theta^*_N > 0,\ \theta^*_L < 0,\ \theta^*_{ww} = 0, \\ \theta^*_{NN} &< 0,\ \theta^*_{LL} > 0,\ \theta^*_{wL} < 0,\ \theta^*_{wN} > 0,\ \theta^*_{NL} \lesseqgtr 0 \end{aligned}$$

It is rather intuitive that average effort increases with the wage and quantity of supervisory resources and decreases with the number of employees. Moreover, it is worth to try to interpret the sign of the cross partial derivatives of average effort w.r.t employment, supervision and

[7]If the firm could pay different wages to different workers, and thus pay more workers that are more inclined to shirk, this could be perceived as unfair by other workers and thus this case would be vulnerable to moral hazard problems. Since the firm cannot be a perfect discriminating monopsonist, there is no adverse selection problem.

the wage. The fact that θ^*_{wL} is negative and θ^*_{wN} is positive means that the wage is more effective in inducing workers to transit from shirking to working when employment is higher, and supervision is held constant and when supervision is higher and employment is held constant respectively. Therefore, the average effort is more responsive in the wage when incentives are relatively better. Alternatively the wage is more effective in enhancing employee's quality when employees are relatively more motivated. The intuition behind this result is that more motivated employees (because for example of more stringent monitoring), are more responsive in putting forth effort, for the same wage increase, relative to less intensively monitored employees because the probability of being detected and dismissed is higher. On the other hand, given that it is more likely for $\theta^*_{NL}$to be negative[8] rather than positive[9] and considering also the fact that θ^*_{wN} is positive, we deduce that supervision is also more effective in inducing effort when motivation is relatively higher. This is quite surprising as one could think that the more supervision increases, the more motivated is the workforce and thus the less responsive is the proportion of non-shirkers to any wage change (this is the case in Calvo-Wellisz model). In fact, most of the seminal efficiency wage models (Shapiro-Stiglitz 1984) generate the results that effort is more responsive in incentive devices, when motivation is relatively lower. A possible explanation of our finding may be that, because θ^*_{NL} is negative and θ^*_{wN} is positive, workers may not like supervision and that is why an increase in supervision increases the negative effect of an extra employee on average effort, given the wage, and also this is why a higher wage increases the proportion of non-shirkers by more when supervision is higher, because it is used to compensate workers for the extra supervision[10].

[8]Note that $\theta^*_{NL} > 0 \Leftrightarrow \frac{(1-q)}{(r+s+q)} > \frac{L}{N}$.

[9]If $\theta^*_{NL} > 0$, this means that supervision is more effective in inducing effort when motivation is relatively lower. Given, that $\theta^*_{wN} > 0$, $\theta^*_{wL} < 0$, which means that the wage is more effective in inducing effort when motivation is higher, we would expect, $\theta^*_{wN} > 0 \neq \theta^*_{Nw} < 0$. Therefore, it is more intuitive, given this interpretation, for $\theta^*_{NL} < 0$.

[10]In general, there are a lot of reasons why workers do not like supervision; firstly workers may perceive extra supervision as an intrusion in their activities or a sign of distrust (Cowen-Glazer 1996, Chang-Lai 1999), or because they have to put more effort in the presence compared to the absence of supervision. However, there are models which suggest that supervision decreases effort (Fray 1993a,b), in our model as it is an efficiency wage model this cannot happen. We just use that argument in order to show that, if workers do not like supervision they will be more reluctant

3 The Firm

The employers decision problem is to choose the optimal combination of the wage, employment and supervision in order to maximize profits subject to the non-shirking condition. Since firms cannot distinguish between workers they recruit their employees from the labour force at random. The typical firm' s profit maximization decision can be written as:

$$\max_{w,L,N} \Pi = \max_{w,L,N} f[\theta^*(w,L,N)L] - wL - cN, \ (10)$$

where $f[\theta^*(w,L,N)L]$, is the production function which is equivalent to the real revenue function. Note that c stands for the exogenously given price of supervisory resources, where we assume that c is sufficiently high, so the firm cannot achieve perfect observability of effort. We will assume that the production function exhibits decreasing returns to scale in efficient labour units($f^{'} > 0$, $f^{''} < 0$)[11]. The first order conditions associated with L, w and N are:

$$\Pi_L = [\theta^*_L(w,L,N)L + \theta^*(w,L,N)] * f^{'} - w = 0, \ (11)$$

$$\Pi_w = [\theta^*_w(w,L,N) - 1] * L * f^{'} = 0, \ (12)$$

$$\Pi_N = [\theta^*_N(w,L,N)L] * f^{'} - c = 0, \ (13)$$

Equation (11)expresses the fact that in equilibrium the worker's wage is equal to his/her net contribution in the firm's revenue. An extra employee increases revenue because of the extra efficient labour units but also decreases revenue because average effort falls, when employment increases marginally and everything else is kept constant. In order to examine the effect of the imposition of a binding minimum wage for

to increase effort, when supervision is increased and that is why they will need a compensating wage differential to increase their effort relatively more ($\theta^*_{Nw} > 0$) and also why an increase in employment will induce more people to transit from working to shirking, when supervision is relatively higher ($\theta^*_{NL} < 0$).

[11] This seems quite reasonable as decreasing returns to efficient labour units imply diminishing marginal productivity of employment, supervision and wage as efficient labour units rise. It is intuitive to expect, the more efficient is the labour force the less the marginal contribution of the higher wage and supervision into output, through higher motivation. Similarly, the more efficient the labour force the less we expect an increase in employment (in heads) to contribute to production.

workers we will assume that the wage is given[12]. As we are using a general functional form for the production function, the model cannot be solved explicitly. That is why we are going to use a graphical analysis for the comparative statics results. Equations (11) and (13) are the equations that determine the optimal L for any given w, and the optimal N, for any given w and c respectively. Moreover, these equations can be used to determine the loci of equilibrium L and N, in (L, N) space respectively and their intersection determines the equilibrium pair of L and N, for any given wage. Consequently a change in the wage will shift both loci and the optimal pair of L and N will change. In order to determine the effect of an exogenous increase in the wage of workers due to the imposition of a minimum wage in the labour market where the typical firm operates we need to determine the slopes and the shifts of the equilibrium loci of $L$and N[13]. Let NN the locus of optimal supervisory resources for any given wage of workers and supervisors and LL the locus of optimal employment, for any given wage of workers. The direction (sign) of the shifts and slopes of LL and NN loci depend on the signs of Π_{Lw} , Π_{Nw} and Π_{LN} respectively[14], which are given by:

$$\begin{aligned}\Pi_{Lw} &= [\theta^*_w(w,L,N)*L][\theta^*_L(w,L,N)*L+\theta^*(w,L,N)]f^{''} \\ &\quad +[\theta^*_{Lw}(w,L,N)*L]f^{'}+[\theta^*_w(w,L,N)f^{'}-1], \quad (14)\end{aligned}$$

$$\Pi_{Nw} = [\theta^*_w(w,L,N)*L][\theta^*_N(w,L,N)*L]f^{''}+[\theta^*_{Nw}(w,L,N)*L]f^{'}, \quad (15)$$

$$\begin{aligned}\Pi_{LN} &= [\theta^*_N(w,L,N)*L][\theta^*_L(w,L,N)*L+\theta^*(w,L,N)]f^{''} \\ &\quad +[\theta^*_{LN}(w,L,N)*L+\theta^*_N(w,L,N)]f^{'}, \quad (16)\end{aligned}$$

[12] Under this environment, the only case under which the wage will be given is when the wage is set exogenously (for example by government) above the equilibrium wage. We need the wage to be given in order to do comparative statics and also we need the condition for the equilibrium wage in order to see how the results are affected when this condition is violated.

[13] From the second order conditions(SOC) of profit maximization, it can be derived that, both first order conditions(FOC) for N and L slope downwards or upwards in (L, N) space depending on the sign of Π_{LN} (The slopes are given by: $\frac{\partial L}{\partial N}|_{LL} = -\frac{\Pi_{LN}}{\Pi_{LL}}$ and $\frac{\partial L}{\partial N}|_{NN} = -\frac{\Pi_{NN}}{\Pi_{NL}}$). Again using the SOC we derive that, whatever is the sign of Π_{LN}, the slope of the FOC for N is always steeper than the slope of the FOC for L in (L, N) space. Additionally, the shifts of the locus of optimal L and the locus of optimal N are given by: $\frac{\partial L}{\partial w} = -\frac{\Pi_{Lw}}{\Pi_{LL}}$ and $\frac{\partial N}{\partial w} = -\frac{\Pi_{Nw}}{\Pi_{NN}}$ respectively.

[14] From the SOC for profit maximization we know that Π_{LL} and Π_{NN} are both negative.

it is easy to show that the first two terms in (16) are negative. As far as for the third term is concerned, from (12) we get that $\theta^*_w(w, L, N)f' - 1 = 0$, evaluated at the optimum. Therefore for a binding minimum wage the last term in (16) is negative (zero, for a just binding minimum wage) and therefore a higher wage decreases the marginal profitability of employment, given everything else, and thus employment must fall. This simply means that LL locus will shift down, after the minimum wage increase. In order to derive the final change in employment of workers and supervisors, after the minimum wage increase, we need to check what will be the change in supervision, as any change in supervision will affect employment of workers and vice verca. The first term in (15) is negative, because of the diminishing marginal product of supervision in efficient labour units and reflects the standard efficiency wages prediction of a trade-off between the wage and supervision, holding effort unchanged (i.e a higher wage, ceteris paribus, must cause a relaxation in monitoring intensity and thus supervision falls). On the other hand, the second term in (15) is positive, and expresses the fact that an increase in the wage has also an increasing effect on the marginal product of supervision, everything else equal, because a higher wage increases the responsiveness of average effort in supervision (as it is shown in (8)) possibly because after the wage increase it pays employers to increase effort and effort is more responsive in an increase in supervision when the wage is relatively higher. This is an implication of the fact that θ^*_{Nw} is positive, i.e there will be more intramarginal workers that transit from shirking to working, for any wage increase, when the firm employs relative more supervisors. The effect of a higher wage on the optimal quantity of supervisors will depend on which of the two effects dominates. The condition for the change in the marginal product of supervision w.r.t to the wage is given by equation (18):

$$\Pi_{Nw} > 0 \text{ if and only if } -\frac{(\theta^* L) * f''}{f'} < 1, (17)$$

where $-\frac{(\theta^* L) * f''}{f'}$ is evaluated at the optimum. The term $-\frac{(\theta^* L) * f''}{f'}$ in (17) is similar to the Arrow-Pratt measure of relative risk aversion, in the sense that is a relative measure of the concavity of the production or real revenue function in a neighborhood of the optimal wage. It is rather intuitive why the direction of the shift of NN locus depends on the concavity of the production function, evaluated at the optimum, since the concavity of the production function determines the diminishing degree of the marginal product of supervision for a wage increase above the equilibrium wage. Therefore, if the concavity of the production function at the optimum is such that (17) is true, an increase in the wage will increase the marginal product and thus the optimal quantity of supervisors, holding everything else constant, suggesting that under specific conditions wage and supervision are complements in inducing more effort. If (17) is true, then NN locus shifts up if NN is negatively sloped, and down if the slope of NN is positive. This finding is not against the standard shirking efficiency wage prediction that an increase in the wage, in order to keep effort unchanged must necessarily lead to a decrease in supervision. Particularly, as (17) must always hold in equilibrium, it becomes apparent that if the wage increases, ceteris paribus, supervision falls. In our case, complementarity between the wage and supervision may arise because, even though after the wage increases, effort must remain in the maximum capacity level ($e = 1$), employers adjust optimally the proportion of non-shirkers. If it pays the firm to increase the proportion of non-shirkers, after the increase in the minimum wage, then supervision will be increased, as we have already noted that when the wage is higher, supervision is more effective in inducing average effort. This finding suggests that, when effort is binary and employers use the wage and supervision to adjust also other qualitative characteristics of workers, or when effort is continuous (in this case average effort $\theta^*$is continuous), then it may be optimal for the employer, either to use the wage and supervision as complements or as substitutes in providing incentives. Furthermore, by (16) we deduce that there are two opposite effects of a change in the quantity of supervision on the marginal revenue product of labour. On the one hand an increase in supervision decreases the marginal product of employment, as it is implied by the diminishing returns exhibited by the production function in efficient labour units. The intuition for this result is that with more supervision the labour force is more efficient and the same output can be produced by using less employees in heads. The reduction in the number of employees will enable the firm to offset some of the cost of a higher wage. On the other hand, an extra supervisor increases monitoring intensity, as it increases the probability of detection, decreases the propensity to shirk and thus increases the marginal product of labour. Hence there is ambiguity for the sign of Π_{LN}. Consequently, an increase in supervision, given everything else constant may increase or decrease employment. Again this finding does not reverse the efficiency wage prediction that results from the same rational as the wage-supervision trade off, i.e that an increase in supervision in equilibrium, ceteris paribus, will increase employment[15]. It is again because of the continuity of the employees efficiency variable (θ^*) that employment and supervision may be either strategic complements or substitutes. The ambiguity of the change in the marginal product of employment if quantity of supervision changes will be resolved only if we know which of the two effects dominates. The sign of Π_{LN} is determined by the following condition:

$$\Pi_{LN} > 0 \text{ if and only if } -\frac{(\theta^* L) * f''}{f'} < 2^{16}, \quad (18)$$

again $-\frac{(\theta^* L) * f''}{f'}$ is evaluated at the optimum. The sign of Π_{LN} depends on the concavity of the production function in a right neighborhood of the equilibrium wage, for the same reason as the sign of Π_{wN}. If (18) holds then both NN and LL loci slope upwards. Combining (17)and (18),we obtain the following propositions.

Proposition 1 If the wage and supervision are complements in providing incentives, then employment and supervision are strategic complements .

Proposition 2 If employment and supervision are strategic substitutes, then wage and supervision are substitutes in providing incentives

Proposition 3 If the wage and supervision are substitutes in providing incentives, then employment and supervision may be either strategic substitutes or strategic complements.

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[15]The same rational of the standard shirking efficiency wage model is used to predict also that an increase in the wage, ceteris paribus, will increase employment. The empirical analogue of this latter positive relationship between employment and the wage is the employer size wage effect (Brown-Medoff 1989). Again, because of the wage and employment change to adjust average effort, we derive that, under our environment an increase in the wage, ceteris paribus will decrease employment. Note that this latter result is unambiguous.

[16]It is possible to show, as we will demonstrate it in the following analysis, that there may exist a class of increasing and concave functions, that are widely used in economics for which (18) and (19) hold for every value in the domain of the function. Moreover, it is true that, $\frac{x * f''}{f'} = 1 \iff f(x) = \gamma \log x$, and that for any concave transformation of $f(x) = \gamma \log x$, $\frac{x * f''}{f'} > 1$.

The above propositions determine the 3 different frameworks, under which we will analyze the effects of the imposition of a binding minimum wage, when employers use the wage and supervision to provide incentives and employees differ in their innate aversion to exert effort on the job. We have just shown that when in general employee's performance variable is continuous, it is ambiguous whether or not there is a trade-off between the wage and supervision or if there is complementarity between employment and supervision or even if there exist a positive relationship between wages and employer's size as the conventional shirking efficiency wage model predicts. This may not be surprising but it has some important empirical implications. Actually, we provide a theoretical explanation of the fact that many empirical studies (Leonard 1987, Kruse 1992, Neal 1993) that attempted to identify the wage-supervision trade-off, in order to check the validity of the predictions generated by the shirking efficiency wage model, and do not control for effort or determinants of employee's performance, rendered inconclusive. Using, simple econometric intuition, determinants of employee's performance, other than supervision (training, screening procedures etc.) are correlated with supervision and the wage causing a bias to the estimate of the wage-supervision trade-off. Other studies (Groshen-Krueger, 1990, Krueger, 1991, Rebitzer, 1995) that try to identify causes of exogenous variation in supervision intensity, in order to deal with the endogeneity problem generate results that are consistent with the trade-off prediction.[17] Finally, dividing (11) by (13) we get:

$$\frac{N}{L} = \sqrt{\frac{(r+s+q)w}{(1-q)c}}, \quad (19)$$

From (19), it is apparent that an increase in the wage of production workers, increases the intensity of monitoring, holding everything else constant. However, monitoring intensity is enhanced by various ways, that vary according to the relationship between inputs, as we will show in the following sections. This implies, that it is optimal for the firm after the increase in the wage to increase average effort or the proportion of non-shirkers by increasing monitoring intensity. Moreover, it is intuitive that the higher the exogenous propensity to shirk (the higher r, s, q) the higher the optimal intensity of monitoring. By manipulating equation

[17] However, these studies were concerned with sources of the endogeneity of the supervision proxy other than employees effort.

(19) we obtain :

$$\frac{w}{c} = \frac{(1-q)N^2}{(r+s+q)L^2}, \quad (20)$$

equation (20) implies that workers are paid less than supervisors[18], a finding which reconciles with evidence as well as conventional wisdom and it is justified by the personnel literature argument that supervisors are likely to be more effective when they are paid more than the workers they supervise, since pay symbolizes a worker's prestige and authority[19].

3.1 Case 1

We have already proved that Π_{Lw} is negative (LL shifts down)[20], for all changes in w. Suppose that proposition 1 is true, which means that Π_{NL} is positive (LL and NN have positive slope) and Π_{Nw} is also positive (NN shifts down). The change in the equilibrium employment of workers is illustrated in figure 2. As it is indicated in the figure, all changes associated with increasing monitoring intensity (N rises L falls, N rises more than L, N falls less than L), after the imposition of a binding minimum wage, as suggested by (20)are possible. The effect of a higher minimum wage on the optimal employment can be decomposed in two distinct effects (see appendix for proof). The one is the 'direct' wage or 'partial' wage effect that decreases employment always as it is proved by (14), for given supervision, and the other is the 'supervision'effect, which in this case is positive[21]. On the one hand, the higher wage, keeping su-

[18] We previously argued that $\theta^*_{LN} < 0$, which is equivalent to $\frac{(1-q)}{(r+s+q)} < \frac{L}{N} < (\frac{L}{N})^2$, as $\frac{L}{N} > 1$, by the imperfect observability of effort. Thus, as $\frac{(1-q)}{(r+s+q)} < (\frac{L}{N})^2 \Rightarrow \frac{w}{c} < 1$, it is true that workers are paid less than supervisors.

[19] As Taylor (1959) puts it, "For a man to believe he is in truth 'the boss,' he must know he is receiving more pay that the men and women he supervises and, with few exceptions, more than any employee in the operation who occupies a non-supervisory job."

[20] Note that the marginal product of labour may rise or fall after the increase in the minimum wage. It can be shown that the marginal product of labour increases if and only if $-\frac{(\theta^* L)*f''}{f'} < 1$. This is also the condition for an increase in the marginal product of supervision, after an increase in the wage. However, even if the marginal product of labour increases, the marginal cost of labour (the wage here), increases always by more and employment falls.

[21] The partial wage effect, which is the shift of LL locus is given by $\frac{\partial L}{\partial w} = -\frac{\Pi_{Lw}}{\Pi_{LL}}$, and thus $sign(\frac{\partial L}{\partial w}) = sign(\Pi_{Lw})$, as Π_{LL} is always negative by the second order conditions of profit maximization. Similarly, the supervision effect depends on the

pervision constant, will decrease employment, but on the other hand the higher wage will increase supervision, given everything else constant, and more supervision, in this case increases employment, as we have assumed that the necessary and sufficient condition (equation (17)) for complementarity of the wage and supervision and employment and supervision holds. Therefore under the above assumptions, the change in employment of covered workers depends on which of the two effects dominates. The 'supervision' effect is more likely to dominate the larger the shift of the NN locus (the more sensitive is supervision in wage changes) and the more steeply sloped is the locus of optimal employment LL at any given wage(see appendix). Similarly, it can be shown that the effect of a higher wage on supervisory resources is decomposed into a 'direct' wage effect, employment kept fixed and the so called 'employment' effect[22]. Supervision increases, under this case, as a result of the higher wage, if and only if the 'partial' wage effect dominates the 'employment' effect i.e the higher the shift of NN (the more elastic is supervision w.r.t the wage, given employment), the smaller the shift of LL (partial elasticity of employment w.r.t the wage) and the steeper the slope of NN in (L, N) space (the smaller is the partial elasticity of supervision w.r.t employment). If, we assume that supervision is fixed at the initial optimal choice level and thus cannot adjust in an exogenous increase in the wage (perhaps because it is based solely on capital services), then employment is definitely decreased. This result is similar to Chung-Cheng Lin (1999) who has shown that an increase in the minimum wage will decrease employment, in a labour market which is characterized by imperfect monitoring and thus shirking problems, if workers are heterogeneous and supervisory resources are fixed. Furthermore, Chung-Cheng Lin claimed that if supervisory resources are flexible again employment will be decreased. Their explanation for this conjecture is that, as long as the worker is paid a wage that is equal to his marginal product, the monopsony result, that employment will be increased for a modest increase in the wage cannot be generated. We show that this may not be true, under this case. In fact the result is ambiguous and depends on the magnitude of the

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slope of LL locus and on the shift of NN locus(see appendix for proof) and is given by: $\frac{\partial L}{\partial N}|_{LL} * \frac{\partial N}{\partial w} = [-\frac{\Pi_{LN}}{\Pi_{LL}}(-\frac{\Pi_{Nw}}{\Pi_{NN}}]$ with $sign(\frac{\partial L}{\partial N}|_{LL} * \frac{\partial N}{\partial w}\ ) = sign(\Pi_{Nw} * \Pi_{NL})$.

[22] The 'direct' wage effect on supervision is given by the shift of NN due to the wage change which is given by: $\frac{\partial N}{\partial w} = -\frac{\Pi_{Nw}}{\Pi_{NN}}$. The employment effect on supervision is given by: $\frac{1}{\frac{\partial L}{\partial N}|_{NN}} * \frac{\partial L}{\partial w} = (-\frac{\Pi_{NL}}{\Pi_{NN}}) * (-\frac{\Pi_{Lw}}{\Pi_{LL}})$, and it depends on the inverse of the slope of NN in (L, N) space and on the shift of LL due to the wage change.

partial elasticity of employment w.r.t the wage (the partial wage effect) and the quantity of supervision respectively, and the partial elasticity of supervisory resources w.r.t the wage(the product of the last two elasticities consists the so-called 'supervision' effect). The employers problem is essentially to choose the wage, employment and supervision to elicit the optimal proportion of non-shirkers. As suggested by (20), after the wage increase it pays the employer to increase monitoring intensity in order to increase the proportion of non-shirkers. Monitoring intensity is increased by three possible ways depending on the magnitudes of the elasticities of employment and supervision w.r.t the wage and supervision w.r.t employment. For example under certain conditions, the firm may choose to fire workers and hire more supervisors. This is because, initially with a higher wage the labour force is more efficient and less employees are needed to produce the same output. With less employees the firm needs less supervisors, but on the other hand the increase in the wage, increases the marginal product of supervision by more than the amount that would exactly offset the negative employment effect on supervision and supervision rises. On the other hand the firm may choose to decrease both employment and supervision, because the higher wage increases efficiency through motivation,but increases also the cost and thus the firm decreases both employment and supervision to decrease the cost generated by the higher wage. Although, employment will fall faster than supervision to keep efficiency high enough for profitability. Finally, the firm may find optimal to increase both supervision and employment. The firm is initially supply constrained as an extra worker must be paid the given wage but also entails a monitoring cost. The higher wage increases the marginal product of supervision and thus the number of supervisors and because with more supervisors more workers can be monitored, the number of workers increases. Note that in this case we show that the number of supervisors is increasing by more than the number of workers, because more workers reduce average effort and thus supervision must increase faster for efficiency of the workforce not to be decreased. Consequently, the proportion of non-shirkers is higher compared to the pre-minimum wage equilibrium state. An intuitive explanation for that could be that an increase in the wage, although it increases average effort, everything else kept constant, it increases effort less that the amount that would compensate employers for the higher wage.

3.2 Case 2

Let Π_{Nw} being negative and Π_{LN} to be positive,(the state described by proposition 2) to be the case. In other words, if the wage is increased above the equilibrium level then supervision falls, everything else kept constant. Similarly, if employment increases, given everything else constant, supervision must rise. These are the standard predictions generated by the efficiency wage theory (trade-off between wage and supervision and complementarity between employment and supervision). The change in the pair of equilibrium L and N, is depicted in figure 3. In this case the result is unambiguous: an increase in the minimum wage will decrease both employment of workers and supervisors. Under this case, the wage and the 'supervision' effect are moving to the same direction (both are negative) and thus employment of covered workers will decrease. Similarly, both the partial wage and the 'employment' effect on supervision are negative and thus supervision falls. However, as we proved in the previous section, monitoring intensity increases, under all cases, which implies the optimal quantity of supervision is less elastic w.r.t the wage in equilibrium, than optimal employment. The above conditions ($\Pi_{Nw} < 0$ and $\Pi_{LN} > 0$), hold in equilibrium also in Calvo-Wellisz (1979)[23]. The difference between Calvo-Wellisz environment and the case we are examining in this section is that in their model, provided that the minimum wage is not set too high, employment increases for an increase in the minimum wage, when supervision is held constant

[23] Calvo-Wellisz assume a two layer hierarchic organization, where employees in the first layer are production workers who are supervised by employees in the second layer(supervisors), who in turn are supervised by the owner of the firm. They further prove that optimal arrangements in the first layer are independent of the layer above. That is the reason why they solve the problem sequentially, by choosing optimally the settings in the first layer, given arrangements in the layer above and then doing the same in the second layer. This type of solution hinges on the trick that in the first layer they set optimally the number of workers per supervisor and not the net number of workers. Given the independence in optimal arrangements between hierarchic layers they proceed and analyze the effect of a higher wage in each layer independently. They conclude that an increase in the minimum wage for production workers increases the quantity and quality of workers and decreases that of supervisors. According to their setting they actually derive that the number of employees **per supervisor** (what we call the partial wage effect) in the first layer increases, while the number of supervisors remains the same (the supervision effect), for a just binding minimum wage. Therefore, there are two counteracting effects on the net number of employees in Calvo-Wellisz setting, even though their result does not change for a just binding minimum wage because the supervision effect is zero.

($\Pi_{Lw} > 0$, i.e the partial wage effect is positive, the LL locus shifts up) (see figure 4)[24]. Therefore, in Calvo-Wellisz there is a neighborhood of the unconstrained wage, where the partial wage effect and the supervision effect are counteractive, and thus the employment effect of a higher minimum wage is ambiguous. Figure 4 presents the comparative statics results for an increase in the minimum wage in the range where Π_{Lw} is positive. In Calvo-Wellisz, even though the quality of workers also adjusts to the minimum wage shock, the standard shirking efficiency wages predictions hold and a decrease in the wage decreases monitoring intensity, which can be done in three different ways as indicated by the figure. Calvo-Wellisz show that if the minimum wage is set infinitesimally above the equilibrium wage, the supervision effect is zero, which suggests that the profit maximizing wage is tautosimous with the supervision maximizing wage and thus beyond this point supervision falls and the supervision effect becomes negative. Therefore employment increases for an infinitesimal increase in the minimum wage because the supervision effect is zero and the 'partial' wage effect is positive. Although it is easily deduced that, there exist a neighborhood beyond the supervision maximizing wage, where employment increases, even though the supervision effect becomes negative, Calvo-Wellisz do not show that it is possible in the range where Π_{Lw} is positive, for the supervision effect to dominate and employment to fall. From the figure we can deduce that this is possible, i.e there is a neighborhood of the wage in the range, where even though the partial wage effect is positive ($\Pi_{Lw} > 0$), the supervision effect (which is negative) dominates and both employment and supervision fall. This result is quite important as it renders clear that the range up to, one can increase the wage and increase employment, is smaller in the case of flexible compared to the case of fixed supervisory resources, in Calvo-Wellisz[25]. Finally, in Calvo-Wellisz it is not possible for both employment and supervision to increase, and thus the third possible adjustment as suggested by the figure cannot occur[26].

[24]If the wage increase, due to the imposition of a minimum wage is sufficiently high, then Π_{Lw} is negative also in Calvo-Wellisz and their predictions are exactly the same generated under this case 2 of our model.

[25]Calvo and Wellisz proved that in the case of heterogeneous workers and fixed supervisory resources employment increases for all wages set in the range where the partial wage effect is positive (as in this range the supervision effect is zero, because supervisory resources are fixed).

[26]Note that in figure 3, we present a general treatment of the possible adjustments of employment and supervision under heterogeneous workers and endogenous super-

3.3 Case 3

The final case arises when Π_{Nw} and Π_{LN} are negative, which suggests that the wage and supervision are substitutes in providing incentives (it is optimal when the wage is increased exogenously for supervision to fall) and employment and supervision are strategic substitutes, as it is stated in proposition 3. Again as in case 1, the partial wage and supervision effects on employment, as well as the wage and employment effect on supervision are counteracting, leading to ambiguity of the effect of the imposition of a higher wage on the employment of workers and supervisors. The possible adjustments are presented in figure 5. The change in optimal employment and supervision depends again on the signs and magnitudes of the shifts of the loci and the relative slopes. Since, by (19), we know that the increase in the wage increases the optimal monitoring intensity, the case that employment will rise and supervision will fall is not possible to occur. Therefore, the only possible cases is for employment and supervision to fall after the minimum wage increase or for employment to fall and supervision to rise. Therefore, under this case a higher minimum wage will decrease employment of affected workers. Under this case, the negative partial wage effect always dominates the supervision effect, which means that employment is relatively more elastic in wage than in supervision changes and that supervision is not so elastic in the wage changes. Furthermore, it is interesting to know whether or not the magnitude of the wage increase is crucial in determining, which out of the 3 cases is more likely to be true. It can be shown, that under certain conditions for the production function, as the increase in the minimum wage above the equilibrium wage becomes higher, we move from case 1 to case 2 and case 3 for a sufficiently high increase in the minimum wage[27]. This prediction reconciles with conventional wisdom, as

visory resources. The result that the case of both employment and supervision rise, is not possible, under Calvo-Wellisz environment, does not mean that this case is always empty. Particularly, we believe, that this is not the case in Calvo-Wellisz because of the assumption of constant returns to scale in efficient labour units which in turn is the reasons why the profit maximizing wage is tautosimous to the supervision maximizing wage. Indeed, it can be shown that under increasing returns to scale in production, both employment and supervision will increase in Calvo-Wellisz model.

[27] If $-\frac{(\theta^* L) * f''}{f'}$ is increasing in the wage, then the higher the minimum wage increase becomes we move from case 1 to case 3, given that the production function is such that can give rise to all three cases.. It can be shown that the relative measure of the concavity of the production function is increasing in the wage for any function with

well as recent evidence (Card-Krueger 1995) i.e a sufficiently high minimum wage will decrease employment of covered workers. Although, if the relative measure of the concavity of the production function is decreasing in the wage, then for a sufficiently high increase in the minimum wage, case 1 arises, which means that it is possible, under certain conditions, for total employment (supervisors plus supervises) to increase even after a high increase in the minimum wage. In both case 1 and case 3, if certain conditions are met, we may have the result that although employment of covered workers decrease, employment of supervisors is increased. This, may reflect the fact that for a high wage increase a cost minimizing firm will substitute high-skilled for low-skilled workers. As supervisors, are normally on average more experienced, even in case where workers and supervisors are relatively homogeneous and since our production function allows for a non-zero elasticity of substitution between workers and supervisors, this case may capture this fact[28]. Finally, as we have assumed that the wage of supervisors is exogenous and that workers are paid less than supervisors, it would be interesting to examine what will be the effect of an increase in the wage of supervisors because of a mandated minimum wage. From (13), it is easy to show that if c increases exogenously, the demand for supervision will fall, which means that the NN locus will shift up[29] in the case, where employment and supervision are complements ($\Pi_{LN} > 0$), (see figure 6) while the LL locus will not shift, and thus supervision will fall. Given that employment and supervision are complements the fall in supervision will cause a fall in employment. Under case 3, where employment and supervision are substitutes, NN locus shifts down, and while supervision falls employment increases, reflecting the fact of substitution of employees for supervisors(see figure 7).

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the property: $(\frac{f'''}{f''} - \frac{f''}{f'})x > -1$

[28]In fact in this case the elasticity of substitution is 0.5, which means that for any two fired workers the firm will hire one supervisor for output to remain unchanged. Thus, in cases 1 and case 3, if employment falls and supervision rises total employment falls. This is another interesting finding reflecting another problem that hinders econometric studies of the wage-supervision trade-off. Any production function that allows for a non-zero elasticity of substitution between employment and supervision may produce a positive relationship between wages and supervision intensity, because of a substitution effect, that takes place after the wage increase(Groshen-Krueger 1990).

[29]The shift is given by $\frac{\partial N}{\partial c} = -\frac{\Pi_{Nc}}{\Pi_{NN}}$, and $sign(\frac{\partial N}{\partial c}) = sign(\Pi_{Nc})$, with $sign(\Pi_{Nc})$ being negative.

4 An Example

In this section we adopt a specific functional form for the production function in order to derive the conditions under which total employment increases or falls, after an exogenous increase in the minimum wage of production workers in a labour market, where shirking is the efficiency wage feature and employers use a combination of the wage and monitoring intensity to prevent shirking. The production function is :

$$f[\theta^*(w, L, N)L] = (\theta^* L)^a, \quad (21)$$

where $a \in (0, 1)$. We assume that the production function belongs to this general class of increasing and concave in efficient labour units, functions. It can be shown,[30] that for this class of functions, $\Pi_{Nw} > 0$ and $\Pi_{LN} > 0$, for all $a \in (0, 1)$and for all $(\theta^* L) \in \Re_+$, where $\Re_+$ denotes the set of all positive real numbers. Thus, our analysis is restricted in our first case[31]. By combining (10), (11)and (13)we get:

$$N^*(w) = L^*(w) \sqrt{\frac{Bw}{Ac}}, \quad (22)$$

$$L^*(w) = \frac{a^{\frac{1}{1-a}} [\Gamma(w)]^{\frac{1+a}{1-a}}}{w^{\frac{1}{1-a}} [\Gamma(w) + B]^{\frac{1+a}{1-a}}} (w - \mu)^{\frac{a}{1-a}}, \quad (23)$$

where $L^*$and N^* are the optimal quantity of workers and supervisors respectively and $A = (1 - q)$, $B = (r + s + q)$ and $\Gamma(w) = \sqrt{\frac{ABw}{c}}$. The change in equilibrium employment and supervision, when the wage of workers is increased above the equilibrium level because of an increase

[30] Let $f(x) = x^a$, where $a \in (0, 1)$ and $x \in \Re_+$. Then $-\frac{x * f''}{f'} = 1 - a$. Thus, $-\frac{x * f''}{f'} < 1$, thus (18) and (19) hold for all $a \in (0, 1)$ and all $x \in \Re_+$.

[31] We mentioned in the previous sections that any concave transformation of $f(x) = \gamma \log x$, can give rise to the case where $-\frac{x * f''}{f'} > 1$, for all x. Consider the composite function $g(x) = \log(\gamma \log x)$. For this function, we have that $1 < -\frac{x * f''}{f'} < 2$, for $x \in [e, +\infty)$ and $-\frac{(\theta^* L) * f''}{f'} > 2$, for $x \in [1, e)$. Therefore there is also an increasing and concave function that can give rise to case 2 and 3 as well. In this case $-\frac{(\theta^* L) * f''}{f'}$ is decreasing in the wage, and thus for a sufficiently high minimum wage case 2 is the case, and therefore our result is consistent with conventional wisdom, that a sufficiently high minimum wage decreases employment of covered workers.

in the minimum wage is given by differentiating both (22) and (23) w.r.t the wage. Thus:

$$\eta_\varepsilon = \frac{1+a}{1-a}\Phi + \frac{1}{1-a}(a\lambda - 1), \quad (24)$$

$$\frac{dN}{dw} = \sqrt{\frac{Bw}{Ac}}\left(\frac{1}{2}\frac{L}{w} + \frac{dL}{dw}\right), \quad (25)$$

where, η_ε is the elasticity of labour demand for production workers w.r.t the wage, $\Phi = \Gamma'(w)w(\frac{1}{\Gamma(w)} - \frac{1}{\Gamma(w)+B})$and $\lambda = \frac{w}{w-\mu}$. By (24) if $a \to 0^+$ then $\eta_\varepsilon \to \Phi - 1 < 0$ and if $a \to 1^-$ then $\eta_\varepsilon \to +\infty$. From (25) then and the fact $\sqrt{\frac{Bw}{Ac}} > 0$, we get that:

$$\text{if } \eta_\varepsilon > 0, \text{ then } \frac{dN}{dw} > 0, \quad (26)$$

$$\text{if } \eta_\varepsilon < 0, \text{ then } sign\ of\ \frac{dN}{dw} = sign\ of\ \left(\frac{1}{2}\frac{L}{w} + \frac{dL}{dw}\right), \quad (27)$$

But

$$\left(\frac{1}{2}\frac{L}{w} + \frac{dL}{dw}\right) > 0 \Leftrightarrow \eta_\varepsilon > -\frac{1}{2}, \quad (28)$$

It can be shown that $\Phi - 1 < -\frac{1}{2}$, and thus it is possible for (28) not to hold in our case in a right neighborhood of $a = 0$. which implies that the total change in supervision w.r.t the wage may be also negative. Thus, under this specific environment all three subcases illustrated in figure 2, are possible. Moreover because $\lim_{a\to 1^-} \eta_\varepsilon = +\infty$, there is a left neighborhood of a, where η_ε is positive and because $\lim_{a\to 0^+} \eta_\varepsilon = \Phi - 1$, there is a right neighborhood of a where η_ε is negative, there will be a value of a, such that $\eta_\varepsilon(a) = 0$. Using the same argument we can show that there exists a value of a such that $\eta_\varepsilon(a) = -\frac{1}{2}$. The signs of the change in employment of workers and supervisors along different subintervals of values of a, are given in table 1. Employers decision problem is to choose employment of workers and supervision in order to elicit the optimal amount of non-shirkers or average effort θ^*, for any given wage. The increase in the minimum wage will increase average effort, given everything else constant, by the change in the FOC we can deduce that the increase in average effort is less than the optimal increase, therefore, monitoring intensity must be increased, which means that employment may be decreased for given supervision and supervision must be increased for given employment. We show that, under this specific example which is captured by general case 1, if labour demand for production workers is very negatively elastic ($\eta_\varepsilon < -\frac{1}{2}$), then the 'employment' effect dominates the 'wage' effect on supervision and supervision falls, but less than employment (see table 1). On the other hand, at the range of a where $-\frac{1}{2} < \eta_\varepsilon < 0$, employment falls but the increasing effect of the higher wage on supervision exceeds the decreasing effect of lower employment of workers on supervision and supervision rises. Finally, there is a left neighborhood of $a = 1$ where supervision is very (positively) elastic in the wage and the elasticity of employment w.r.t the quantity of supervisors is such that the 'supervision' effect on employment exceeds the (negative) elasticity of employment of workers w.r.t the wage (the 'partial' wage effect), and thus employment of covered workers as well as total employment (workers plus supervisors) rise. Although, in this latter case employment rises by less than supervision after the minimum wage increase. This is because, under case 1 the employer must increase monitoring intensity after the minimum wage rises and thus in each subcase of case 1, the changes in L and N may be such that the probability of detection rises after the minimum wage shock. In table 1, it is indicated that for $a = a'$, we get Lin's result, i.e employment falls and supervisory resources are fixed. It is apparent by table 1 that the effect of the minimum wage on the employment of workers and supervisors depends on the value of the parameter a. In this case a is an indicator of the degree of the diminishing returns to scale exhibited by the production function. As a tends to one the returns to scale tend to be constant, and given that $-\frac{(\theta^* L) * f''}{f'} = 1 - a$, the measure of the concavity tends to zero, the positive Π_{Nw} (and therefore the wage effect on supervision) is maximized, supervision rises and also it rises in a way such that the supervision effect dominates the wage effect on employment ($\Pi_{Lw} < 0$) which leads also employment to increase. On the other hand, when $a \to 1$, by (17)we get that $\Pi_{Nw} \to 0$, the wage effect on supervision tends to zero, thus the employment effect which is negative dominates and supervision falls (this case is the case where the fall in supervision is maximized). In the one polar case, of constant returns to scale($a = 1$) in efficient labour units, both supervision and employment increase in contrast with Calvo-Wellisz, where with constant returns to scale supervision falls and employment increases for a marginal increase in the wage. In the other polar case($a = 0$) where the production function approaches a constant(in fact it approaches one!), both employment and supervision fall. Consequently, the degree of the decreasing returns to scale exhibited by the production function is a critical condition for results generated not only because it is the criterion which we use in order to identify which case, out of the three arises, but also because it affects results within cases (here, within case 1). Therefore, by using an example, in which the production function belongs to a general class of functions widely used in economics and thus we can solve the model explicitly, we derive the conditions under which each different adjustment of monitoring intensity can be the case. We show that all adjustments are possible and that because of this, it is possible for an increase in the minimum wage to increase both employment and supervision, or to decrease both or decrease employment and increase supervision, although it is discussed that in the latter case total employment falls.

5 The case of homogeneous workers

In this section we are considering a special case that arises in our model when workers are homogeneous ($\theta^* = 1$) in order to test the robustness of our predictions in the generalized setting[32]. Under workers homogeneity the problem becomes:

$$\max_{w,L,N} \Pi = \max_{w,L,N} f(L) - wL - cN \quad (29)$$

$$s.t\ w = \mu + e + \frac{e(r+s+q)}{\frac{N}{L}(1-q)} \quad (30)$$

Equation (30) can be used to express supervisory resources as a function of employment and the wage;

$$N(w,L) = \frac{Le\,(r+s+q)}{(1-q)\,(w-\mu-e))} \quad (31)$$

with $N_w < 0$, $N_L > 0$, $N_{ww} > 0$ and $N_{Lw} < 0$. From the sign of these partial derivatives it is unambiguous that, in equilibrium, there is a wage-supervision trade-off and a complementarity between supervision and the wage. If we further substitute (31) into (29), then the maximization problem becomes;

$$\max_{w,L} \Pi = \max_{w,L} f(L) - wL - cN(w,L) \quad (32)$$

[32] This case may also represent a special case of the model with heterogeneous workers, when the constraint on θ^* is binding(recall that $\theta^* \leq 1$). In the previous section we implicitly assume that is non-binding.

The first order conditions for profit maximization are given by the following equations:

$$\Pi_L = 0 \Rightarrow f_L = w + cN_L \ = 0 \ (33)$$

$$\Pi_w = 0 \Rightarrow -\frac{cN_w}{L} = 1 \ (34)$$

Equation (33) expresses the fact that in equilibrium the marginal revenue product of labour exceeds the wage. In fact the marginal cost of labour has two components, the wage and the marginal monitoring cost of employment, which is decreasing in the wage. The marginal revenue product of labour exceeds the wage suggesting that the firm has some monopsony power, arising from the upward sloping relationship between the wage and employment from the non-shirking condition. Equation (34)denotes the standard Solow condition: the wage is chosen to minimize the average cost of labour. This is because a higher wage has as a result to increase average cost but on the other hand it also decreases average labour cost as it decreases the average monitoring cost, because of the wage-supervision trade-off. In equilibrium the wage increase is exactly offset by the decrease in the average monitoring cost of employment. The change in employment after the introduction of a binding minimum wage is given if we totally differentiate equation (32):

$$\frac{dL}{dw} = -\frac{\Pi_{Lw}}{\Pi_{LL}} \ (35)$$

where Π_{LL} the own second order partial derivative of the profit function w.r.t employment, and Π_{Lw} is the cross partial derivative of the profit function. Therefore

$$sign\frac{dL}{dw} = sign\Pi_{Lw} \ (36)$$

Where Π_{Lw} is given by:

$$\Pi_{Lw} = -1 - cN_{wL}(37)$$

by (34) and the fact that $cN_{Lw} = \frac{cN_w}{L}$, we obtain that employment does not change, after the imposition of a just binding minimum wage($\Pi_{Lw} =$

0).[33] This implies that the profit maximizing wage is the employment maximizing wage[34]. Alternatively, a higher wage, on the one hand increases the marginal cost of labour but on the other hand it decreases the marginal monitoring cost of labour, as it increases motivation and thus monitoring intensity can be relaxed. In this case, the increase in the wage is exactly offset by a decrease in the marginal monitoring cost and the increase in the minimum wage has no effect on employment. However, it is easily deduced that any non-infinitesimal increase in the wage will decrease employment. On the other hand, profits fall because a binding minimum wage increases the average cost of labour, as the increase in the wage is less than offset by the fall in the average monitoring cost of labour, as it can be understood by (34). Moreover, it can be also shown that supervisory resources fall for a just binding minimum wage. In fact the effect of an exogenously set higher wage on supervision is calculated using (31)and is given by:

$$\frac{dN}{dw} = \frac{\partial N}{\partial w} + \frac{\partial N}{\partial L}\frac{dL}{dw} \quad (38)$$

Under homogeneous workers, and binary effort and as it is also suggested by (31) the standard efficiency wages predictions hold, i.e there is a trade-off between supervision and the wage ($\frac{\partial N}{\partial w} > 0$), there is strategic complementarity between employment and supervision ($\frac{\partial N}{\partial L} > 0$) and also there is the positive so called 'employer-size' wage effect($\frac{\partial L}{\partial w} > 0$). Therefore, once more the total effect of a higher wage on supervisory resources has two components, as in the case of heterogeneous workers (but the signs of the effects are different in this case): the one component is the effect of a higher wage on supervision for given employment, which is negative as wage and supervision incentives are substitutes. On the other hand there is the employment effect, which is positive as employment and

[33] In general, in the optimal employment decision of the firm is given by an equation of the form: $\Pi_L = R_L - C_L = 0$, where R_L stands for the marginal revenue product of labour and C_L stands for the marginal cost of labour. Moreover, we have shown that the change in employment is given by equation (35), with $sign\Pi_{Lw} = sign(R_{Lw} - C_{Lw}) = sign(R_{Lw}\frac{w}{R_L} - C_{Lw}\frac{w}{C_L}) = sign(E_w^R - E_w^C)$, the change in employment depends on whether or not in equilibrium the elasticity of the marginal revenue product of labour w.r.t the wage (E_w^L) exceeds the elasticity of the marginal cost of labour w.r.t the wage (E_w^L).

[34] If the supervision cost function is convex in the quantity of supervisory resources, it can be shown that employment increases and supervision falls for a just binding minimum wage.

supervision are strategic complements. In this case the 'employment' effect on supervision is zero as $\frac{dL}{dw} = 0$, for a just binding minimum wage, implying that supervision decreases for a just binding minimum wage and decreases by more for larger wage increases. Another interesting result is that, since there is an employment maximizing wage[35], the wage employment relationship is backward bending in the (w,L) space (or concave function of the wage and exhibits a maximum).[36] Additionally, it can be shown that, if there is a wage where supervision is maximized w.r.t the wage then this wage is non-binding, which further implies that a wage for which both employment and supervision increase is non-binding. In general, a higher wage increases motivation and leads to a relaxation in monitoring intensity. Lower monitoring intensity essentially means less supervisors per employee or more workers per supervisor. This can be achieved if both the number of supervisors and employees decrease but the decrease is higher for supervisors or both supervisors and workers increase but the increase in the number of workers is higher or even if the number of employees increases and that of supervisors declines[37] (there is also the polar case of employment to remain unchanged and supervision to fall or supervision to remain unchanged and employment to rise, with the latter not being possible as we discussed above). We show that, when the minimum wage is set infinitesimally above the equilibrium wage one of the polar case arises. Furthermore, it is also shown that the firm will never choose, to increase both employment and supervision or increase employment and decrease supervision, as optimal adjustments of the monitoring intensity, for a binding minimum wage. It is intuitive why the former adjustment cannot take place for a binding minimum wage, as profits fall and the firm will try to save resources somehow, it is not possible to increase inputs and save resources, in this case. Alternatively, if we used (30) to substitute for L as a function of w and N, and thus solve the maximization problem and do the comparative statics

[35] It has been shown that, $\frac{dL}{dw}|_{w=w^*} = 0$. Using the same procedure, we have that: for $w > w^*$, $\Pi_{Lw} < 0 \Rightarrow \frac{dL}{dw}|_{w>w^*} < 0$, and for $w < w^*$, $\Pi_{Lw} > 0 \Rightarrow \frac{dL}{dw}|_{w>w^*} > 0$. Suggesting that w^* is the employment maximizing wage, in this case.

[36] The concept of labour demand is not well defined for wages below the efficiency wage as no firm would ever choose such a wage. Blanchard and Summers (1988) suggest that models with upward-sloping labor demand curves may be useful in macroeconomics.

[37] From equation (30) NSC we get that $\frac{d(\frac{N}{L})}{dw} < 0$. Which implies that $E_w^N < E_w^L$, where E_w^N and E_w^L is the elasticity of supervisory resources w.r.t the wage and the elasticity of employment w.r.t the wage respectively.

for N, and then use the NSC to do the comparative statics for L, the results will be exactly the same. Using this way to treat the problem, the change in optimal L can be expressed by :

$$\frac{dL}{dw} = \frac{\partial L}{\partial w} + \frac{\partial L}{\partial N}\frac{dN}{dw}, (39)$$

The first term is the effect of a higher wage on employment for given supervisory resources(the employer size wage effect or the partial wage effect), which is clearly positive. A higher wage increases incentives and thus monitoring can be relaxed. For given supervisory resources, monitoring is relaxed by increasing employment. The second term expresses the supervision effect of a higher wage and is negative because a higher wage decreases supervision and less supervisors will lead to less employees as supervision and employment are strategic complements. We have shown above that for a just binding minimum wage the total employment effect is zero, which means that the partial wage effect is equal in absolute value to the supervision effect. In general, if we assume that supervisory resources are held fixed to the initial optimal level and that they cannot adjust instantaneously to any exogenous shock (perhaps because supervision is solely based on capital services), the negative term in (39)vanishes and thus the employment effect is positive. However, the positive employment effect is local, as one cannot increase the wage without limit and increase employment. Moreover, by (39) it also becomes clear why the range up to which one can increase the wage and increase employment is greater in the case of fixed than in the case of flexible supervisory resources, which it was also shown that it holds under heterogeneity of workers. Therefore, we show that although the employment effect of a higher minimum wage is positive, when supervision is fixed, the positive employment effect doesn't persist when supervision is endogenized. This last finding, shows that the result of Rebitzer and Taylor(1995), which is widely cited in the minimum wage literature, that an increase in the minimum wage in a shirking efficiency wages environment, where workers are homogeneous, will increase employment, hinges heavily on the fixity of supervisory resources. This finding is important, as in the real world, except of few cases where supervision is exogenously regulated by government or other institutions[38], the employment of supervisory resources is

[38]In the USA, in the hospital industry the supervisor to staff ratio is often regulated by the state or federal government (Groshen-Krueger 1990). Moreover, in some industries, safety regulations may impose a fixed supervisor to staff ratio for some professions(Rebitzer 1995).

a choice of the firm. Hence, we show that by accounting for more realistic features of the low-wage labour market more accurate predictions can be generated. Under workers heterogeneity the employment effect of a higher minimum wage is ambiguous and it can be positive in some cases and negative in some other, while with homogeneous workers the prediction is more clear, as employment of covered workers remains unchanged or decreases. The predictions we generate seem to reconcile with the recent evidence (Card-Krueger 1995, Brown 1999), that point towards to zero or small positive or negative estimates of minimum wage employment elasticities. We further believe that, our latter result is empirically relevant as it may also provide another theoretical explanation, particularly of the evidence from the fast food studies in the US (Card-Krueger 1994, Katz and Krueger 1992), where employment increased in low-wage restaurants compared to high wage restaurants in the same state, after the increase in the minimum wage. There is evidence (Card-Krueger 1995), that in fast food industry high-wage restaurants are larger in size compared to low-wage restaurants. As the fast food industry is competitive, non-unionized and workers are relatively homogeneous(Krueger 1991), monitoring problems may consist a very good explanation of the positive employer-size wage effect[39]. If it is true that small establishments pay lower wages and thus their employees are less motivated than in larger restaurants, then we would expect an increase in the wage to increase motivation by more in small, low-wage restaurants compared to high wage restaurants. This would mean that monitoring intensity will be relaxed by more in low-wage restaurants, and thus for given supervision, employment will be increased by more, compared to high-wage establishments. This, simply means that the first term in (39)is higher for low wage than for high-wage restaurants.[40] Similarly, given that high-wage restaurants are larger in size, monitoring difficulties will be more significant in these restaurants. Given this argument, employment will be more elastic in a change in supervision in high-wage compared to low-wage restaurants, because a marginal fall in supervision, induces even more monitoring difficulty in large establishments, and given the wage,

[39]Other potential explanations as the threat arising from unionization, market power and heterogeneity of workforce are dismissed.

[40]The first term in equation (39) is the change in employment, when supervision is held constant, for an increase in the wage, for given level of effort and motivation. The higher the increase in incentives, after the wage change, the more monitoring intensity must be relaxed to keep effort fixed and thus, the more employment increases for given supervision.

employment must fall by more, for detection problems to be mitigated. Thus, the first term from the left in the second part of (39) is smaller in absolute value in low-wage compared to high-wage restaurants. Finally, we believe that a change in the wage, will induce smaller changes in supervision in a small establishment compared to high-wage, mainly because of the physical structure of the fast-food restaurants.[41] This implies that also the second term in the second part of (39) is smaller in absolute value for low-wage restaurants. Consequently, our theoretical analysis in this section, as summarized by equation (39)which reflects the standard decomposition of the employment effect of a higher wage into the partial wage and to the supervision effect, could possibly explain the relative employment gains in the fast food restaurants in the Texas and New-Jersey-Pennsylvania studies, as estimated by Katz-Krueger(1992) and Card-Krueger(1994) respectively. Finally, as our latter discussion points out, findings in the fast-food industry can be rationalized using as a basis a shirking efficiency wage framework, the validity of our initial perception that our shirking model may capture some major features of some low-wage labour markets is enhanced.

6 Extensions and Variants

In this section, we relax the assumption that the price of supervisory resources is exogenous and independent of the wage of workers, in order to check the validity of our previous results but also in order to offer some alternative treatment of the problem. We, will assume that supervision is based solely on labour services and that the firm employs homogeneous workers who are randomly allocated across tasks (production and supervision). Therefore, the assumption we made for the workers side in the previous sections, hold in this section also for supervisors. There is imperfect observability of workers' effort and that is why the employer

[41] A small fast food restaurant will probably use a supervisor in the kitchen to supervise employees that prepare the food and probably one in the cash-registers. Given this structure, it is quite hard, to imagine, given the limited space, that any change in the wage that will motivate employees will induce any changes in the supervision of a small restaurant. Because of this argument, we expect supervision to be relatively fixed in low-wage restaurants and quite flexible in high-wage establishments. Given, this last argument and our previous results that the employment effect of a higher wage is exaggerated, under fixed supervision, it is easy to understand why employment increased in low-wage relative to high-wage restaurants in New-Jersey and Texas.

hires supervisors to monitor employees, and he, in turns monitor supervisors. Let, the employer to have unitary supervisory capacity. Then the probability of detection or monitoring intensity of supervisors effort is given by the following equation:

$$Q = \min[\frac{1}{N}, 1], \ (40)$$

while the probability of detection of workers is, under this case given by:

$$P = \min[\frac{eN}{L}, 1], \ (41)$$

if supervisors shirk ($e = 0$), then it becomes impossible to detect shirking workers and an infinite wage must be paid to workers in order to prevent shirking. Therefore, if supervisors shirk, workers will shirk, and the firm generates losses. The employer must decide the optimal combination of carrots (wages) and sticks(dismissal threats based on supervision) to prevent shirking in production and supervision. We are interested for the case, where one in equations (40) and (41) is non-binding. Furthermore, if we follow the standard procedure in order to derive the worker's and the supervisor's decision making condition and given that the industry in which the firm operates is covered by a minimum wage, the employer solves the following problem:

$$\max_{w,c,L,N} f(L) - wL - cN, \ (42)$$

$$\begin{aligned} s.t\ w &= \mu + e + \frac{e(r+s+q)}{(1-q)P}, \ (42) \\ c &= \mu + e + \frac{e(r+s+q)}{(1-q)Q}, \ (43) \\ w &\geq w_m, \ (44) \\ c &\geq w_m, \ (45) \end{aligned}$$

From (42) and (43), it is implied that homogeneous workers that are allocated in different tasks, which we will assume that are equally difficult, may receive different wages. The wage differential depends on the monitoring difficulty. As neoclassical economics postulate that any wage differential must be attributed in differences in workers characteristics or working conditions, this result may provide an explanation of why the evidence that interindustry wage differentials cannot be explained solely by the neoclassical reasoning (Krueger-Summers, 1988). The firm chooses the cost minimizing wages and thus the minimum wage constraints are both binding and (42) and (43) are equivalent to:

$$w_m = \mu + e + \frac{e(r+s+q)L}{(1-q)N}, \ (46)$$

$$w_m = \mu + e + \frac{e(r+s+q)N}{(1-q)}, \ (47)$$

By (46) and (47) we conclude that the cost minimizing firm will pay the same wages to workers and supervisors and supervise them by the same stringency, $P = Q$ or $\frac{N}{L} = \frac{1}{N}$. The model can be solved descriptively, as by (46)and (47), an increase in the minimum wage, firstly increases employment of supervisors, and since employment of workers is increasing in both quantity of supervisors and the wage, it increases employment of workers as well. This is another way to derive a result that it is also possible, if certain conditions hold, in the first case of heterogeneous workers, analysed in the previous sections, but with homogeneous workers[42]. This result seems rather intuitive: because of the fixed supervisory capacity, if the firm wants to hire more supervisors it must pay a higher wage. The constant capacity to supervise supervisors, lead the firm to employee less supervisors, and thus leads to a lower probability of detection of shirking workers. Consequently the firm is supply constraint in terms of supervisors and for this reason is supply constraint in terms of workers as well. An increase in the minimum wage enables the supply constraint firm to employ more supervisors and thus more workers, leading to an increase in total employment. The problem becomes slightly different if initially there is no binding minimum wage constraint and employers choose wages optimally. We will analyze the effect of a higher minimum wage firstly for production workers and then for supervisors, under this framework. Solving (42) for N, plugging that in (43)and solve for c and use both constraints to substitute in the objective function for N and c as functions of w and L the first order conditions are:

$$\Pi_L = f_L - w - c_N N_L N - c N_L \ = 0, \ (48)$$

[42]The relaxation of the assumption of fixed wage of supervisors, under heterogeneous workers does not change the results, compared to the previous analysis of the three different cases that arise, under heterogeneity of workforce, but makes the algebra messier.

$$\Pi_w = -L - c_N N_w N - cN_w \ = 0, \ (49)$$

if a minimum wage for production workers is introduced, just above the optimal wage for employees, then the direction of the change in employment of workers will be given, as explained previously by the sign of Π_{Lw}. Manipulating, (48)and using the fact that equation (49), holds if the minimum wage is set infinitesimally above the wage of production workers, we get :

$$\Pi_{Lw} = -2c_N N_L N_w > 0, \ (50)$$

Therefore, by (50) employment of workers increases, after the imposition of a just binding minimum wage for production workers. It is also shown (see appendix), that if the production function exhibits constant returns to scale in the labour input, the quantity of supervisors remains unchanged, i.e the profit maximizing wage is the supervision maximizing wage. This result is quite important, as we essentially show that under a very similar environment as in Calvo-Wellisz(1979) and mainly by assuming constant returns to scale, a just binding minimum wage increases employment and does not affect supervision. This result is identical with Calvo-Wellisz, even though we assume that workers are homogeneous, suggesting that Calvo-Wellisz result is mainly driven from their assumption of constant returns to scale in efficient labour units. The explanation is again the same as we discussed in case 2 in the previous section: there is also here a wage range above the equilibrium wage, where an increase in the wage, given everything else, increases employment (the partial wage effect is positive) and for a just binding minimum wage the supervision effect is zero, the wage of supervisors remains also constant and therefore the total employment effect is positive. The most important implication of this latter result is that under the most complex variant of Calvo-Wellisz model, where workers are heterogeneous and supervisory resources are endogenous, if one relaxes the assumption of constant returns to scale and instead assumes decreasing returns to scale the imposition of a just binding minimum wage has no more a positive effect on the employment of covered workers and the effect becomes ambiguous. However, the effect remains positive in Calvo-Wellisz when workers are homogeneous, suggesting that also heterogeneity of workforce moderates the employment effect of a higher minimum wage. Assuming constant returns to scale, is critical in generating a zero total wage effect on supervision and thus a positive employment effect in the case of heterogeneous workers. If, on the other hand the wage of supervisors is increased because of the introduction of a minimum wage then, both employment of supervisors and workers rise as well as the wage of workers. The intuition is similar, as in the case of this section, where the minimum wage is a binding constraint for both workers and supervisors. Finally, we show that, if the assumption of the fixed wage for supervisors is relaxed, the effect of a higher wage on employment is positive, for a just binding minimum wage and is negative for a sufficiently high minimum wage, as beyond the neighborhood of the optimal wage the supervision effect becomes significantly negative and employment falls. This suggest, that Rebitzer and Taylor(1995) finding, that a higher minimum wage increases employment of covered workers, under fixed supervision, does not change neither in sign, nor in magnitude, under endogenous supervision, if the production function exhibits constant returns to scale, for a just binding minimum wage and supervisors are similar to workers in their innate propensity to shirk. However, the range up to which one can increase the wage and increase employment is shorter, if the supervision choice is endogenous. If the production function is a standard increasing and concave function of labour input, then a just binding minimum wage decreases supervision, and the positive employment effect of a higher minimum wage is more pronounced under fixed supervisory resources, compared to the case where the choice of supervision becomes endogenous. Finally, if there exist some values of the exogenous parameters (r, s, q), for which in equilibrium $\theta^* = 1$, then for these values the homogeneous workers case is equivalent to a special case of heterogeneous workers. Therefore, the case with homogeneous workers, where supervisory resources are fixed (the Rebitzer-Taylor case), under certain conditions, may produce the same predictions as if workers have been assumed to be heterogeneous. Combining this latter result with the result which is predicted by Calvo and Wellisz, under particular conditions, that a just binding minimum wage increases employment of covered workers, under fixity of supervision, when workers are heterogeneous, we refute the result of Lin(1999), that with heterogeneous workers and fixed supervisory resources employment of covered workers, necessarily falls, after a minimum wage increase.

7 Conclusions

There is evidence from low-wage industries (Krueger-Summers 1987), where the minimum wage is particularly binding, that gives rise to efficiency wages considerations. Particularly, more evidence(Brown-Medoff 1989, Krueger 1991), provide further support to the shirking version of efficiency wages. Therefore, we believe that efficiency wages models that try to predict the employment effect of a binding minimum wage, may be particularly relevant in some low-wage industries. On the other hand, theoretical work on the employment effects of a higher minimum wage, under efficiency wage considerations seems incomplete, as the existing seminal models do not capture some important features of the low-wage labour market (endogeneity of supervisory resources, imperfect information about the workers genetic characteristics etc.) and some of their results may hinge heavily on the environment assumed. Calvo-Wellisz (1979), first examined the effects of a binding minimum wage for production workers employed by a competitive hierarchic firm in an asymmetric information environment, where the management of human resources within firms involves a "game" between employees who seek to maximize utility and residual owners whose aim is to maximize profits and who resort to incentives and punishments to achieve their goal. Calvo-Wellisz concluded that under this kind of environment, an increase in the minimum wage will increase quantity of covered workers and decrease quantity of supervisors. Although, Calvo-Wellisz devote a minor part of their analysis in predicting the effects of the imposition of a binding minimum wage, under their environment and thus we believe that there are some gaps for further research on the shirking approach of the effects of minimum wages on employment. More recently Rebitzer-Taylor (1995), offered a theoretical explanation of the positive effect of the increase in the minimum wage on employment, that identified in recent studies (Card and Krueger 1995), suggesting that monopsony may arise by imperfect monitoring. However, Lin (1999) after extending Rebitzer and Taylor work to account for heterogeneity of workforce generated the standard neoclassical result of the increase in the minimum wage, suggesting that his findings cast doubt on the validity of Rebitzer and Taylor results, which seem to hinge on a number of simplified assumptions, as homogeneity of workforce and fixity of supervisory resources. Finally, Manning (1995) also presents an efficiency wages treatment of the effects of an exogenous increase in the wage on employment, in an environment where employees differ in their valuation of leisure and employers have full information about worker's type. Manning's prediction is that the imposition of a binding minimum wage increase employment of covered workers. In this paper we develop a generalized shirking model, that is used to predict the effects of a higher minimum wage on the employment of covered workers. By allowing for features of the low-wage labour market that are not captured by the existing models in the field, we manage to generate their results as special cases and also allow for more predictions that except of indicating the limitations and weaknesses of the existing model, have interesting policy implications. The standard shirking efficiency wages model predicts that an increase in the wage, decreases the propensity to shirk, and thus monitoring intensity must fall, for effort to remain constant. Given that monitoring intensity is negatively correlated with the number of employees in the firm and positively with the quantity of supervisors, an increase in the wage must increase employment, for given supervision, and decrease supervision for given employment. Moreover, using the same rational of the shirking model, an increase in employment, must necessarily lead to an increase in supervision, in order for effort to remain unchanged (employment and supervision are strategic complements). The above predictions hold, for effort or any other employee's qualitative characteristic that also depends on the incentive schemes provided by the firm, being constant in each case. Therefore, we normally expect that if the employer uses the wage and monitoring intensity to adjust any kind of employee's performance characteristic, then the standard efficiency wages predictions may not be always the case. However, this is not the case in Calvo-Wellisz (1979), where employers may always be interested in keeping effort fixed into a maximum capacity level, but they adjust employees quality in the light of any exogenous shock. In the contrary, we show that under our general environment, wage and supervision and employment and supervision may be strategic complements as well as strategic substitutes and an increase in the wage, for given supervision, decreases employment always, reflecting the fact that is often the case as suggested by Brown (1999) that if employers increase the effort requirement on the job to offset the cost of a higher minimum wage then the negative employment effect may be magnified, rather than mitigated, as it is the case with other kind of offsets. This finding has some important implications for empirical studies that try to test the validity of the shirking model, as it provides a theoretical explanation of why studies (Neal 1993, Kruse 1992, Leonard 1987) that try to identify the wage-supervision trade-off, and do not control for determinants of employee's performance rendered inconclusive. We further show that under an efficiency wages environment, with endogenous supervisory resources the total employment effect of a higher minimum wage can be decomposed into two effects; the 'partial' wage effect and the 'supervision' effect. The former represents the effect of an increase in the wage, for given supervision, which in our model and when workers are heterogeneous is negative, whereas the supervision effect depends on whether or not employment and supervision and wage and supervision are complements or substitutes. In particular, under workers heterogeneity, if the wage and supervision are complements, then employment and supervision are complements, the supervision effect is positive and thus the employment effect of the introduction of a minimum wage is ambiguous. An interesting result, under this case, that is not the case in models of similar flavor, is that it is also possible for both employment and supervision to increase after the increase in the minimum wage. Ambiguity as far as the employment effect of a higher wage also arises, if employment and supervision are substitutes and thus wage and supervision are also substitutes. Nevertheless, in this case employment of covered workers falls but supervision may also rise, reflecting the neoclassical prediction of substitution of high-skilled for low-skilled workers. Finally, if the wage and supervision are substitutes and employment and supervision are complements, then the supervision effect is negative and both employment of workers and supervision fall. Under workers' homogeneity, the minimum wage employment and supervision elasticity may be zero, negative or positive, depending on the assumptions imposed. We show that, if the minimum wage employment elasticity is positive, then this holds locally and it is higher, if supervision is assumed to be constant. The same holds for the range up to which, one can increase the wage and increase employment. Rebitzer and Taylor result that a higher minimum wage will increase employment, cannot be sustained under endogenous supervision. However, their result remains the same in sign and magnitude, for a just binding minimum wage, with endogenous supervision choice, if the production function exhibits constant returns to scale and workers are randomly assigned between production and supervision. Our findings that, if certain conditions are met, a higher minimum wage may increase employment of heterogeneous workers, when supervision is fixed rebuts the validity of Lin's predictions. Furthermore, we infer that the assumption that in Calvo-Wellisz the production function exhibits constant returns to scale into efficient labour units is critical for Calvo-Wellisz result that up to a point an increase in the minimum wage will increase employment of workers and decrease employment of supervisors. If this assumption is relaxed, the minimum wage effect on employment becomes ambiguous, as we also show in our heterogeneous workers case. Our theoretical prediction sreconcile with recent empirical studies (Card 1992a, 1992b, Card-Krueger 1994, 1995, Dickens, Machin and Manning, 1993 and Machin-Manning 1994), that find a small positive, a zero or even an insignificantly negative estimate of the employment effect of a higher minimum wage. Since the validity of a theoretical model depends on the accuracy at which it can explain observed phenomena, we try to check whether or not our model can be used to explain observed phenomena in a low-wage industry. Particularly, there is evidence from the fast food industry that support the shirking efficiency wages story (Krueger 1991). Moreover the fast food industry is a low-wage industry and the minimum wage has a significant bite and there are also supervisory workers on the job. Given, these observations, we should expect that our model may explain any estimated employment effect of a higher minimum wage in this low-wage industry. In fact, we believe that, the employment gains in low-wage restaurants compared to high-wage restaurants, in the fast food industry, in Texas and Pennsylvania as estimated by Card-Krueger (1994) and Katz-Krueger(1992) can be explained by our general theoretical model. Finally, some interesting hypotheses for future research arise: the employer-size wage effect cannot be explained solely by monitoring difficulties and thus it may not provide a satisfactory test for the validity of the shirking model. On the other hand, any attempt to identify a wage supervision trade-off suffers from endogeneity and measurement error problems (Rebitzer 1995). An alternative way to test the validity of the shirking efficiency wages story would be to identify whether or not larger in size establishments tend to supervise their employees more intensively, after controlling for the wage. In fact, there is little evidence supporting this hypothesis (Neal 1993). Finally, an empirical test of the shirking efficiency wages predictions could provide us with estimates of the 'partial' wage and the 'supervision' effect, rendering possible to calibrate our theoretical model in order to find an estimate of the minimum wage employment elaticity.

8 Appendix

8.1 The effect of a just binding minimum wage, when workers are homogeneous and are randomly assigned between employment and supervision.

From (31) we have

$$\frac{dN}{dw} = N_w + N_L \frac{dL}{dw} \; (A.1)$$

and

$$\Pi_{LL} = f_{LL} - c_{NN}(N_L)^2 N - c_N N_{LL} - 2c_N(N_L)^2 = f_{LL} - 2c_N(N_L)^2 (A.2)$$

, as it can be shown that $c_{NN} = N_{LL} = 0$. From (35), (50)and $(A.2)$and if the production function exhibits constant returns to scale in efficient labour units, we get that;

$$\frac{dL}{dw} = -\frac{N_w}{N_L}, \; (A.3)$$

Therefore, from $(A.1)$and $(A.3)$it is derived that:

$$\frac{dN}{dw} = 0, \; (A.4)$$

Thus, it is derived that under homogeneity of workforce(or heterogeneity if there are values for r,s,q such that $\theta^* = 1$), with constant returns to scale production technology, the profit maximizing wage is the employment maximizing wage and the supervision effect is zero, which in turn implies that the employment effect of a just binding minimum wage, under endogenous supervision is identical with the employment effect, under exogenous supervision. This holds in Calvo-Wellisz (1979). Thus, because of the assumption of constant returns to scale, Calvo-Wellisz fail to show that the employment effect of a binding minimum wage is in general more pronounced under exogenous supervision. Moreover, in their model, if the production technology exhibited decreasing returns to scale the total employment effect of a just binding minimum wage becomes ambiguous.

Figure 1:

8.2 The decomposition of the total employment effect of the minimum wage into the partial wage and supervision effect

Using figure 1 we will prove that the sign or the direction of the change in employment L, after the minimum wage increase depends on the partial wage effect, which in fact is the shift of LL locus for a change in w, plus the supervision effect which is the product of the slope of the LL locus in (L, N) space with the shift of NN locus. Initially, employment and supervision pair is given by point A. The increase in the wage, for L unchanged, shifts NN locus to the right and, given that the LL locus is not shifting, the new pair of (L, N) is given by point B. If, after the wage shock we allow for LL to shift, keeping N constant, then LL shifts to the right and the pair of optimal L and N moves from point A to point C. Accounting for both changes in LL and NN locus respectively, the optimal (L, N) pair is given by point D. The total change in L and N is given by comparing L and N in point A with L and N in point D. On the other hand the levels of N and L in D, can be derived by the difference between the levels of N and L of point B and C. Consider firstly the change in (L, N) arising by the shift of NN, and thus by moving from A to B. The change from A to B is given by the slope of LL in point A (the slope of LL and NN is the same in all points):

$$slop_L = \frac{ch_{L_1}}{ch_{N_1}}, \ (B.1)$$

where $slop_L$ stands for the slope of LL locus and ch_{L_1}, $ch_{N_1}$are the changes in L and N, when NN shifts out. Moreover, the change in N is given by the vertical distance AE which consists of two parts: the shift in NN and the horizontal distance IE. Furthermore the horizontal distance IE is given by the quotient product of the slope of NN locus by the change in L. Thus $(B.1)$is equivalent to:

$$slop_L = \frac{ch_{L_1}}{sh_N + \frac{ch_{L_1}}{slop_N}}, \ (B.2)$$

where sh_N is the shift of N. Solving $(B.2)$ w.r.t ch_{L_1}, and using $(B.1)$to solve also for ch_{N_1}we derive:

$$ch_{L_1} = \frac{slop_N * sh_N * slop_L}{slop_N - slop_L}, \ (B.3)$$

$$ch_{N_1} = \frac{sh_N * slop_N}{slop_N - slop_L}, \ (B.4)$$

Using the same procedure to derive the changes in N and L arising by moving from point A to point C, we conclude that :

$$ch_{L_2} = \frac{slop * sh_L}{slop_N - slop_L}, \ (B.5)$$

$$ch_{N_2} = \frac{sh_L}{slop_N - slop_L}, \ (B.6)$$

The total change in L and N is derived by combining , $(B.3)$, $(B.4)$, $(B.5)$and $(B.6)$:

$$ch_L = \frac{slop_N(slop_L * sh_N + sh_L)}{(slop_N - slop_L)}, \ (B.7)$$

.

$$ch_N = \frac{slop_N * sh_N + sh_L}{(slop_N - slop_L)}, \ (B.8)$$

We know that in this case, $slop_N$ and $slop_L$ are positive, with $slop_N$ being always greater than $slop_L$. Therefore, by $(B.7)$and $(B.8)$we have:

$$sign(ch_L) = sign(sh_L + slop_L * sh_N), \ (B.9)$$

$$sign(ch) = sign(sh_N + \frac{1}{slop_N} * sh_L), \ (B.10)$$

orN

$$sign(ch_L) = sign(\frac{\partial L}{\partial w} + \frac{\partial L}{\partial N}|_{LL} * \frac{\partial N}{\partial w}), (B.11)$$

$$sign(ch_N) = sign(\frac{\partial N}{\partial w} + \frac{1}{\frac{\partial L}{\partial N}|_{NN}} * \frac{\partial L}{\partial w}), \ (B.12)$$

by $(B.11)$and $(B.12)$ it turns out that the change in employment depends on the ‘partial’ wage on employment and on the ‘supervision’ effect and the change in supervision depends on the ‘partial’ wage on supervision effect and the ‘employment’ effect.

9 Tables

9.1 Table

a	$(0, a^{'}]$	$(a^{'}, a^{''})$	$[a^{''}, 1)$
η_{ε}	$< -\frac{1}{2}(= \frac{1}{2}$,for $a = a^{'})$	$> -\frac{1}{2}$	$> 0(= 0$, for $a = a^{''})$
$\frac{dL}{dw}$	$-$	$-$	$+(= 0$, for $a = a^{''})$
$\frac{dN}{dw}$	$-(= 0,\ a = a^{'})$	$+$	$+$

Figure 2:

10 Figures

In this figure we present possible changes of optimal L and N when the wage and supervision and employment and supervision are complements, which means that both loci are upward sloping and that NN shifts out, when the minimum wage is increased. As it is depicted in the figure, different changes in L and N are possible, depending on the magnitude of the shifts and the relative slopes. For example if the relative shifts and slopes are such that, after the imposition of the minimum wage the equilibrium pair of N and L moves from A to points B, C or D, then employment and supervision increase. However, it is possible for the relative shifts and slopes of the loci to be such that after the imposition of the minimum wage, the optimal (L, N) pair moves to points E or F, where employment falls and supervision increases or to points G, H, where both supervision and employment fall.

Figure 3:

Figure 3 illustrates possible changes in N and L, when wage and supervision are substitutes and employment and supervision are complements. As it is depicted in the figure, no matter the magnitude of the relative slopes and relative shifts of the optimal loci both employment and supervision fall, in this case.

Figure 4:

In figure 4, it is presented the case of Calvo-Wellisz model, when workers are heterogeneous and supervision endogenous. The only difference with case 2 of our model and Calvo-Wellisz is that in Calvo -Wellisz there is a neighborhood of the unconstrained wage where employment increases if the wage is increased and supervision is held constant and thus LL locus shifts up. In this case, as in case 1, the change in employment of covered workers and supervisors depends on the relative slopes and shifts of the optimal loci. Hence, the possible changes by the figure are either both employment and supervision increases, (which is not the case in Calvo-Wellisz because of certain conditions that they impose), or employment increases and supervision falls(which is the result of Calvo-Wellisz), or both employment and supervision fall (which we show that it is the case in Calvo-Wellisz for a sufficiently high wage increase in the range where the partial employment effect is positive). These possible adjustments reflect the fact that monitoring intensity falls, when the wage increases.

Figure 5:

In figure 5, we present the comparative statics result of a higher minimum wage on employment and supervision when wage and supervision, and employment and supervision are substitutes. Again there is not only one possible way of optimal adjustment. In fact the adjustment again depends on the relative slopes (the difference between the partial elasticity of employment w.r.t supervision and the inverse of the partial elasticity of supervision w.r.t employment), and relative shifts (the relative elasticities of employment and supervision w.r.t. the wage. The possible cases are either for employment to increase and supervision to fall (this case is dismissed in our model, as it turns out that monitoring intensity always increases), or for both supervision and employment to rise or for employment to rise and supervision to fall.

Figure 6:

In this figure it is depicted the effect of an exogenous increase in the wage of supervisors on employment and supervision, when the wage and supervision are substitutes in incentives and employment and supervision are strategic complements (case 1). However, the same analysis can be applied if case 2 is the case. It turns out that, however big is the shift of NN locus, employment and supervision will fall after the increase in the minimum wage of supervisors.

Figure 7:

In figure 7, it is depicted the change in optimal L and N, for an increase in the minimum wage of supervisors, when the wage and supervision and employment and supervision are strategic substitutes. It is clear that however big the shift of NN locus employment of covered workers increases and supervision decreases.

11 References

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