Claimant fraud in workers compensation – How firms discipline their workers

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December 30, 2024

Abstract

I study claimant fraud in workers compensation insurance and the measures perfectly experienced-rated or self-insured firms apply in order to reduce the impact of the same on profits. Firms determine the wage rate and demand labor in a market with oversupply, hired workers have the opportunity to fraudulently claim workers compensation benefits, and ex-post claims investigation may be applied if the savings outweigh the costs. In order to prevent claimant fraud, firms offer efficiency wages, which render fraud unattractive for workers, below some critical wage replacement rate and rely on claims investigation or labor provision of fully honest workers above the critical wage replacement rate. Above the critical wage replacement rate, claims investigation can be partially substituted by investment in injury prevention or firms entirely rely on labor provision of fully honest workers and combat fraud through investment in staff screening.

Keywords: Workers compensation · Claimant fraud · Anti-fraud measures · Wages

JEL Classifications: C73 · D21 · G22 · J23 · J31

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1 Introduction

I address the question by what means firms try to combat workers compensation claimant fraud and how the choice of these means is affected by the wage replacement rate. The importance of researching this question is underlined by recent estimates showing that workers compensation claimant fraud annually amounts to $9 Billion in the United States (Coalition against Insurance Fraud, 2022). The workers compensation system in the United States (and many other countries) makes firms fully liable for any worker injuries arising at the workplace, which requires firms to insure against this liability by purchasing workers compensation coverage from a third-party insurer or self-insuring them.[1] Benefits for workers include reimbursement for medical expenses and wage replacement payments. If insurance premiums are experience-rated (and therefore depend on the firm's claim history) or firms are self-insured (and therefore insure liabilities themselves), any type of claimant fraud (e.g. build-up or faking an injury) drives costs for the firm up creating an economic incentive to combat fraudulent worker activities (Butler et al., 2013). As the (regulatory determined) wage replacement rate determines the share of lost earnings which are reimbursed in the case of an injury with absence from work, it determines both firm incentives to prevent claimant fraud as well as worker incentives to fraudulently claim workers compensation benefits. An increase in the wage replacement rate simultaneously increases fraud incentives on workers' side and fraud prevention incentives on firms' side. Thus, the effect of a change in the wage replacement rate on fraud frequency and firms' fraud prevention strategy is ambiguous. An answer to this question provides information about wage levels in labor markets, the dependence of injury and claim rates on the wage replacement rate, and welfare implications of claimant fraud.

In contrast to other employer-provided benefits such as paid sick leave, workers compensation insurance gives workers an incentive to misreport the state of nature and firms a *possibility* to prevent shirking of workers. In the case of sick leave, for instance, firms have little possibility to influence workers' behavior as sick leaves often are either unpaid or paid at 100% of the formerly gained wage, implying that the wage level has no impact on the decision to misreport the true state of nature. Moreover, injury prevention and monitoring at the workplace cannot prevent false reporting as injuries may as well arise outside the work environment. Thus, the workers compensation system provides a suitable environment to study the impact of firms' measures on absenteeism.[2]

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[1] Workers compensation is a form of liability insurance assigning full liability to the employer. Shavell (1982) and Nell and Richter (1996) analyze incentive effects of different liability rules and insurance.

[2] Butler et al. (2011) study the simultaneous effect of WC and sick leave benefits on workers' incentives to classify an injury as eligible for WC benefits. In this paper, I assume that workers cannot decide whether to file a sick leave or WC claim for an injury, but the injury itself predetermines the type of claim.

Firms have different measures at their disposal to combat fraudulent claiming behavior of their workers. Following the efficient wage hypothesis, the firm may offer a wage rate large enough such that illegitimately claiming benefits (shirking) becomes unattractive for workers (Akerlof, 1982; Shapiro and Stiglitz, 1984; Katz, 1986; Krueger and Summers, 1988; Barmby et al., 1994; Hansen, 1997; Chen and Sandino, 2012). Moreover, firms may use (imperfect) monitoring instead of efficiency wages to discipline workers. Ex-post monitoring includes measures to challenge workers' claims for benefits (Butler et al., 2013), such as claims auditing to identify fraudulent ones which can be rejected immediately. This measure is often accompanied by ex-ante injury prevention (Thomason and Pozzebon, 2002). Investment in injury prevention aims at improving workplace safety such that fewer injuries occur and fraud becomes easier to detect. Eventually, the existence of heterogeneous worker types (honest/strategic) gives firms another alternative measure to reduce workers compensation costs. The use of integrity tests and similar procedures in the hiring process is intended to increase the share of honest workers so that there are less potential fraudsters in the workforce (Cooper et al., 2021).

Using a one-period model I study the impact of the wage replacement rate on firms' claimant fraud prevention strategy given that some workers never commit fraud and ex-post claims auditing is available. In particular, I consider three different decision variables:

- Firms' determination of the wage rate,
- firms' ex-ante fraud prevention strategy – injury prevention or staff screening –,
- and workers' ex-post claiming decision.

A profit-maximizing firm demands labor in a market where supply exceeds demand and workers supply labor at their reservation wages. The demanded labor entails a binary risk of incurring a workplace injury which entitles to receive wage replacement benefits. The firm is liable for workplace injuries and either self-insures this liability or purchases a fully experience-rated workers compensation contract. Once hired by the firm, the choice space of workers consists of the strategies working and filing a workers compensation claim. The strategy choice depends on the worker's type: Non-strategic workers work without injury and file a claim with injury. Strategic workers choose the utility-maximizing action which allows for working with injury and claiming of benefits without injury (claimant fraud). The firm cannot distinguish between worker types. Workers who claim insurance benefits do not provide labor and a detected fraud attempt entails termination of employment. The insurer (or in case of self-insurance the firm) decides on the basis of a cost comparison whether to audit claims to identify fraudulent ones before benefits are paid out. In extended versions of the model, the firm can invest either in injury prevention, which reduces the likelihood of a workplace injury, or in staff screening, which increases the share of non-strategic workers in the workforce.

I show that there exists a critical wage replacement rate below which strategic workers work independently of injury occurrence and above which injured workers always claim insurance benefits and fraud occurs in equilibrium. Below the critical wage replacement rate, the firm hires only strategic workers at their reservation wage or both worker types at non-strategic workers' reservation wage as long as neither of these wage rates induces claimant fraud, and switches to efficiency wages when reservation wages cannot prevent fraud. At the critical wage replacement rate, entire prevention of fraud through efficiency wages becomes too costly such that setting the wage rate equal to non-strategic workers' reservation wage rate is optimal. For wage replacement rates above the critical one, there is either no claims auditing and all strategic workers commit fraud if the costs of auditing are too large, or the equilibrium is in mixed strategies with occasional auditing and fraud. As fraud has a negative impact on profits, the firm has an incentive to reduce claimant fraud above this critical wage replacement rate. If costly injury prevention is at the firm's disposal and workers play a mixed strategy, the investment amount decreases in the wage replacement rate. As the incentive to audit increases with an increase in the wage replacement rate, workers need to reduce the fraud probability given that investment in injury prevention stays unchanged. Thus, the expected labor provision per worker increases, which gives the firm the opportunity to save injury prevention costs. The claims investigation process substitutes investment in injury prevention and the real injury rate is increasing in the wage replacement rate.

Staff screening as a measure to combat claimant fraud is only beneficial if there is no claims auditing. With claims auditing, the share of strategic workers in the workforce has no impact on the profit due to the mixed strategies of workers and insurer/firm. Thus, staff screening and claims investigation are perfect substitutes and investment in staff screening can only be beneficial if the audit costs are sufficiently large. It follows that investment in staff screening may be never beneficial and if it is beneficial, the firm cannot rely on claims investigation to reduce fraudulent claiming behavior after an increase in the wage replacement rate. This can result in more investment in staff screening with a higher wage replacement rate.

This study contributes to the analysis of claimant fraud in workers compensation insurance and to the literature on the effect of worker screening on operational costs. Theoretical studies in the workers compensation literature mostly focus on compensating wage differentials and safety investment incentives of workers and firms. Regarding compensating wage differentials, Ehrenberg (1985) argues that a change in the wage replacement rate does not affect workers' total remuneration in perfectly competitive labor markets with perfect information, as the higher benefit in the case of an injury is exactly offset by a reduction in the wage rate. Viscusi and Moore (1987) provide empirical evidence for the negative effect of workers compensation benefits on wage levels, which is in line with the argument of Ehrenberg (1985). Taking moral hazard into account, Krueger (1990) shows that workers invest less in ex-ante injury prevention with increasing benefit levels whereas the effect of a change in benefits on firm incentives is indeterminate if the firm is the Stackelberg leader. Ruser et al. (2010) investigate the behavior of a firm and homogeneous workers who both can reduce the injury probability by exerting costly effort and decrease or increase respectively the likelihood of an injury entailing wage replacement benefits by investing in classification effort. On the workers' side, results indicate risk-bearing and claims reporting moral hazard. Moreover, a sufficiently high level of experience rating incentivizes the firm to increase investment in injury prevention and in classification with an increase in the insurance benefit. Consequently, firms' and workers' incentives go in opposite directions such that the net effect is ambiguous (Krueger, 1990). Lanoie (1991) considers equilibrium behavior (Nash and Stackelberg) of a firm and workers who can both influence the injury probability. He finds that non-cooperative equilibria imply suboptimal levels of precaution. The empirical literature also gives no unambiguous answer to the question whether claims and injuries increase with benefits, but there is the tendency that benefits and injuries/claims are positively related (Butler et al., 2013).

My analysis theoretically underpins this empirical finding, as the claim rate increases when the firm switches from efficiency wages to reservation wages in any specification of the model. Furthermore, there is empirical literature on the interaction between experience rating, claims investigation activities, and claim frequency (Thomason and Pozzebon, 2002), but the underlying economic incentives are unclear. I find that claims investigation and investment in injury prevention are substitutes, which is in line with empirical findings (Thomason and Pozzebon, 2002). As claims auditing reduces fraud with an increase in the wage replacement rate, the firm can save on injury prevention costs, implying that the injury rate is increasing in the wage replacement rate. This contrasts the common hypothesis that corporate investment in injury prevention increases in the wage replacement rate. Moreover, it provides an alternative explanation for the empirical observation of a positive relation between injury rates and benefits.

Thomason and Pozzebon (2002) moreover provide empirical evidence that high-wage firms are more likely to substitute claims management with safety investments than low-wage firms, for which efficiency wages can be an explanation. To the best of my knowledge, the economic models in the workers compensation literature do not consider efficiency wages as a potential measure to combat claimant fraud. However, paying above-market wages has been shown to be beneficial in the prevention of shirking (Shapiro and Stiglitz, 1984; Barmby et al., 1994) and worker theft (Hansen, 1997). Inspired by the model of Hansen (1997), I combine optimal wage determination and costly state verification (Townsend, 1979; Picard, 1996) to study how firms impact the claiming behavior of workers. The firms' profit function is similar to the one in Albrecht and Vroman (1999), who study the effects of unemployment compensation finance in a labor market in which firms pay efficiency wages, but I focus on a single period and changes in the underlying cost parameter. I find that firms use efficiency wages as a tool to prevent fraudulent worker behavior, but only below some critical wage replacement rate. Firms exploit the fact that claiming insurance benefits becomes suboptimal for workers if the wage rate is sufficiently large as then the income loss is too large. This result ties in with the findings of Shapiro and Stiglitz (1984), Rasmusen (1992), and Hansen (1997). However, the availability of monitoring (claims investigation) and the existence of different worker types results in the reliance on other fraud reduction measures for large wage replacement rates.

Besides reducing claimant fraud through efficiency wages and claims investigation, I theoretically show how worker screening affects workers compensation costs. I thereby complement the literature analyzing worker screening as a measure to reduce workers compensation costs. Overt integrity tests measure attitudes toward theft and other forms of dishonesty and include questions about own involvement in theft and other counterproductive activities (Sackett et al., 1989). Thus, integrity tests may not only predict worker theft, but also a wide variety of counterproductive behaviors such as fraudulently claiming workers compensation benefits. Using integrity tests in the hiring process could prevent that workers who are most likely to engage in fraudulent claiming behavior are hired. Empirical studies find a negative correlation between using integrity tests and workers compensation costs (Sturman and Sherwyn, 2009; Oliver et al., 2012; Cooper et al., 2015). Cooper et al. (2021) argue that integrity test scores are directly related to malingering, which implies that the application of integrity tests should reduce workers compensation costs. The application of worker screening was shown to be particular useful when worker monitoring is hardly possible (Huang and Cappelli, 2007). However, to the best of my knowledge, there is no economic model linking the application of integrity tests and workers compensation costs. I fill this gap in the literature by providing a theoretical basis for firms' incentive to invest in worker screening. It turns out that worker screening is only beneficial if there is no claims auditing. Otherwise, strategic workers adjust their claiming strategy such that the claim rate is independent of the share of strategic workers, which renders investment in worker screening suboptimal.

The remainder of the paper is organized as follows: Section 2 introduces the model framework and I derive the equilibrium in the claiming game and the eligible wages rate in Section 3. Section 4 analyzes the outcome without investment in a fraud reduction measure. In Section 5, I study injury prevention as a fraud reduction measure before I discuss the potential of staff screening as a fraud reduction measure in Section 6. Section 7 concludes the paper.

2 Model framework

Firm

A risk-neutral firm produces an output with the input factors labor L and capital K. The production function f has a Cobb-Douglas form, i.e. $f(K,L) = AK^{\alpha}L^{1-\alpha}$ for some $A > 0$ and $\alpha \in (0,1)$.[3] Each output unit is sold for an exogenously given price $p > 0$. The firm disposes over a fixed amount of capital $K > 0$, employs $N > 0$ workers, and pays a wage $w > 0$ to workers who provide labor. Labor provision per worker is normalized to 1. Once hired by the firm, all workers face the risk of a work-related injury which occurs with probability $\rho \in (0,1)$.[4] Injury occurrence at the workplace is private information of workers, but the firm is fully liable for any injury occurring at the workplace. In particular, the firm has to provide wage replacement payments for injured workers who stay absent from work. To cover liabilities arising from the workplace injury risk, the firm is obliged to purchase workers compensation insurance such that injured workers can directly claim workers compensation benefits with the insurer.[5] All workers who claim workers compensation benefits do not provide labor. The insurance premium is denoted by π. Injured workers can either claim workers compensation benefits or work which reduces their output compared to no injury. Labor provision of an injured worker is given by $\gamma < 1$.[6] Non-injured workers can either work or pretend having suffered a work-related injury and claim workers compensation benefits. Consequently, the firm's profit function is given by the following expression:

$$\Pi = pAK^{\alpha}\big[N_h + \gamma N_u\big]^{1-\alpha} - w\big[N_h + N_u\big] - \pi, \tag{1}$$

where N_h denotes the number of workers without work-related injury who do not claim workers compensation benefits and N_u denotes the number of workers with work-related injury who do not claim workers compensation benefits.

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[3] In microeconomics, the Cobb-Douglas production function is frequently applied to model the behavior of profit-maximizing firms (Turnovsky, 2000; Maté-García and Rodríguez-Fernández, 2008; Balk, 2024). Furthermore, the use of Cobb-Douglas production functions can be empirically justified (Aigner and Chu, 1968; Gurbaxani et al., 2000).

[4] I assume that, at the beginning of the planning period, it is more beneficial for the firm to hire so many workers that absences can be coped with than to hire fewer workers and replace absent workers later. This applies, for instance, if a firm chooses employment for a particular project and offers temporary employment contracts, which is the case in the construction industry and agriculture (The Center for Construction Research and Training, 2024). The hiring of workers during the specified period may be suboptimal due to too little remaining time for hiring or significantly higher hiring costs compared to one-time hiring (Abowd and Kramarz, 2003).

[5] The model framework and the results refer to the case of a third-party insurer. However, the model can be transferred 1:1 to the case of self-insurance (where firm and insurer are the same entity).

[6] Injured workers are limited in their productivity (e.g. pain when performing physical tasks), so they can provide less labor than non-injured workers.

Workers

Workers' utility depends on wealth, health, and leisure, and is additive. Workers are risk-neutral w.r.t. wealth and have an endowed wealth of $B \geq 0$.[7] Working generates wage income of $w > 0$, but also a disutility of effort $e > 0$. An injury entails a disutility of $d = e$. If a worker is injured and claims workers compensation benefits, he receives insurance benefits if the claim is approved by the insurer and nothing otherwise. The benefit is given by bw, where $b \in [0, 1]$ denotes the wage replacement rate.

There are two different types of workers, strategic and non-strategic, and their type is private information. Non-strategic workers work if they do not suffer an injury and stay absent from work and file a workers compensation claim if they suffer an injury. Strategic workers choose the utility-maximizing action when deciding whether to work or to file a workers compensation claim. The conditional probability that an strategic worker files a workers compensation claim when not injured (fraud) is denoted by η. If a worker is caught having filed a fraudulent claim, he loses his job and receives utility B.[8] The conditional probability that a strategic worker chooses to work in the case of an injury is given by ξ.

Workers compensation insurer

Workers compensation insurance is offered in a competitive insurance market. Insurers are risk-neutral and offer workers compensation coverage to firms. The insurance benefits are paid to workers (third party in the insurance contract) and consist of wage replacement payments with rate $b \in [0, 1]$. Before paying out the insurance benefit, an insurer can audit claims to identify fraudulent ones at a cost $c > 0$. Identified fraudulent claims are denied and the firm (policyholder) is informed about the fraudulent behavior of the worker. Insurers cannot commit to an auditing strategy and the audit probability is given by ν. Insurance premiums are actuarially fair and perfectly experience-rated.[9]

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[7] Risk neutrality of workers is a common assumption in the literature on efficiency wages (Shapiro and Stiglitz, 1984; Barmby et al., 1994; Hansen, 1997). Moreover, the main results also apply to risk-averse workers. For instance, Propositions 1 and 2 also hold for risk-averse workers if the coefficient of absolute risk aversion is sufficiently small.

[8] I assume that expected utility received in future periods does not impact utility in the current period. This assumption holds true if the expected utility from all future periods is independent of the decisions made in the current period. This implies that detected fraudsters have no disadvantage in finding a job in future periods, but they only experience a disutility in the current period (Shapiro and Stiglitz, 1984).

[9] Most (small) employers in the US pay manual premiums which do not reflect individual claim history. Larger employers, however, pay experienced-rated premiums which reflect individual claim history or they may be allowed to self-insure their liabilities (Butler et al., 2013). In California, for instance, 7,000 employers were active self-insurers in 2023.

Sequence of the game and decision variables

All information except injury occurrence and worker type are common knowledge. The former information asymmetry is only possible to overcome with an audit. Strategic workers choose the action that maximizes expected utility. An insurance company minimizes its costs. If no measure for fraud reduction is available (I call this the benchmark case and discuss it in Section 4), the firm maximizes profits by determining the optimal wage rate w^* and the optimal number of workers N^* for a given wage replacement rate b. The labor market, in which the firm demands labor and the workers supply labor, is characterized by significantly lower demand than supply. Both worker types supply labor at their respective reservation wages, which allows the firm to hire as many strategic and non-strategic workers as it wants at the non-strategic workers' reservation wage w_c or to hire as many strategic workers as it wants at the strategic workers' reservation wage (if it is different from w_c).[10] $\theta \in (0, 1)$ denotes the share of hired non-strategic workers, which equals the share of non-strategic workers in the labor market if the firm does not take measures.[11] Then, the insurance contract is concluded at stage 3 and the claiming game is played (Stages 4 – 7).

In sections 5 and 6 the firm may invest $s \geq 0$ in measures to reduce the share of workers who (need to) stay absent from work. In particular, I discuss the possibilities of injury prevention in section 5 and staff screening in section 6. The investment decision precedes the determination of the wage rate such that potential workers and insurers are able to observe the investment decision. If one measure for fraud reduction is available, the firm does not change the choice of w^* and N^* compared to the benchmark case if $w^* \leq w_c$ and $\eta = 0$. The reason for this assumption is that the firm has no need to invest anything in fraud reduction in this case. Otherwise, if $w^* > w_c$ and/or $\eta > 0$ in the benchmark case, the firm determines the optimal set (N^*, w^*, s^*) if injury prevention (Section 5) or staff screening (Section 6) is available. Figure 1 shows the sequence of the game.

[10] The assumption of labor oversupply applies to several industries. For example, labor oversupply has been recently documented in the European construction and manufacturing industry (EURES (EURopean Employment Services), 2024). The specification of labor supply allows for unlimited labor supply implying perfect elasticity throughout (Lewis et al., 1954) and limited labor supply which is perfectly elastic at the reservation wages and perfectly inelastic otherwise (Minami, 1964). Perfectly elastic labor supply is commonly assumed in labor economics and is also empirically supported at the firm-level (Hamermesh, 1986; Slaughter, 2001; Popp, 2023). Note that the labor supply says nothing about the labor demand. In particular, there may be multiple firms demanding labor in the same market (competitive labor market) or the firm may be a monopsonist (Boal and Ransom, 1997).

[11] Due to (almost) unlimited supply in the labor market, the impact of each firm on the labor market is negligible, and therefore the share of hired non-strategic workers equals the share of non-strategic workers in the labor market for $w \geq w_c$. Consequently, other firms who demand labor in the same labor market have no impact on the decisions of the firm in question.

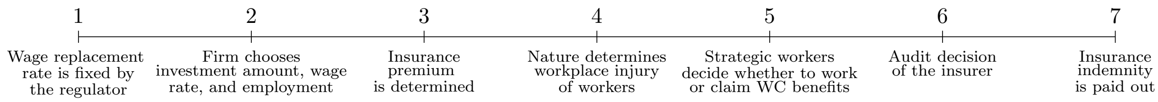


Figure 1: Sequence of the game

3 Equilibrium in the claiming game and eligible wage rates

Before I determine the optimal set (N^*, w^*) for each $b \in [0, 1]$, I first elaborate the possible equilibria in the claiming game (Stages 4 – 7) and the eligible wage rates. In particular, two wage rates will be of importance in the optimization process, the first of which is the non-strategic workers' reservation wage w_c. This wage rate represents a first reference point for the optimization and is given by

$$EU(\text{Non-strategic}) = (1-\rho)\big[B + w - e\big] + \rho\big[B + bw - e\big] = B \Leftrightarrow w_c = \frac{e}{1-\rho+\rho b}. \tag{2}$$

The reservation wage rate is the minimal wage the firm has to pay in order to attract non-strategic workers. As strategic workers obtain at least the same expected utility as non-strategic workers, both worker types are willing to enter the work contract for $w \geq w_c$. The premium is then given by:

$$\pi = N\Bigg[\Big(\theta\rho + \rho(1-\theta)(1-\xi)\Big)\Big(bw + c\nu\Big) + (1-\theta)(1-\rho)\eta(1-\nu)bw + (1-\theta)(1-\rho)\eta\nu c\Bigg]. \tag{3}$$

For $w < w_c$, there is either no labor supply or only strategic workers supply labor and the firm can only hire strategic workers. In this case, the insurance premium is given by:

$$\pi = N\Bigg[\Big((1-\rho)\eta(1-\nu) + \rho(1-\xi)\Big)bw + c\nu\Big(\rho(1-\xi) + \eta(1-\rho)\Big)\Bigg]. \tag{4}$$

Whereas non-strategic workers' behavior does not depend on the wage rate, strategic workers' decision whether to work or to file a claim is influenced by the wage rate:

$$\begin{aligned} EU(\text{Strategic}) =&(1-\rho)\Big[(1-\eta)\big[B + w - e\big] + \eta\big[(1-\nu)(B+bw) + \nu B\big]\Big] \\ &+ \rho\Big[(1-\xi)\big[B + bw\big] + \xi\big[B + w - e\big]\Big] - \rho e. \end{aligned} \tag{5}$$

Using (5) shows that strategic workers do not commit fraud if $B + w - e \geq B + bw$, as the maximally possible utility with fraud is smaller than the utility without fraud.[12] The second wage rate, which will be of importance in the optimization process, is thus defined by the

[12] If $B + w - e = B + bw$, I assume that strategic workers choose $\xi = 1$ and $\eta = 0$.

smallest wage rate preventing claimant fraud w_d:

$$B + w - e = B + bw \Leftrightarrow w_d = \frac{e}{1-b} \tag{6}$$

For $w \geq w_d$, working is always preferred over claiming insurance benefits. This implies that $\xi = 1$ and $\eta = 0$ for all $w \geq w_d$. As illustrated in Figure 2, w_d is increasing in b, w_c is decreasing in b, and they intersect at $b = \frac{\rho}{1+\rho}$. If $b \leq \frac{\rho}{1+\rho}$, it follows that $w_c \geq w_d$ implying that there is

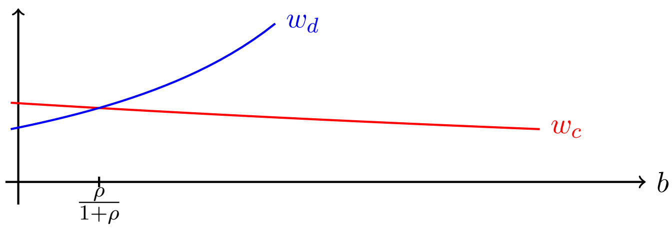


Figure 2: Wage rates w_c and w_d as functions of b

no claimant fraud if the firm sets $w = w_c$. Consequently, setting a wage rate above w_c cannot be beneficial for the firm, as the expected labor provision per worker $(1-\rho) + \rho(1-\theta)\gamma$ is constant in the wage rate and the expected costs per worker increase in the wage rate. However, it may be beneficial to set the wage rate below w_c, which would imply that only strategic workers are hired. This is possible since strategic workers are strictly better off than non-strategic workers for $w = w_c$ and therefore supply labor for $w < w_c$. As strategic workers choose $\xi = 1, \eta = 0$ for $w \geq w_d$, their expected utility is given by $B + w - (1+\rho)e$ and the minimal wage rate $w_a < w_c$ to hire strategic workers is given by

$$B + w - (1+\rho)e = B \Leftrightarrow w_a = (1+\rho)e. \tag{7}$$

The wage rate w_a satisfies the condition $B + w_a - e > B + bw_a$. Any wage rate below w_a is too small to attract any workers. Setting the wage rate equal to w_a instead of w_c implies that the expected labor provision per worker is higher and the expected costs per worker may be smaller or higher. Thus, both wage rates w_c and w_a could be an optimal choice if $b \leq \frac{\rho}{1+\rho}$.

Lemma 1. *For $b \leq \frac{\rho}{1+\rho}$, the optimal wage rate is either given by $w^* = w_a$ or $w^* = w_c$. In any case, strategic workers prefer working over claiming insurance benefits independently of the state of nature.*

Proof. Follows from the previous discussion. □

If, on the other hand, $B + w_c - e < B + bw_c$, i.e. $b > \frac{\rho}{1+\rho}$, holds, the reservation wage rate w_c and any wage rate below w_c cannot prevent claimant fraud. To show this, I determine the equilibrium in the claiming game (stages $4-7$) for $w \in [w_c, w_d)$. If a strategic worker did suffer an injury, he needs to decide between claiming insurance benefits and working. The utility from working is given by $B+w-2e$ and the utility from claiming insurance benefits is given by $B+bw-e$, which implies that $\xi = 0$. Intuitively, staying absent from work and claiming workers compensation benefits is only beneficial for the worker if insurance benefits are sufficiently large. If the wage replacement rate is small, insurance benefits are not sufficient to outweigh the income loss following the decision not to work. Conversely, a strategic worker's decision situation in the case of no injury looks as follows: The utility from working is given by $B+w-e$ and the expected utility from claiming workers compensation benefits is given by:

$$EU(\text{Fraud}) = (1-\nu)\big[B+bw\big] + \nu B. \tag{8}$$

As $B+w-e < B+bw$, non-injured strategic workers have an incentive to commit fraud if ν is sufficiently small. To determine the equilibrium if $B+w-e < B+bw$, I consider the insurer's decision situation. The insurer's audit decision depends on the expected costs with and without auditing. Whereas the expected costs without audit are given by bw, the expected costs with audit are given by:

$$c + \frac{\rho bw}{\rho + (1-\rho)(1-\theta)\eta}. \tag{9}$$

Setting $\eta = 1$ shows that auditing is only beneficial for the insurer if $bw \geq \frac{c[\rho+(1-\rho)(1-\theta)]}{(1-\rho)(1-\theta)}$. If $B+w-e < B+bw$ and $bw \geq \frac{c[\rho+(1-\rho)(1-\theta)]}{(1-\rho)(1-\theta)}$, a mixed-strategy equilibrium arises as the insurer has an incentive to audit if $\eta = 1$ and strategic workers have an incentive to commit fraud if $\nu = 0$ (Boyer, 2000). A stable situation where no player has an incentive to deviate can only be reached if all players are indifferent. If $B+w-e < B+bw$ and $bw < \frac{c[\rho+(1-\rho)(1-\theta)]}{(1-\rho)(1-\theta)}$, it follows that $\eta = 1$ and $\nu = 0$, as the insurer has no incentive to audit and strategic workers have an incentive to defraud if $\nu = 0$. The results are summarized in Lemma 2:

Lemma 2. *For $b > \frac{\rho}{1+\rho}$ and $w_c \leq w < w_d$, injured strategic workers prefer claiming insurance benefits over working. Regarding non-injured strategic workers' decision, there is*

(a) either an equilibrium in pure strategies with $\eta = 1$ and $\nu = 0$ if $bw < \frac{c[\rho+(1-\rho)(1-\theta)]}{(1-\rho)(1-\theta)}$, or

(b) an equilibrium in mixed strategies with

$$\eta = \frac{\rho}{(1-\theta)(1-\rho)} \frac{c}{bw-c} \quad \text{and} \quad \nu = \frac{e-(1-b)w}{bw}. \tag{10}$$

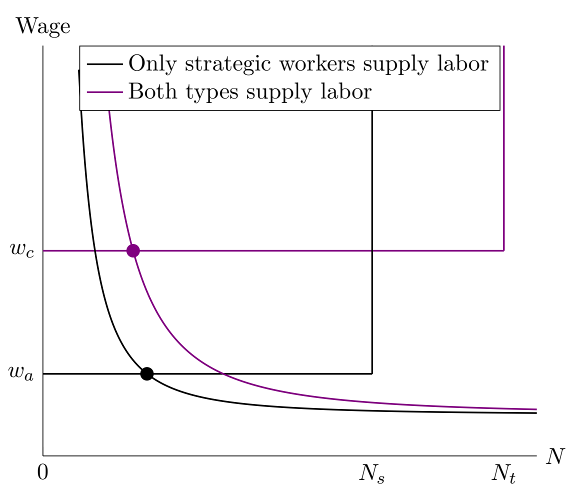
Proof. Follows from the previous discussion. □

As setting $w = w_c$ cannot prevent claimant fraud, the firm could increase the wage rate above w_c such that $B+w-e \geq B+bw$, which would prevent claimant fraud. The smallest possible wage rate which would entirely prevent claimant fraud is w_d. Moreover, setting a wage rate above w_d is not beneficial for the firm, as the expected labor provision per worker $(1-\rho)+\rho(1-\theta)\gamma$ is constant in the wage rate and the expected costs per worker increase in the wage rate. Setting a wage rate below w_c also cannot be optimal, as this would either attract no workers or only strategic workers who do not provide any labor at all. Consequently, the optimal wage rate lies in the interval $[w_c, w_d]$. In fact, only w_c and w_d will be chosen if the auditing costs are either sufficiently small or sufficiently large.

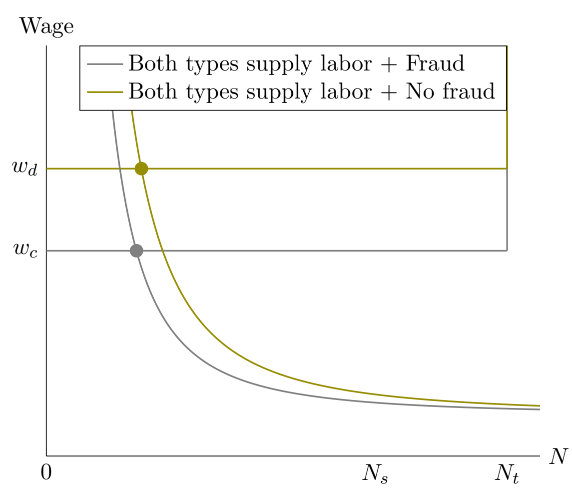
Lemma 3. *For $b > \frac{\rho}{1+\rho}$, the optimal wage rate is either given by $w^* = w_c$ or $w^* = w_d$ if the auditing costs c are either sufficiently small or sufficiently large.*

Proof. Follows from Proposition 1. □

Figure 3 visualizes the different possible employment outcomes by revealing the firm-specific labor demand and supply curves. In particular, only the N_s strategic workers supply labor for $w_a < w_c$ if $b \leq \frac{\rho}{1+\rho}$ and all N_t workers supply labor for $w \geq w_c$. The firm's profit function (and the resulting labor demand) depends on the expected labor provision per hired worker. This corresponds either to (i) Expected labor provision of a strategic worker and there is no claimant fraud (black), or (ii) average labor provision if both worker types are hired and the there is claimant fraud (gray), or (iii) average labor provision if both worker types are hired and there is no claimant fraud (violet, olive). This gives three different labor demand functions and four possible employment outcomes which are visualized by the dots in the graphic. The firm chooses the profit-maximizing outcome between (i) and (iii) if $b \leq \frac{\rho}{1+\rho}$ and between (ii) and (iii) if $b > \frac{\rho}{1+\rho}$.



(a) Labor supply and demand for $b \leq \frac{\rho}{1+\rho}$



(b) Labor supply and demand for $b > \frac{\rho}{1+\rho}$

Figure 3: Labor supply and demand

4 Benchmark case: No use of a fraud reduction measure

In the benchmark case, the firm can neither influence the injury probability ρ nor the composition of the staff θ. The firm decides on the wage rate w and employment N at stage 2 of the game, strategic workers face the decision whether to work or to claim insurance benefits at stage 5, and the insurer decides whether to audit a claim at stage 6 of the game. The results of section 3 show that strategic behavior of workers can go in two different directions depending on the wage replacement rate b. If b is small, working generates a higher utility than not working independently of the state of nature as the insurance payment in the case of staying absent from work is too small to outweigh the wage loss. Accordingly, non-injured strategic workers never commit fraud and injured strategic workers work even though it generates an additional disutility. Conversely, a large wage replacement rate b makes staying absent from work and receiving workers compensation benefits more attractive than working. Thus, injured strategic workers stay absent from work and non-injured workers commit fraud if the wage rate is not large enough to render fraud unattractive.

Given the behavior of strategic workers after nature's move, the firm has to choose the optimal wage rate w^* and decide about employment N^*. Given any wage rate w, optimal employment $N^*(w)$ is given by

$$N^*(w) = \left[\frac{pAK^\alpha(1-\alpha)\big[1-\rho-(1-\theta)(1-\rho)\eta+\rho(1-\theta)\gamma\big]^{1-\alpha}}{wb+\big[1-\rho-(1-\theta)(1-\rho)\eta+\rho(1-\theta)\big]w(1-b)}\right]^{\frac{1}{\alpha}}. \tag{11}$$

Inserting $N^*(w)$ in the profit function Π shows that wage and insurance costs are a fixed share (namely $1-\alpha$) of the revenue. The revenue, in turn, is given by some increasing function of expected labor provision per worker divided by expected costs per worker. Consequently, the firm's profit increases if the fraction $\frac{\text{Expected labor provision per worker}}{\text{Expected costs per worker}}$ increases and vice versa. Having determined the optimal number of workers for a given wage rate, the next step is to determine the optimal wage rate w^*. Whereas w_d is increasing in b, the reservation wage rate w_c is decreasing in b. Thus, setting the wage rate above w_c in order to prevent claimant fraud might be beneficial for sufficiently small wage replacement rates but too costly for larger wage replacement rates. This intuition is formalized in Proposition 1.

Proposition 1. *Let $w_c = \frac{e}{1-\rho+\rho b}$. Then it follows:*

(i) If $b \leq \frac{\rho}{1+\rho}$, the optimal wage rate is given by w_c or $w_a < w_c$ with $w_a = e(1+\rho)$.

(ii) If $b > \frac{\rho}{1+\rho}, \gamma > 1-\rho$, and $\min\left\{\frac{1-\rho}{2}, \frac{(1-\rho)(1-\theta)}{\rho+(1-\rho)(1-\theta)}\right\}\rho e > c$ or $\theta > \frac{e}{c}$, the optimal wage rate is given by $w_d = \frac{e}{1-b}$ until some $1 > b_2 > \frac{\rho}{1+\rho}$ and by w_c for $b \geq b_2$.

For $b \geq b_2$, claimant fraud reduces employment and profits if $b \geq \alpha$.

Proof. See Appendix. □

Proposition 1 underlines the two-sided effect of strategic workers on firms' profits and the effect of wages on worker behavior. Whereas the firm wants to hire strategic workers for small wage replacement rates due to their positive effect on revenue and costs, it aims to prevent the cost-increasing effect of strategic workers for large wage replacement rates. For $b > \frac{\rho}{1+\rho}$, the firm relies on the self-selection effect (Stiglitz and Weiss, 1981; Malcomson, 1981). In contrast to the case $b < \frac{\rho}{1+\rho}$, strategic workers provide less expected labor than non-strategic workers for $b > \frac{\rho}{1+\rho}$, which is why the firm tries to increase average labor provision by setting a sufficiently high wage rate to attract non-strategic workers as well. In order to prevent fraud by strategic workers for large wage replacement rates ($b > \frac{\rho}{1+\rho}$), the firm sets the wage rate above the non-strategic workers' reservation wage as long as the minimal wage rate inducing non-fraudulent worker behavior is not too large. This result is in line with Shapiro and Stiglitz (1984) and Rasmusen (1992) who show that wages need to exceed the competitive wage in order to prevent worker misbehavior. In my setting, setting the wage rate at a sufficiently high level renders claiming workers compensation benefits without injury disadvantageous for strategic workers. This procedure, however, is only desirable if the gain in expected production output outweighs the cost increase. Otherwise, the firm sets the wage equal to the reservation wage w_c and relies on other measures to reduce claimant fraud (Figure 4). In particular, the

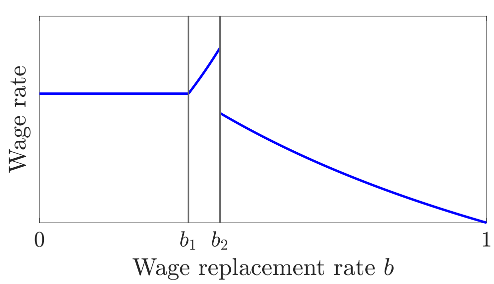


Figure 4: Wage rate in dependence of the wage replacement rate

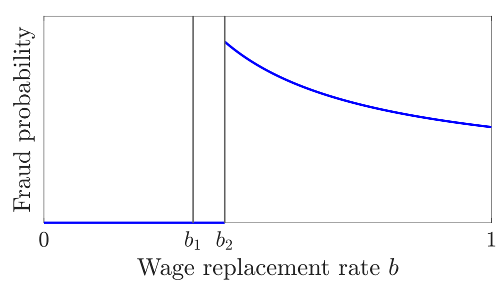


Figure 5: Fraud probability in dependence of the wage replacement rate

firm benefits from claims auditing or labor provision of non-strategic workers for sufficiently large wage replacement rates. Hence, the firm weighs up between wages and alternative measures for fraud reduction and the advantageousness of the respective measures depends on the wage replacement rate. The negative impact of claimant fraud on profits manifests itself if $b \geq \rho > \frac{\rho}{1+\rho}$. Independently of the wage rate w^*, the opportunity of claimant fraud reduces the firm's profit. In particular, if $w^* = w_c$, one can interpret the firm's profit as a function of the fraud probability η:

$$\Pi(\eta) = \frac{\alpha}{1-\alpha}\left[\frac{pAK^{\alpha}(1-\alpha)\big(1-\rho-(1-\rho)(1-\theta)\eta\big)^{1-\alpha}}{\big[wb+\big(1-\rho-(1-\rho)(1-\theta)\eta\big)w(1-b)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}}, \tag{12}$$

where the case of no fraud corresponds to $\eta = 0$. Clearly, the firm's profit decreases with the occurrence of claimant fraud ($\eta > 0$). For $b \geq b_2$ fraud occurs in equilibrium, whereby $\eta < 1$ if claims are audited or $\eta = 1$ if claims are not audited. If there is claims auditing, an increase in the wage replacement rate increases expected costs per worker due to the increase in the insurance premium. As the expected labor provision per worker $1 - \rho\frac{bw}{bw-c}$ increases faster than the costs per worker $wb + \left(1 - \rho\frac{bw}{bw-c}\right)w(1-b)$, the firm's profit is increasing in the wage replacement rate. It follows that the marginal benefit and the marginal cost of hiring one additional worker increase, implying that the effect of an increase in the wage replacement rate on employment is ambiguous. If labor is relatively important in comparison to capital as production factor (α small), the increase in the marginal benefit outweighs the cost increase. In this case, it is optimal for the firm to increase the number of workers with an increase in the wage replacement rate. Conversely, if labor is relatively unimportant in comparison to capital as production factor (α large), the cost-increasing effect outweighs the positive effect on labor. In this case, the firm wants to reduce the number of workers with increasing wage replacement rate. Without claims auditing, there is only labor provision of non-strategic workers implying that the production output per worker is constant in b. Moreover, the expected costs per worker are increasing in b such that the overall profit as well as employment decrease in the wage replacement rate. Proposition 2 summarizes these results:

Proposition 2. *For given $b \geq b_2$, claimant fraud occurs in equilibrium ($\eta > 0$) and reduces the firm's profit compared to no fraud ($\eta = 0$). Moreover, it holds:*

(i) If $\eta < 1$ for all $b \geq b_2$, employment is strictly increasing in b if $b \geq \frac{1}{2}$ and α is below a certain threshold and employment is decreasing if α is sufficiently close to 1. The firm's profit is increasing in the wage replacement rate.

(ii) If $\eta = 1$ for all $b \geq b_2$, employment and the firm's profit decrease in b.

Proof. See Appendix. □

Besides efficiency wages (i.e. $w > w_c$), possible fraud prevention measures include corporate investment in injury prevention (which reduces the injury probability ρ) and corporate investment in staff screening (which reduces the share of strategic workers $1 - \theta$ in the workforce). Both approaches are aimed at reducing the claim rate. A reduction of the claim rate would benefit the firm on the one hand (as the profit is decreasing in the claim rate), and simultaneously has the potential to increase employment (as the marginal benefit of work increases). The decision whether to invest in any of these measures strongly depends on the wage replacement rate, which is why I address the impact of these two measures on workers' behavior and the influence of the wage replacement rate on the firm's fraud prevention strategy in the following subsections.

5 Corporate investment in injury prevention

Corporate investment in injury prevention includes any measure that aims at reducing the injury likelihood such as the acquisition of safety goggles or protective clothing. I assume that injury prevention impacts the injury probability ρ in the following way:

$$\rho(s) = \rho(0) - rs, \tag{13}$$

where $s \geq 0$ denotes the investment amount, $\rho(0)$ denotes the injury probability without investment, and $r > 0$ denotes the efficiency of investment. As non-strategic workers' reservation wage rate depends on the injury probability and therefore on the investment amount s, I denote by $w_c(s, b)$ the reservation wage rate as a function of s and b. The firm's investment decision follows the specification of the wage replacement rate b, is common knowledge, and precedes the determination of the wage rate. The workers compensation contract is concluded once the investment is made, which implies that there is no information asymmetry between insurer and firm ruling out adverse selection. As fraud does not occur and the wage rate is smaller than w_c for $b \leq \frac{\rho(0)}{1+\rho(0)}$, I focus on the case $b > \frac{\rho(0)}{1+\rho(0)}$. Furthermore, I assume that $\eta < 1$ for each $b > \frac{\rho(0)}{1+\rho(0)}$ given that there is no investment in injury prevention (i.e. case (ii) of Proposition 1 with $\min\left\{\frac{1-\rho(0)}{2}, \frac{(1-\rho(0))(1-\theta)}{\rho(0)+(1-\rho(0))(1-\theta)}\right\}\rho(0)e > c$). If injury prevention is available, the firm needs to determine the optimal tuple (N^*, w^*, s^*). Without investment in injury prevention, the firm had the choice between setting $w = w_d$ which entirely alleviates fraud and $w = w_c$ which cannot prevent fraud. In the latter case, the mixed strategy equilibrium with $\eta, \nu \in (0, 1)$ followed. As the wage rate w_d is independent of ρ, it is still the case that setting $w = w_d$ entirely prevents claimant fraud. Furthermore, the equilibrium in the claiming game does not change if the firm chooses to invest in injury protection $s > 0$ and sets $w = w_c(s, b) < w_d$, which is summarized in the Lemma 4:

Lemma 4. *For $b > \frac{\rho(0)}{1+\rho(0)}$, $s \geq 0$, and $w = w_c(s, b)$, the equilibrium in the claiming game is in mixed strategies with*

$$\eta = \frac{\rho(s)}{(1-\rho(s))(1-\theta)} \frac{c}{bw_c(s, b) - c} \quad \text{and} \quad \nu = \frac{e - (1-b)w_c(s, b)}{bw_c(s, b)}. \tag{14}$$

Proof. See Appendix. □

The intuition behind this finding is straightforward: Without investment in injury prevention, a mixed strategy equilibrium arises for $w = w_c(0, b)$ and the claim rate is given by $l = \rho(0)\frac{bw_c(s,b)}{bw_c(s,b)-c}$. Investment in injury prevention has both an impact on workers' incentive to commit fraud and on the insurer's incentive to audit, which changes the claim rate l and the wage rate. As a reduction of the injury probability implies a lower wage rate, workers' incentive to commit fraud increases. This follows from the fact that the difference between the potential gain from the fraud lottery and the sure gain without fraud increases. Thus, the insurer needs to increase the audit probability ν, as otherwise all strategic workers commit fraud. However, as the utility without injury and occupation is larger than the utility without occupation, it is still possible to make workers indifferent. Moreover, the terms $\frac{\rho c}{(1-\rho)(bw-c)}$ and $\rho\frac{bw}{bw-c}$ decrease with investment in injury prevention as the reduction in the injury probability ρ outweighs the decrease in the wage rate. In particular, the overall effect of investment in injury prevention is given by:

$$\frac{\partial l}{\partial s} = -r\frac{bw}{bw-c} - \frac{\rho cb}{(bw-c)^2}\frac{\partial w}{\partial s} < 0. \tag{15}$$

It follows that the equilibrium is still in mixed strategies and investment in injury prevention reduces the fraud probability and the claim rate $l = \rho\frac{bw}{bw-c}$ compared to no investment in injury prevention.

Lemma 4 implies that setting a wage rate below $w_c(s,b)$ cannot be optimal for any $s \geq 0$, as workers would either not accept to enter the work contract at all or only strategic workers enter the work contract and commit fraud at any occasion such that there would be no labor. Consequently, there exists an interval of possible wage rates $[w_c(s,b), w_d]$ for each given investment amount $s \geq 0$. Lemma 5 outlines that the choice reduces again to setting $w = w_c$, which implies that $\eta > 0$, and setting $w = w_d$, which implies that $\eta = 0$ (Section 4). Moreover, setting the wage rate above the reservation wage w_c is disadvantageous if the wage replacement rate is sufficiently large in the benchmark case. With investment in injury prevention $s > 0$, the marginal benefit of an increase in the wage rate (namely the reduction of the fraud probability) becomes even smaller such that the firm changes earlier from efficiency wages to the reservation wage rate. This is summarized in Lemma 5:

Lemma 5. *For $b > \frac{\rho(0)}{1+\rho(0)}$ and $\alpha > \frac{1}{2}$, the optimal wage rate is given by $w_d = \frac{e}{1-b}$ until some $1 > \bar{b} \geq \frac{\rho(0)}{1+\rho(0)}$ and by w_c for $b \geq \bar{b}$. For $b < \bar{b}$, strategic workers do not commit fraud ($\eta = 0$) and for $b \geq \bar{b}$ strategic workers commit fraud ($\eta > 0$).*

Proof. See Appendix. □

For the remainder of the section, I focus on the case $b \geq \bar{b}$ and assume that $\alpha > \frac{1}{2}$. This condition is needed to guarantee that the maximization problem $\max_s \Pi(s)$ has a unique solution s^*. Then the profit function in dependence of s is given by:

$$\Pi(s) = \frac{\alpha}{1-\alpha}\left[\frac{pAK^\alpha(1-\alpha)\left(1-\rho(s)\frac{bw_c(s,b)}{bw_c(s,b)-c}\right)^{1-\alpha}}{\left[w_c(s,b)b + \left(1-\rho(s)\frac{bw_c(s,b)}{bw_c(s,b)-c}\right)w_c(s,b)(1-b)\right]^{1-\alpha}}\right]^{\frac{1}{\alpha}} - s. \tag{16}$$

The optimal investment amount s^* is a function of the wage replacement rate b. This implies that wage rate and claim rate depend directly and indirectly (through s^*) on the wage replacement rate b. Overall, a change in the wage replacement rate has the following effect on the claim rate:

$$\frac{dl}{db} = \underbrace{-r\frac{ds^*}{db}\frac{bw}{bw-c}}_{\text{Change in the injury probability}} - \frac{\rho c}{(bw-c)^2}\Bigg[\underbrace{\Big(w\Big)}_{\substack{\text{Direct effect}\\\text{of a change in } b}} + b\underbrace{\left(\frac{\partial w}{\partial b} + \frac{ds^*}{db}\frac{\partial w}{\partial s}\right)}_{\text{Change in the wage rate}} \Bigg], \tag{17}$$

where $\frac{ds^*}{db}$ denotes the change in the optimal investment level s^* with a change in the wage replacement rate b. Accordingly, the claim rate may increase or decrease in the wage replacement rate depending the firm's investment decision s^*. I address the question how the investment level s^* and the claim rate l change with the wage replacement rate. Clearly, adjustments of the investment level s^* are long-term consequences of a change in the wage replacement rate b. In particular, a change in the wage replacement rate entails short-term and long-term consequences, which might be potentially different. As the firm cannot adjust the number of workers and workplace security measures immediately after a change in the wage replacement rate, only η and ν might change in the short term while N and s stay unchanged. In the long run, however, the firm can adjust its choices N and s to the wage replacement rate, implying that N, s, η, and ν are subject to changes. Proposition 3 summarizes how the wage replacement rate impacts investment in injury prevention in the long run:

Proposition 3. *For $\alpha > \frac{1}{2}$ and sufficiently small r, the optimization problem $\max_s \Pi(s)$ has a unique solution s^* with $\rho(s^*) \in \big(0,1\big)$. Furthermore, investment in injury prevention is decreasing in the wage replacement rate $\frac{ds^*}{db} \leq 0$.*

Proof. See Appendix. □

Intuitively, an increase in the wage replacement rate simultaneously increases labor provision, and wage and insurance costs per worker. This follows from the reduction in the wage rate and a reduction of the fraud probability due the insurer's increased incentive to audit claims which entails workers to adjust the fraud probability η. Due to the concavity of the production function and optimal employment choice N^*, the labor provision increase outweighs the cost increase implying a profit increase (see Proposition 2). Consequently, the marginal benefit of investing in injury prevention became smaller. It follows that investing in injury prevention becomes less beneficial for the firm after an increase in the wage replacement rate, as the ex-post claims investigation system already leads to a reduction in the claim rate given constant investment in injury prevention. Thus, the firm can save on injury prevention costs and transfer a part of the fraud prevention task to the claims investigation system.

Proposition 3 illustrates the interplay between claimant fraud, investment in injury prevention, and claims investigation activities. Workers' increased incentive to commit fraud after an increase in the wage replacement rate is counteracted by the claims investigation system such that the claim rate decreases automatically if there is no change in injury prevention. Consequently, the firm benefits from the reduction in the claim rate (as the expected labor provision increases independently of the investment) and can therefore save on injury prevention costs. This finding is in line with empirical results from Thomason and Pozzebon (2002) who show that safety investments and claims investigation appear to be substitute inputs in the process of reducing firms' workers' compensation costs. Moreover, this result also provides a (further) theoretical explanation for the empirical observation that an increase in workers compensation benefits increases the injury rate (Chelius, 1982). However, the explanation is different from the standard explanation in the literature. Besides reduced safety incentives on the worker side, it may also be the case that firms reduce their safety measures due to increased reliance on the claims investigation system with an increase in the wage replacement rate which ultimately lead both to an increased injury rate. Besides investment incentives on the firm side, it remains to determine the net effect of a change in the wage replacement rate on the claim rate. Most empirical studies find that an increase in the wage replacement results in an increase in the claim rate (Worrall and Appel, 1982; Butler and Worrall, 1991). This finding is supported by the hypothesis that incentive effects for workers (ex-ante and ex-post) dominate those for firms. However, this argument does not incorporate ex-post claims investigation. Corollary 1 outlines that the claim rate may increase or decrease in the wage replacement rate depending on the relative importance of labor as production factor $1-\alpha$.

Corollary 1. *The claim rate* $l = \rho \frac{bw}{bw-c}$ *may increase or decrease in* b*. For sufficiently large* α *and sufficiently small* c *the claim rate is decreasing in the wage replacement rate, whereas it is increasing in the wage replacement rate if* α *is sufficiently close to* $\frac{1}{2}$*.*

Proof. See Appendix. □

The firm reduces investment in injury prevention with an increase in the wage replacement rate (Proposition 3). Less investment in injury prevention implies less expected labor provision and less costs per worker with an overall negative impact on production minus wage and premium costs. If the production output is at a low level and the production function is sufficiently concave (large α), the loss in production minus wage and premium costs is very large for each unit of saved injury prevention costs. Consequently, the decrease in investment in injury prevention after an increase in the wage replacement rate is small such that the claim rate decreases nevertheless (Figure 6). Conversely, the loss in production minus wage and premium costs is very small for each unit of saved injury prevention costs if the production function is not "too" concave. Thus, it is beneficial for the firm to significantly reduce investment

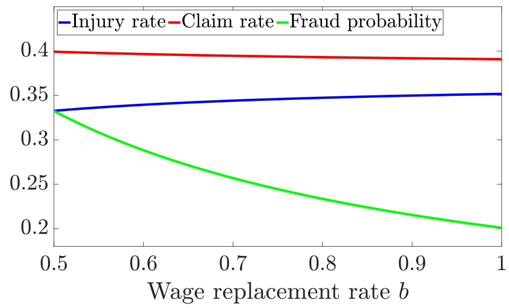


Figure 6: Injury, claim rate, and fraud probability for large α

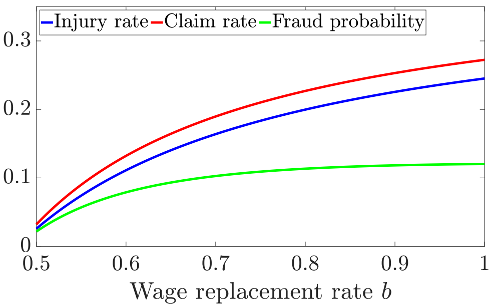


Figure 7: Injury, claim rate, and fraud probability for small α

in injury prevention implying that the claim rate is increasing in the wage replacement rate (Figure 7). As the claim rate is the sum of real injuries plus fraud, it turns out that an increase in the claim rate after an increase in the wage replacement rate is rather driven by an increase in real injuries than by an increase in the fraud probability. In particular, it can occur that the claim rate increases with a simultaneous decrease in the fraud probability. This theoretical result is the exact opposite effect of what Butler and Worrall (1991) empirically find, as their findings suggest that real injuries decrease and "claims reporting moral hazard" increases as insurance benefits increase. The reason for this discrepancy lies in the ex-post claims investigation system which reduces the impact of fraud.

6 Corporate investment in staff screening

The idea of using integrity tests in the hiring process for controlling workers compensation costs was broad forward by several researchers (Sturman and Sherwyn, 2009; Oliver et al., 2012; Cooper et al., 2021). The studies on the effect of conducting integrity tests on workers compensation costs suggest that staff screening is beneficial in reducing worker malingering and the related workers compensation claims. The firm's incentive to invest in the implementation of integrity tests depends on the amount of workers compensation costs and therefore on the wage replacement rate. However, the effect of the wage replacement rate on investment in staff screening is, to the best of my knowledge, yet unexplored. In this section, I study to what extent staff screening expenditures depend on the wage replacement rate. Applied to my model framework, investment in staff screening represents an expenditure $s \geq 0$ which reduces the share $1 - \theta$ of strategic (and therefore potentially dishonest) workers in the workforce. Accordingly, θ is a function of the investment amount s:

$$\theta(s) = \theta(0) + ms, \tag{18}$$

where $\theta(0)$ denotes the share of non-strategic workers without investment, and $m > 0$ denotes the efficiency of investment. The analysis in Section 4 revealed that fraud does not occur and $w^* \leq w_c$ for $b \leq \frac{\rho}{1+\rho}$ and fraud cannot be prevented by setting $w = w_c$ if there is no investment in fraud prevention for $b > \frac{\rho}{1+\rho}$. If $b > \frac{\rho}{1+\rho}$ and there is auditing for $s = 0$, investment in staff screening has no immediate effect on fraud occurrence. This follows from the fact that strategic workers make the insurer indifferent between auditing and not auditing, which implies that $(1-\rho)(1-\theta)\eta$ does not depend on θ. As I am interested in the effect of staff screening on fraud occurrence, I focus on the case that $\eta = 1$ and $\nu = 0$ if there is no investment in staff screening (i.e. case (ii) of Proposition 1 with $\theta > \frac{e}{c}$). If staff screening is available, the firm needs to determine the optimal tuple (N^*, w^*, s^*). Taking the optimal employment choice $N^*(w, \theta)$ from (11) as given, I start with the determination of the optimal wage rate w^*. The reservation wage rate w_c represents a lower boundary. Any wage rate below w_c implies that only strategic workers are hired and since there is no auditing, the expected labor provision per worker is zero. As in the case of injury prevention (Section 5), entire prevention of fraud by setting $w = w_d$ is only beneficial for the firm if b is sufficiently close to $\frac{\rho}{1+\rho}$. Otherwise, entire fraud prevention becomes too costly and setting $w = w_c$ is optimal. If the firm sets $w = w_c$, the equilibrium in the claiming game entails $\eta = 1, \nu = 0$, as $\rho c > (bw_c - c)(1-\rho)(1-\theta(s))$ holds for any $s \geq 0$.

Lemma 6. *If $b > \frac{\rho}{1+\rho}$ and m is sufficiently small, the optimal wage rate is given by $w_d = \frac{e}{1-b}$ until some $1 > \bar{b} > \frac{\rho}{1+\rho}$ and by w_c for $b \geq \bar{b}$. For $b < \bar{b}$, strategic workers do not commit fraud ($\eta = 0$) and for $b \geq \bar{b}$ strategic workers commit fraud ($\eta = 1$).*

Proof. See Appendix. □

For $b \geq \bar{b}$, the firm determines the optimal investment amount s^* by maximizing the following expression:

$$\Pi(s) = \frac{\alpha}{1-\alpha}\left[\frac{pAK^\alpha(1-\alpha)\big(\theta(s)(1-\rho)\big)^{1-\alpha}}{\big[w_c b + \theta(s)(1-\rho)w_c(1-b)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}} - s. \tag{19}$$

Proposition 4 outlines the properties of the solution $\theta^*(s)$ to the optimization problem $\max_s \Pi(s)$:

Proposition 4. *If*

$$\frac{\big[pAK^\alpha(1-\alpha)(1-\rho)^{1-\alpha}\big]^{\frac{1}{\alpha}} m w_c b}{\big[bw_c\big]^{\frac{1}{\alpha}}} < 1 \tag{20}$$

holds, the optimization problem $\max_s \Pi(s)$ has a unique solution s^* with $\theta(s^*) \in (0,1)$. Investment in staff screening $s^*(b)$ depends on the wage replacement rate in the following way:

(i) If $\alpha \leq \frac{1}{2}$ or $\alpha > \frac{1}{2}$ and $\theta(0)$ sufficiently large, it is optimal not to invest in staff screening ($s^* = 0$).

(ii) If $\alpha > \frac{1}{2}$ and $\theta(0)$ sufficiently small, it is optimal to invest in staff screening ($s^* > 0$). Given that $s^* > 0$, investment in staff screening is increasing in the wage replacement rate ($\frac{ds^*}{db} > 0$) if α is sufficiently close to 1.

Proof. See Appendix. $\square$

Intuitively, the profit function is given by a multiple of $\left[\frac{\theta}{b+\theta(1-\rho)(1-b)}\right]^{\frac{1}{\alpha}-1}$. For $\alpha \leq \frac{1}{2}$, the profit function is convex and the marginal benefit is given by $\theta^{\frac{1}{\alpha}-2}\times$ a term that is smaller than one due to condition (20). It follows that the marginal benefit is smaller than 1 implying that investment in staff screening is suboptimal. If, however, $\alpha > \frac{1}{2}$, it follows that the profit function is concave and the marginal benefit of investing may be strictly larger than 1 (as $\theta^{\frac{1}{\alpha}-2} > 1$) such that investment in staff screening may be beneficial. For $\alpha > \frac{1}{2}$, the benefit of investment in staff screening depends on the difference between production output with investment and production output without investment. If $\theta(0)$ is large, the difference is small (as the production reduction due to fraud is small) which implies that investment in staff screening is not optimal for the firm. If, however, $\theta(0)$ is small, the production reduction due to fraud is large such that investment in staff screening is beneficial for the firm.

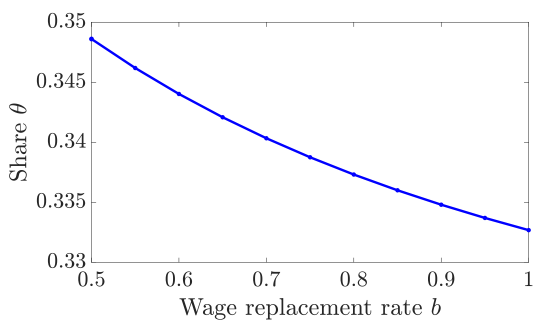


Figure 8: Share of non-strategic workers for small α

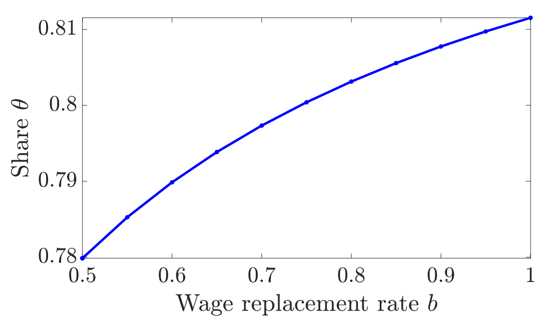


Figure 9: Share of non-strategic workers for large α

Furthermore, it turns out that investment in staff screening might increase in the wage replacement rate which contrasts the case of injury prevention. Whereas the fraud probability decreases in the wage replacement rate in the case of injury prevention, this is not the case for staff screening. In particular, an increase in the wage replacement rate leaves the expected labor provision per worker unchanged and increases expected costs per worker for given θ. Thus, there is the option to reduce investment in staff screening to save costs and the option to increase investment in staff screening to offset the cost increase implying the net effect of an increase in the wage replacement rate is ambiguous. If α is close to 1, the marginal benefit of investing in staff screening is almost linear in s and increasing in b such that it is optimal for the firm to increase investment in staff screening in the wage replacement rate (Figure 9). Whereas injury prevention and claims investigation can be applied simultaneously, claims investigation makes investment in staff screening obsolete. It follows that injury prevention investments can be reduced with a higher wage replacement rate, as the claims investigation system takes over a larger stake in the fraud prevention task. Conversely, claims investigation and staff screening are perfect substitutes implying that investment in staff screening can increase in the wage replacement rate under certain circumstances.

7 Conclusion

Claimant fraud represents a considerable source of costs for firms and insurers/providers of workers compensation coverage. Workers who claim workers compensation benefits illegitimately reduce the production output (and therefore sales) and simultaneously create costs for firms. Accordingly, combating fraudulent claiming behavior of workers is one of the top priorities for firms and insurers. Potential anti-fraud measures range from efficiency wages (setting the wage rate sufficiently high such that fraud becomes unattractive for workers) over monitoring (claims auditing) to injury prevention and staff screening. Given that workers are of different types (honest/strategic) and claims auditing is available, firms only resort to efficiency wages below some critical wage replacement rate. This finding is in line with the efficient wage hypothesis (Shapiro and Stiglitz, 1984), but entire prevention of fraud through paying efficiency wages becomes costlier the higher the wage replacement rate. Accordingly, firms rely on claims auditing or labor provision of fully honest workers above the critical wage replacement rate and set the wage rate equal to the reservation wage rate of honest workers. Above the critical wage replacement rate, claims investigation is applied (i.e. claims are audited in order to identify fraudulent ones) if costs are small enough and the share of strategic workers in the labor market is sufficiently large. In this case, claims are audited randomly and workers commit fraud randomly. If, on the other hand, the costs for claims investigation outweigh the potential savings, there is no auditing and strategic workers commit fraud at any occasion. In any case, fraud occurs above the critical wage replacement rate and reduces firms' profits, which creates an economic incentive to reduce fraud.

One possibility for fraud reduction consists of preventing injuries at the workplace (i.e. reducing the injury probability). Given that claims are audited, the conditional probability that a claim is fraudulent increases with investment in injury prevention. As a result, strategic workers need to reduce the fraud probability to meet the indifference condition for auditing. The optimal investment amount thereby depends on the effectiveness of claims investigation in reducing claimant fraud. As the incentive to audit increases in the wage replacement rate, the fraud probability decreases in the wage replacement rate given constant investment in injury prevention. Thus, firms can exploit the fraud reduction effect from claims auditing following an increase in the wage replacement rate by reducing the investment amount in injury prevention. This has the consequence that the injury rate increases in the wage replacement rate, whereas the effect on the claim rate is ambiguous and depends on the firm's production function. Besides changing the working conditions by increasing workplace safety, firms may focus on the hiring process to reduce fraudulent claiming behavior. In particular, worker screening has the potential to reduce fraud-related costs by preventing the hiring of strategic (potentially fraudulent) workers. However, the benefit of staff screening only becomes apparent when there is no claims auditing, as the share of strategic workers has no impact on the profit with claims auditing due to the mixed strategies of workers and insurer. This implies that staff screening and claims investigation are perfect substitutes. If the firm invests in staff screening, it cannot rely on claim investigation to reduce fraudulent claiming behavior after an increase in the wage replacement rate implying that investment in staff screening may be positively correlated with the wage replacement rate.

The implications of my research are manifold. I show that the wage replacement rate is the main determinant in firms' choice of a fraud prevention strategy. This explains, for instance, why efficiency wages and claims investigation appear to be substitutes in the fraud prevention process (Barmby et al., 1994; Thomason and Pozzebon, 2002) and the simultaneous observation of injured workers who do not claim benefits and not injured workers who claim benefits (Biddle and Roberts, 2003). Moreover, my findings have an implication for public policy. In particular, an increase in the wage replacement rate does not necessarily have a negative impact on firms and employment (Edmiston, 2006), but it may even lead to a welfare improvement if claims investigation is sufficiently effective and not too expensive. This effect can be traced back to the fact that fraud occurrence is decreasing in the wage replacement rate given that there is no further investment in safety or staff screening.

While this paper provide some valuable insights in incentive effects of workers compensation benefits on firms and workers, there is still a need for research in this area. For instance, the model could be extended to include different injury types with different recovery times in order to illustrate how different injury types are treated differently by the firm and by claims investigation entities. Moreover, I do not consider utility in future periods which may influence workers' claiming decision in the current period (Shapiro and Stiglitz, 1984).

Appendix

Proof of Proposition 1. Three different wage rates are of importance in the following analysis. Therefore, I define the following: Let w_c be defined through

$$w_c = \frac{e}{1-\rho+\rho b}, \tag{A.1}$$

and w_a defined through

$$w_a = e(1+\rho), \tag{A.2}$$

and w_f defined through

$$w_f = \frac{\rho e}{b}. \tag{A.3}$$

It follows that $w_c = w_a = w_f$ for $b = \frac{\rho}{1+\rho}$ such that $w_c(1-b) = e$. For $b < \frac{\rho}{1+\rho}$, I have $w_f > w_c > w_a$ and for $b > \frac{\rho}{1+\rho}$, I have $w_a > w_c > w_f$. Before I go over to the determination of the optimal w^*, I determine the optimal $N^*(w)$ as a function of w. For this, let $A(w)$ be the expected labor provision per worker, $B(w)$ the expected wage costs per worker, and $C(w)$ the expected workers compensation costs per worker. Then, the profit function is given by:

$$\Pi(N) = pAK^\alpha N^{1-\alpha}[A(w)]^{1-\alpha} - NB(w) - NC(w). \tag{A.4}$$

The FOC w.r.t N is given by:

$$\frac{\partial \Pi}{\partial N} = pAK^\alpha(1-\alpha)N^{-\alpha}[A(w)]^{1-\alpha} - B(w) - C(w) \overset{!}{=} 0. \tag{A.5}$$

Clearly, it follows $\frac{\partial^2\Pi}{\partial N^2} < 0$ which implies that there exists a unique optimum $N^*(w)$ for each given w. Inserting $N^*(w)$ into the profit function yields

$$\Pi(w) = \frac{\alpha}{1-\alpha}\left[\frac{pAK^\alpha(1-\alpha)\big(A(w)\big)^{1-\alpha}}{\big[B(w)+C(w)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}}. \tag{A.6}$$

First, I focus on the case $b > \frac{\rho}{1+\rho}$. If $\frac{\rho c}{(\rho e - c)(1-\rho)(1-\theta)} \leq 1$, it follows that the mixed-strategy equilibrium with $\eta, \nu \in (0,1)$ arises for any $b > \frac{\rho}{1+\rho}$ and any $w \geq w_f$ with $w(1-b) < e$, as bw_c is increasing in b and bw_f is constant in b. Thus, the minimum wage that the firm has to pay is given by w_c. Let $w \geq w_c$. As long as $w(1-b) < e$, the mixed-strategy equilibrium with $\eta, \nu \in (0,1)$ is played. If $w(1-b) \geq e$, the equilibrium with $\xi = 1, \eta = 0, \nu = 0$ arises. Let $w_d = \frac{e}{1-b}$. Clearly, $w > w_d$ cannot be optimal, as the expected labor provision is constant for $w > w_d$. It follows that the optimal w^* lies in the interval $[w_c, w_d]$. For $w < w_d$, the equilibrium in the claiming game is in mixed strategies with $\eta, \nu \in (0,1)$. Using the formula

(A.6), I obtain that the profit $\Pi(w)$ (with optimal employment choice N^*) is given by

$$\Pi(w) = \frac{\alpha}{1-\alpha}\left[\frac{pAK^{\alpha}(1-\alpha)\big(1-\rho\frac{bw}{bw-c}\big)^{1-\alpha}}{\big[wb+\big(1-\rho\frac{bw}{bw-c}\big)w(1-b)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}} \tag{A.7}$$

for any given ρ, b, w. Differentiating (A.7) w.r.t. w yields:

$$\frac{\partial \Pi}{\partial w} = \left[\frac{pAK^{\alpha}(1-\alpha)\big(1-\rho\frac{bw}{bw-c}\big)^{1-2\alpha}}{\big[wb+\big(1-\rho\frac{bw}{bw-c}\big)w(1-b)\big]^{1-2\alpha}}\right]^{\frac{1}{\alpha}} \frac{\frac{b^2\rho wc}{(bw-c)^2} - \big[1-\rho(1-b)\frac{bw}{bw-c}\big]\big[1-\rho\frac{bw}{bw-c}\big]}{\big[wb+w(1-b)\big(1-\rho\frac{bw}{bw-c}\big)\big]^2}. \tag{A.8}$$

Thus, I obtain that $\frac{\partial \Pi}{\partial w} < 0$ if $\frac{c}{bw-c} < 1-\rho\frac{bw}{bw-c}$. This is the case if $c < \frac{(1-\rho)bw_c}{2}$. Therefore, the optimal w^* is given by w_c or w_d. The profit with $w = w_d$ is given by

$$\Pi(w_d) = \frac{\alpha}{1-\alpha}\left[\frac{pAK^{\alpha}(1-\alpha)\big((1-\rho)+\gamma\rho(1-\theta)\big)^{1-\alpha}}{\big[w_d b+\big(1-\theta\rho\big)w_d(1-b)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}}. \tag{A.9}$$

Since $\Pi(w_c)$ is increasing in b (see Proof of Proposition 3), $\Pi(w_d)$ is decreasing in b, and $\Pi(w_c) < \Pi(w_d)$ for $b = \frac{\rho}{1+\rho}$ due to $\gamma > 1-\rho$, there exists a unique $1 > b_2(c) > \frac{\rho}{1+\rho}$ for which $\Pi(w_c)$ equals $\Pi(w_d)$. It follows that the firm chooses $w^* = w_d$ for $b < b_2$ and $w^* = w_c$ for $b \geq b_2$. Now I focus on the case that $\frac{\rho c}{(e-c)(1-\rho)(1-\theta)} \notin [0,1]$. The range of possible wage rates is given by $[w_f, w_d]$. If $\theta > \frac{e}{c}$, it follows that $\Pi(w_c) > \Pi(w)$ for each $w \in (w_c, w_d)$ that satisfies $\frac{\rho c}{(bw-c)(1-\rho)(1-\theta)} \leq 1$. Consequently, the optimal w^* is either given by w_c, w_f, or w_d. As $\Pi(w_f) = 0$ for all $b > \frac{\rho}{1+\rho}$, the choice reduces to w_c and w_d. As $\big[\Pi(w_c)\big]^{\frac{\alpha}{1-\alpha}} - \big[\Pi(w_d)\big]^{\frac{\alpha}{1-\alpha}}$ either decreases first before it starts to increase or increases for all $b \geq \frac{\rho}{1+\rho}$ and $\Pi(w_c) > \Pi(w_d)$ for $b = 1$, there exists a unique $1 > b_2 > \frac{\rho}{1+\rho}$ for which $\Pi(w_c)$ equals $\Pi(w_d)$. It follows that the firm chooses $w^* = w_d$ for $b < b_2$ and $w^* = w_c$ for $b \geq b_2$.

Now, let $b < \frac{\rho}{1+\rho}$. In this case, it follows that $w_a < w_c$. Any wage rate $w \notin \{w_a, w_c\}$ cannot be optimal, as there is no labor provision for $w < w_a$, expected labor provision does not change compared to $w = w_a$ for $w_a < w < w_c$ and does not change compared to $w = w_c$ for $w_c < w$. As $w_c(1-b) > e$, it also follows that $w_a(1-b) > e$. Furthermore, I denote by Π_a and Π_c the corresponding profit. It follows that $\Pi_c < \Pi_a$ if

$$\frac{(1-\rho)+(1-\theta)\gamma\rho}{w_c b+\big(1-\theta\rho\big)w_c(1-b)} < \frac{(1-\rho)+\gamma\rho}{w_a}. \tag{A.10}$$

Whereas Π_a is constant in b, Π_c is increasing in b. It follows that $\Pi_a > \Pi_c$ for all $b < \frac{\rho}{1+\rho}$, or $\Pi_a < \Pi_c$ for all $b < \frac{\rho}{1+\rho}$, or there exists $0 < \hat{b} < \frac{\rho}{1+\rho}$ such that $\Pi_a > \Pi_c$ for $b < \hat{b}$ and $\Pi_a < \Pi_c$ for $b > \hat{b}$. Consequently, $w^* = w_a$ or $w^* = w_c$ for $b < \frac{\rho}{1+\rho}$.

Finally, I focus on the welfare implications of claimant fraud for $b \geq b_2$. Without claimant fraud, the firm's profit and employment would be given by

$$\Pi_{nf} = \frac{\alpha}{1-\alpha}\left[\frac{pAK^{\alpha}(1-\alpha)\big(1-\rho\big)^{1-\alpha}}{\big[w_c b + w_c(1-b)(1-\rho)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}}, \tag{A.11}$$

and

$$N_{nf} = \left[\frac{pAK^{\alpha}(1-\alpha)\big(1-\rho\big)^{1-\alpha}}{w_c b + w_c(1-b)(1-\rho)}\right]^{\frac{1}{\alpha}}. \tag{A.12}$$

With claimant fraud, $w^* = w_c$, and auditing, I have

$$\Pi = \frac{\alpha}{1-\alpha}\left[\frac{pAK^{\alpha}(1-\alpha)\big(1-\rho\frac{bw_c}{bw_c-c}\big)^{1-\alpha}}{\big[w_c b + \big(1-\rho\frac{bw_c}{bw_c-c}\big)w_c(1-b)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}}, \tag{A.13}$$

and

$$N = \left[\frac{pAK^{\alpha}(1-\alpha)\big(1-\rho-\frac{\rho c}{bw_c-c}\big)^{1-\alpha}}{w_c b + \big(1-\rho-\frac{\rho c}{bw_c-c}\big)w_c(1-b)}\right]^{\frac{1}{\alpha}}. \tag{A.14}$$

If $b \geq \alpha$, it follows that employment and profit are decreasing with the occurrence of claimant fraud. With claimant fraud, $w^* = w_c$, and no auditing, I have

$$\Pi = \frac{\alpha}{1-\alpha}\left[\frac{pAK^{\alpha}(1-\alpha)\big(\theta(1-\rho)\big)^{1-\alpha}}{\big[w_c b + \big((1-\rho)\theta\big)w_c(1-b)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}}, \tag{A.15}$$

and

$$N = \left[\frac{pAK^{\alpha}(1-\alpha)\big(\theta(1-\rho)\big)^{1-\alpha}}{w_c b + \big(\theta(1-\rho)\big)w_c(1-b)}\right]^{\frac{1}{\alpha}}. \tag{A.16}$$

The same condition as in the case of auditing applies.

Proof of Proposition 2. Let $b \geq b_2$ be given and c sufficiently small such that auditing is beneficial for the insurer. The wage rate is given by $w = w_c = \frac{e}{1-\rho+\rho b}$. I denote the wage rate by $w(b)$ and omit the argument if not necessary. The profit is given by:

$$\Pi(N) = pAK^{\alpha}\left[N\left[1-\rho-\frac{\rho c}{bw-c}\right]\right]^{1-\alpha} - wN\left[1-\rho-\frac{\rho c}{bw-c}\right] - wNb\left[\rho+\frac{\rho c}{bw-c}\right]. \tag{A.17}$$

The FOC w.r.t N is given by:

$$
\begin{aligned}
\frac{\partial \Pi}{\partial N} &= pAK^{\alpha}(1-\alpha)N^{-\alpha}\left[1-\rho\frac{bw}{bw-c}\right]^{1-\alpha} - w\left[1-\rho\frac{bw}{bw-c}\right] - wb\left[\rho\frac{bw}{bw-c}\right] \overset{!}{=} 0 \\
\Leftrightarrow & \left[1-\rho\frac{bw}{bw-c}\right]\left[\frac{pAK^{\alpha}(1-\alpha)N^{-\alpha}}{\left(1-\rho-\frac{\rho c}{bw-c}\right)^{\alpha}} - w(1-b)\right] - wb = 0 \\
\Leftrightarrow N &= \left[\frac{pAK^{\alpha}(1-\alpha)\left(1-\rho-\frac{\rho c}{bw-c}\right)^{1-\alpha}}{wb+\left(1-\rho-\frac{\rho c}{bw-c}\right)w(1-b)}\right]^{\frac{1}{\alpha}}.
\end{aligned}
\tag{A.18}
$$

Consequently, the sign of $\frac{dN}{db}$ depends on the following term:

$$
(1-\alpha)(1-\rho)\left(1-(1-b)\rho\frac{bw}{bw-c}\right) - \left(1-\rho\frac{bw}{bw-c}\right)\left(1-(1-b)\rho-\frac{c}{w}\right). \tag{A.19}
$$

It follows that $\frac{dN}{db} < 0$ if $1-\alpha < \frac{\theta\rho^2}{1+\rho}$. Conversely, $\frac{dN}{db} > 0$ if $b \geq \frac{1}{2}$ and α sufficiently small. The firm's profit as a function of the wage replacement rate b is given by:

$$
\Pi(b) = pAK^{\alpha}\left[N(b)\left[1-\frac{\rho bw}{bw-c}\right]\right]^{1-\alpha} - wN(b)\left[1-\frac{\rho bw}{bw-c}\right] - wN(b)b\left[\frac{\rho bw}{bw-c}\right], \tag{A.20}
$$

where $N(b) = \left[\frac{pAK^{\alpha}(1-\alpha)\left(1-\rho-\frac{\rho c}{bw-c}\right)^{1-\alpha}}{wb+\left(1-\rho-\frac{\rho c}{bw-c}\right)w(1-b)}\right]^{\frac{1}{\alpha}}$. Using the Envelope theorem, I obtain:

$$
\begin{aligned}
\frac{d\Pi}{db} &= \left[(1-\alpha)pAK^{\alpha}N^{-\alpha}\left[1-\rho-\frac{\rho c}{bw-c}\right]^{-\alpha} - w(1-b)\right]N\left[\frac{\rho c\frac{\partial bw}{\partial b}}{(wb-c)^2}\right] \\
&- \frac{\partial w}{\partial b}N\left[1-(1-b)\rho\frac{bw}{bw-c}\right] - wN\rho\frac{bw}{bw-c}.
\end{aligned}
\tag{A.21}
$$

Using (A.18), it follows that

$$
\begin{aligned}
\frac{d\Pi}{db} &= \frac{N\rho}{bw-c}\left[\frac{\left[w+\frac{\partial w}{\partial b}b\right]c}{1-\frac{c}{bw}-\rho} - bw^2\right] - \frac{\partial w}{\partial b}N\left[1-(1-b)\rho\frac{bw}{bw-c}\right] \\
&= \frac{N\rho}{bw-c}\left[w+\frac{\partial w}{\partial b}b\right]\left[-bw+\frac{c}{1-\frac{c}{bw}-\rho}\right] - N\frac{\partial w}{\partial b}\left[1-\rho\frac{bw}{bw-c}\right].
\end{aligned}
\tag{A.22}
$$

Since $\frac{\partial w}{\partial b} = -\frac{\rho w}{1-\rho+\rho b}$, I obtain:

$$
\begin{aligned}
\frac{d\Pi}{db} &= N\frac{\left[w+b\frac{\partial w}{\partial b}\right]\rho}{bw-c}\left[-bw+\frac{c}{1-\frac{c}{bw}-\rho}\right] - N\frac{\partial w}{\partial b}\left[1-\rho\frac{bw}{bw-c}\right] \\
&= \frac{Nw\rho}{(1-\rho)+\rho b}\,\frac{c\left[(1-\rho)\left[\frac{c}{bw}+\rho\right]-\rho\left(1-\frac{c}{bw}-\rho\right)\right]}{(bw-c)\left(1-\frac{c}{bw}-\rho\right)} > 0.
\end{aligned}
\tag{A.23}
$$

For the case that auditing is not beneficial for the insurer, I can use the formulas (A.15) and (A.16) derived in Proof of Proposition 1 and obtain that $\frac{d\Pi}{db} < 0$ and $\frac{dN}{db} < 0$.

Proof of Lemma 4. First of all, I note that setting $w < w_c(s,b)$ cannot be optimal. Thus, I focus on the case $w \geq w_c(s,b)$. Let b such that $w_c(0,b)b > \frac{[\rho(0)+(1-\theta)(1-\rho(0))]c}{(1-\rho(0))(1-\theta)}$. It follows that $w_c(s,b)b > \frac{[\rho(s)+(1-\theta)(1-\rho(s))]c}{(1-\rho(s))(1-\theta)}$ for $s > 0$ if $\big(1-\rho(s)\big)(1-\theta)w_c(s,b)b - \big[\rho(s)+(1-\theta)\big(1-\rho(s)\big)\big]c$ is increasing in s. As workers are risk-neutral, I obtain:

$$\frac{\partial}{\partial s}\Big[\big(1-\rho(s)\big)(1-\theta)w_c(s,b)b - \big[\rho(s)+(1-\theta)\big(1-\rho(s)\big)\big]c\Big] = \frac{rw_c(s,b)(1-\theta)b^2}{1-\rho+\rho b} + r\theta c > 0. \tag{A.24}$$

Thus, $w_c(s,b)b > \frac{[\rho(s)+(1-\theta)(1-\rho(s))]c}{(1-\rho(s))(1-\theta)}$ for all $s > 0$ and therefore the insurer has an incentive to audit for all $s > 0$ and $w \geq w_c(s,b)$. Without investment in injury prevention, I have that $e > w_c(0,b)(1-b)$. Furthermore, I obtain

$$\nu(s,b) = \frac{e - w_c(s,b)(1-b)}{e-(1-\rho(s))w_c(s,b)(1-b)} \tag{A.25}$$

for each b and s such that $e > w_c(s,b)(1-b)$. As $\frac{\partial w_c}{\partial s} < 0$, it follows that $e > w_c(s,b)(1-b)$ for all $s \geq 0$ if $e > w_c(0,b)(1-b)$. The same holds true for each $w_d > w > w_c(s,b)$.

Proof of Lemma 5. Let $b > \frac{\rho(0)}{1+\rho(0)}$. The optimal wage rate w^* lies in the interval $[w_c(s,b), w_d(b)]$ for each given b and each given $s \geq 0$. This follows from the fact that there is no labor supply for $w < w_c$ and $\Pi(w)$ is decreasing in w for $w > w_d$. Moreover, $w_c(s,b) < w < w_d$ cannot be optimal, as $\Pi(w)$ is decreasing in w for given $s \geq 0$ due to $c < \frac{(1-\rho(0))bw_c(0,b)}{2}$ and the fact that $(1-\rho(s))bw_c(s,b)$ is increasing in s. The remaining candidates are therefore w_c and w_d. For $\alpha > \frac{1}{2}$, $\Pi(w_c)$ and $\Pi(w_d)$ are concave in s having inserted the optimal $N^*(w_c)$ and $N^*(w_d)$ respectively. Let s_c^* be the optimal level of investment in injury prevention given that $w = w_c$. Then the profit is given by:

$$\Pi^*(w_c) = \frac{\alpha}{1-\alpha}\left[\frac{pAK^\alpha(1-\alpha)\big(1-\rho(s_c^*)\frac{bw_c(s_c^*,c)}{bw_c(s_c^*,b)-c}\big)^{1-\alpha}}{\big[w_c(s_c^*,b)b + \big(1-\rho\frac{bw_c(s_c^*,b)}{bw_c(s_c^*,b)-c}\big)w_c(s_c^*,b)(1-b)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}} - s_c^*. \tag{A.26}$$

Furthermore let s_d^* be the optimal level of investment in injury prevention given that $w = w_d$. The corresponding profit is given by:

$$\Pi^*(w_d) = \frac{\alpha}{1-\alpha}\left[\frac{pAK^\alpha(1-\alpha)\big((1-\rho(s_d^*)) + \gamma\rho(s_d^*)(1-\theta)\big)^{1-\alpha}}{\big[w_d b + \big(1-\theta\rho(s_d^*)\big)w_d(1-b)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}} - s_d^*. \tag{A.27}$$

Applying the Envelope Theorem shows that $\Pi^*(w_c)$ is increasing in b and $\Pi^*(w_d)$ is decreasing in b. Moreover, $\Pi^*(w_c) > \Pi^*(w_d)$ for $b = 1$. Consequently, there exists a unique $1 > \bar{b}$ such that $\Pi^*(w_c) = \Pi^*(w_d)$ for $b = \bar{b}$. It follows that the firm sets $w = w_d$ for $b < \max\left\{\bar{b}, \frac{\rho(0)}{1+\rho(0)}\right\}$ and $w = w_c$ for $b \geq \max\left\{\bar{b}, \frac{\rho(0)}{1+\rho(0)}\right\}$.

Proof of Proposition 3. I denote the wage rate by $w(s,b)$, the injury probability by $\rho(s)$, and omit the arguments if not necessary. The firm's profit function $\Pi(s,N)$ is defined over $[s_b, s^0] \times [0, N^{max}]$ with $s_b < 0$ such that $\rho(0) < \rho(s_b) = \frac{bw(s_b,b)-c}{bw(s_b,b)}$, $\rho(s^0) = 0$, and $N^{max} > 0$ large. With this, the profit function is given by:

$$\begin{aligned}\Pi(s,N) = pAK^{\alpha}\left[N\left[1-\rho-\frac{\rho c}{bw-c}\right]\right]^{1-\alpha} - wN\left[1-\rho-\frac{\rho c}{bw-c}\right] \\ - wNb\left[\rho+\frac{\rho c}{bw-c}\right] - s.\end{aligned} \tag{A.28}$$

The FOC w.r.t. s is given by:

$$\begin{aligned}\frac{\partial \Pi}{\partial s} = \left[\frac{pAK^{\alpha}(1-\alpha)N^{-\alpha}}{\left(1-\rho-\frac{\rho c}{bw-c}\right)^{\alpha}} - w(1-b)\right] N\left[\frac{rbw}{bw-c} + \frac{\rho cb}{(bw-c)^2}\frac{\partial w}{\partial s}\right] \\ - \frac{\partial w}{\partial s}N\left[1-(1-b)\frac{\rho bw}{bw-c}\right] - 1 \stackrel{!}{=} 0.\end{aligned} \tag{A.29}$$

Furthermore, the FOC w.r.t. N is given by:

$$\begin{aligned}\frac{\partial \Pi}{\partial N} &= pAK^{\alpha}(1-\alpha)N^{-\alpha}\left[1-\rho\frac{bw}{bw-c}\right]^{1-\alpha} - w\left[1-\rho\frac{bw}{bw-c}\right] - wb\left[\rho\frac{bw}{bw-c}\right] \stackrel{!}{=} 0 \\ &\Leftrightarrow \left[1-\rho\frac{bw}{bw-c}\right]\left[\frac{pAK^{\alpha}(1-\alpha)N^{-\alpha}}{\left(1-\rho-\frac{\rho c}{bw-c}\right)^{\alpha}} - w(1-b)\right] - wb = 0 \\ &\Leftrightarrow N = \left[\frac{pAK^{\alpha}(1-\alpha)\left(1-\rho\frac{bw}{bw-c}\right)^{1-\alpha}}{wb + w(1-b)\left(1-\rho\frac{bw}{bw-c}\right)}\right]^{\frac{1}{\alpha}}.\end{aligned} \tag{A.30}$$

The SOC w.r.t. N is given by:

$$\frac{\partial^2 \Pi}{\partial N^2} = -\alpha pAK^{\alpha}(1-\alpha)N^{-1-\alpha}\left(1-\rho-\frac{\rho c}{bw-c}\right)^{1-\alpha} < 0. \tag{A.31}$$

As $\frac{\partial^2 \Pi}{\partial N^2} < 0$, there exists a unique optimum $N^*(s)$ for each given $s \geq 0$ and I can reduce the two-dimensional optimization problem $\max_{s,N} \Pi(s,N)$ to a one-dimensional optimization problem $\max_s \Pi(s) \coloneqq \max_s \Pi(s, N^*(s))$. Inserting (A.30) in (A.29) yields:

$$\begin{aligned}
\frac{\partial \Pi}{\partial s} &= \frac{wb\left[\frac{rbw}{bw-c} + \frac{\rho cb}{(bw-c)^2}\frac{\partial w}{\partial s}\right]}{\left[1-\rho\frac{bw}{bw-c}\right]} N - \frac{\partial w}{\partial s} N \left[1-(1-b)\frac{\rho bw}{bw-c}\right] - 1 \\
&= \left[pAK^\alpha(1-\alpha)\right]^{\frac{1}{\alpha}} \left[\frac{1-\rho\frac{bw}{bw-c}}{w\left[1-(1-b)\rho\frac{bw}{bw-c}\right]}\right]^{\frac{1}{\alpha}-2} \\
&\times \frac{wb\left[\frac{rbw}{bw-c} + \frac{\rho cb}{(bw-c)^2}\frac{\partial w}{\partial s}\right] - \frac{\partial w}{\partial s}\left[1-(1-b)\frac{\rho bw}{bw-c}\right]\left[1-\rho\frac{bw}{bw-c}\right]}{w^2\left[1-(1-b)\rho\frac{bw}{bw-c}\right]^2} - 1.
\end{aligned} \tag{A.32}$$

For the further calculations, I need the terms for $\frac{\partial w}{\partial s}$ and $\frac{\partial w}{\partial b}$. I obtain:

$$\frac{\partial w}{\partial s} = -\frac{r(1-b)w}{1-\rho+\rho b}, \tag{A.33}$$

and

$$\frac{\partial w}{\partial b} = -\frac{\rho w}{1-\rho+\rho b}. \tag{A.34}$$

The SOC is given by:

$$\begin{aligned}
\frac{\partial^2 \Pi}{\partial s^2} =& \left[pAK^\alpha(1-\alpha)\right]^{\frac{1}{\alpha}} \left[\frac{1}{\alpha}-2\right] \left[\frac{1-\rho\frac{bw}{bw-c}}{w\left[1-(1-b)\rho\frac{bw}{bw-c}\right]}\right]^{\frac{1}{\alpha}-3} \\
&\times \left[\frac{wb\left[\frac{rbw}{bw-c} + \frac{\rho cb}{(bw-c)^2}\frac{\partial w}{\partial s}\right] - \frac{\partial w}{\partial s}\left[1-(1-b)\frac{\rho bw}{bw-c}\right]\left[1-\rho\frac{bw}{bw-c}\right]}{w^2\left[1-(1-b)\rho\frac{bw}{bw-c}\right]^2}\right]^2 \\
&+ \left[pAK^\alpha(1-\alpha)\right]^{\frac{1}{\alpha}} \left[\frac{1-\rho\frac{bw}{bw-c}}{w\left[1-(1-b)\rho\frac{bw}{bw-c}\right]}\right]^{\frac{1}{\alpha}-2} \\
&\times \frac{\partial}{\partial s}\left[\frac{wb\left[\frac{rbw}{bw-c} + \frac{\rho cb}{(bw-c)^2}\frac{\partial w}{\partial s}\right] - \frac{\partial w}{\partial s}\left[1-(1-b)\frac{\rho bw}{bw-c}\right]\left[1-\rho\frac{bw}{bw-c}\right]}{w^2\left[1-(1-b)\rho\frac{bw}{bw-c}\right]^2}\right].
\end{aligned} \tag{A.35}$$

It follows that $\frac{\partial^2\Pi}{\partial s^2} < 0$ if $\alpha > \frac{1}{2}$ and the second term is not positive. I therefore calculate:

$$
\begin{aligned}
&\frac{\partial}{\partial s}\left[\frac{wb\left[\frac{rbw}{bw-c}+\frac{\rho cb}{(bw-c)^2}\frac{\partial w}{\partial s}\right]-\frac{\partial w}{\partial s}\left[1-(1-b)\frac{\rho bw}{bw-c}\right]\left[1-\rho\frac{bw}{bw-c}\right]}{w^2\left[1-(1-b)\rho\frac{bw}{bw-c}\right]^2}\right]\\
=&\frac{\partial}{\partial s}\left[\frac{\frac{w^2b^2r}{(1-\rho+\rho b)(bw-c)^2}\left[bw(1-\rho+\rho b)-c\right]+\frac{w(1-b)r}{1-\rho+\rho b}\left[1-\frac{\rho(1-b)bw}{bw-c}\right]\left[1-\frac{\rho bw}{bw-c}\right]}{w^2\left[1-(1-b)\rho\frac{bw}{bw-c}\right]^2}\right]\\
=&\frac{\partial}{\partial s}\left[\frac{w^2b^2r+w(1-b)r\left[bw(1-\rho)-c\right]}{(1-\rho+\rho b)w^2\left[bw(1-\rho+\rho b)-c\right]}\right]\\
=&\frac{\partial}{\partial s}\left[\frac{r\left[bw(1-\rho+\rho b)-(1-b)c\right]}{(1-\rho+\rho b)w\left[bw(1-\rho+\rho b)-c\right]}\right]\\
=&0.
\end{aligned}
\tag{A.36}
$$

Thus, $\Pi(s)$ is concave for $\alpha > \frac{1}{2}$ and there exists a unique optimum s^*. The optimal level of investment in injury prevention s^* satisfies $\rho(s^*) < \frac{bw(s_b,b)-c}{bw(s_b,b)}$. This follows from the fact that $bw(s,b)(1-\rho(s)+\rho(s)b)$ is invariant under s and $\frac{\partial\Pi}{\partial s} > 0$ for s_k with $\rho(s_k) = \frac{bw(s_b,b)-c}{bw(s_b,b)} - \varepsilon$ with $\varepsilon > 0$ small. Moreover, I have $\rho(s^*) > 0$ if

$$
\left[pAK^\alpha(1-\alpha)\right]^{\frac{1}{\alpha}}\frac{r}{e^{\frac{1}{\alpha}-1}}\frac{eb-(1-b)c}{eb-c} < 1,
\tag{A.37}
$$

which holds true for sufficiently small $r > 0$. Furthermore, I am interested in the sign of $\frac{ds^*}{db}$. The sign of $\frac{ds^*}{db}$ depends on the following term:

$$
\begin{aligned}
\frac{\partial^2\Pi}{\partial b\partial s} =&\left[\frac{1}{\alpha}-2\right]\left[pAK^\alpha(1-\alpha)\right]^{\frac{1}{\alpha}}\left[\frac{1-\rho\frac{bw}{bw-c}}{w\left[1-(1-b)\rho\frac{bw}{bw-c}\right]}\right]^{\frac{1}{\alpha}-3}\\
&\times\left[\frac{wb\left[\frac{rbw}{bw-c}+\frac{\rho cb}{(bw-c)^2}\frac{\partial w}{\partial s}\right]-\frac{\partial w}{\partial s}\left[1-(1-b)\frac{\rho bw}{bw-c}\right]\left[1-\rho\frac{bw}{bw-c}\right]}{w^2\left[1-(1-b)\rho\frac{bw}{bw-c}\right]^2}\right]\\
&\times\left[\frac{\partial}{\partial b}\frac{(1-\rho\frac{bw}{bw-c})}{w\left[1-(1-b)\rho\frac{bw}{bw-c}\right]}\right]\\
&+\left[pAK^\alpha(1-\alpha)\right]^{\frac{1}{\alpha}}\left[\frac{1-\rho\frac{bw}{bw-c}}{w\left[1-(1-b)\rho\frac{bw}{bw-c}\right]}\right]^{\frac{1}{\alpha}-2}\\
&\times\frac{\partial}{\partial b}\left[\frac{wb\left[\frac{rbw}{bw-c}+\frac{\rho cb}{(bw-c)^2}\frac{\partial w}{\partial s}\right]-\frac{\partial w}{\partial s}\left[1-(1-b)\frac{\rho bw}{bw-c}\right]\left[1-\rho\frac{bw}{bw-c}\right]}{w^2\left[1-(1-b)\rho\frac{bw}{bw-c}\right]^2}\right].
\end{aligned}
\tag{A.38}
$$

I already know that the first term on the RHS of (A.38) is negative for $\alpha > \frac{1}{2}$. Therefore, I still need to determine the sign of the second term:

$$
\begin{aligned}
&\frac{\partial}{\partial b}\left[\frac{wb\Big[\frac{rbw}{bw-c}+\frac{\rho cb}{(bw-c)^2}\frac{\partial w}{\partial s}\Big]-\frac{\partial w}{\partial s}\Big[1-(1-b)\frac{\rho bw}{bw-c}\Big]\Big[1-\rho\frac{bw}{bw-c}\Big]}{w^2\Big[1-(1-b)\rho\frac{bw}{bw-c}\Big]^2}\right]\frac{w^2\Big[1-(1-b)\rho\frac{bw}{bw-c}\Big]^2}{r}\\
=&\frac{w^2(1-\rho)b}{(1-\rho+\rho b)^2}\left(\frac{bw(1-\rho+\rho b)-c}{(bw-c)^2}\right)+wb\left[\frac{2\rho(1-b)bw^2c(1-\rho)+(bw-c)wc\big[-(1-\rho)+\rho b\big]}{(bw-c)^3(1-\rho+\rho b)^2}\right]\\
&-\frac{w\rho c2wb^2\big[(bw-c)+w(1-b)(1-\rho)\big]}{(bw-c)^3(1-\rho+\rho b)^2}-\left(1-\rho\frac{bw}{bw-c}\right)\left(1-(1-b)\rho\frac{bw}{bw-c}\right)\frac{w}{(1-\rho+\rho b)^2}\\
&+\frac{w(1-b)\rho cw(1-\rho)}{(bw-c)^2(1-\rho+\rho b)^2}\left(1-(1-b)\rho\frac{bw}{bw-c}\right)\\
&-\frac{(1-b)w\rho c}{(bw-c)^2(1-\rho+\rho b)^2}\left(1-\rho\frac{bw}{bw-c}\right)\Big[(bw-c)+w(1-b)(1-\rho)\Big]\\
=&\frac{w(1-\rho)wb}{(1-\rho+\rho b)^2}\left(\frac{bw(1-\rho+\rho b)-c}{(bw-c)^2}\right)-\frac{wcwb}{(bw-c)^2(1-\rho+\rho b)}\\
&-\left(1-\rho\frac{bw}{bw-c}\right)\left(1-(1-b)\rho\frac{bw}{bw-c}\right)\frac{w}{(1-\rho+\rho b)^2}+\frac{(1-b)cw\rho c}{(bw-c)^2(1-\rho+\rho b)^2}\\
=&-\frac{wc^2}{(bw-c)^2(1-\rho+\rho b)}-\frac{(1-b)cw\rho c}{(bw-c)^2(1-\rho+\rho b)^2}+\frac{(1-b)cw\rho c}{(bw-c)^2(1-\rho+\rho b)^2}\\
=&-\frac{wc^2}{(bw-c)^2(1-\rho+\rho b)}<0.
\end{aligned}
\tag{A.39}
$$

It follows that $\frac{ds^*}{db} < 0$ for $\alpha > \frac{1}{2}$.

Proof of Corollary 1. I denote the wage rate by $w(s,b)$, the injury probability by $\rho(s)$, and omit the arguments if not necessary. The claim rate is given by $l = \rho\frac{bw}{bw-c}$. It follows that

$$
\begin{aligned}
\frac{dl}{db} &= -r\frac{ds^*}{db}\frac{bw}{bw-c}-\frac{\rho c}{(bw-c)^2}\left[w+b\left(\frac{\partial w}{\partial b}+\frac{ds^*}{db}\frac{\partial w}{\partial s}\right)\right]\\
&= -\frac{\rho c}{(bw-c)^2}\left[w+b\frac{\partial w}{\partial b}\right]-\frac{ds^*}{db}\left[r\frac{bw}{bw-c}+\frac{\rho cb}{(bw-c)^2}\frac{\partial w}{\partial s}\right].
\end{aligned}
\tag{A.40}
$$

Using the Proof of Proposition 3, it follows that

$$
\frac{ds^*}{db} = -\frac{\left[\left(2-\frac{1}{\alpha}\right)\Big[bw(1-\rho+\rho b)-(1-b)c\Big]\rho+\Big(1-\rho+\rho b\Big)\Big[(1-\rho)bw-c\Big]\right]c^2}{\left(2-\frac{1}{\alpha}\right)\Big[bw(1-\rho+\rho b)-(1-b)c\Big]^2\Big[(1-\rho+\rho b)bw-c\Big]r}, \tag{A.41}
$$

evaluated at $s = s^*(b)$. Consequently, $\frac{dl}{db} > (<)\ 0$ if

$$\rho(1-\rho) < (>) \frac{\left[\left(2-\frac{1}{\alpha}\right)\left[bw(1-\rho+\rho b)-(1-b)c\right]\rho + \left(1-\rho+\rho b\right)\left[(1-\rho)bw - c\right]\right]cb}{\left(2-\frac{1}{\alpha}\right)\left[bw(1-\rho+\rho b)-(1-b)c\right]^2}. \tag{A.42}$$

It follows that $\frac{dl}{db} < 0$ if

$$\left(2-\frac{1}{\alpha}\right)\rho(1-\rho) > \frac{\left[bw(1-\rho+\rho b)-c\right]cb}{\left[bw(1-\rho+\rho b)-c(1-b)\right]^2}. \tag{A.43}$$

Let $\alpha \geq 0.9$ be given and $k(\alpha, c) := \frac{2\alpha bc}{\left[bw(1-\rho+\rho b)-c(1-b)\right]}$. Now I can find $c > 0$ so small such that $k(\alpha, c) < 0.25$ for all α and $k(\alpha, c) < \rho < 1 - k(\alpha, c)$ holds for all b. In particular, the term $k(\alpha, c)bw - c \to 0$ for $c \to 0$ and therefore $\left(\frac{\partial \Pi}{\partial s}\right)\Big|_{\{\rho=1-k(\alpha,c)\}} > 0$. Conversely, I have $\left(\frac{\partial \Pi}{\partial s}\right)\Big|_{\{\rho=k(\alpha,c)\}} < 0$ for sufficiently small c due to condition (A.37). Let $\bar{c} > 0$ be so small such that $k(\alpha, \bar{c}) < 0.25$ for all α and $k(\alpha, \bar{c}) < \rho < 1 - k(\alpha, \bar{c})$ holds for all b. Then, it follows

$$\begin{aligned}
\left(2-\frac{1}{\alpha}\right)\rho(1-\rho) &> \left(2-\frac{1}{\alpha}\right)\frac{2\alpha b\bar{c}}{\left[bw(1-\rho+\rho b)-\bar{c}(1-b)\right]}\left[1-\frac{2\alpha b\bar{c}}{\left[bw(1-\rho+\rho b)-\bar{c}(1-b)\right]}\right] \\
&= \left(2\alpha-1\right)\frac{2b\bar{c}}{\left[bw(1-\rho+\rho b)-\bar{c}(1-b)\right]}\left[1-\frac{2\alpha b\bar{c}}{\left[bw(1-\rho+\rho b)-\bar{c}(1-b)\right]}\right] \\
&> \frac{b\bar{c}}{\left[bw(1-\rho+\rho b)-\bar{c}(1-b)\right]}\left[1-\frac{b\bar{c}}{\left[bw(1-\rho+\rho b)-\bar{c}(1-b)\right]}\right].
\end{aligned} \tag{A.44}$$

The last inequality follows from the fact that $k(\alpha, \bar{c}) < 0.25$. It follows that (A.42) holds with $>$ implying that $\frac{dl}{db} < 0$ if α is sufficiently close to 1 and c is sufficiently small. Conversely, I show that (A.42) holds with $<$ implying that $\frac{dl}{db} > 0$ if α is sufficiently close to $\frac{1}{2}$. Solving (A.32) shows that $\rho(s^*(b))$ is given by:

$$\rho(s^*(b)) = \frac{be-c}{be-c(1-b)} - \left[\left[pAK^\alpha(1-\alpha)\right]^{\frac{1}{\alpha}}\frac{r}{e^{\frac{1}{\alpha}-1}}\right]^{\frac{1}{2-\frac{1}{\alpha}}}\left[\frac{be-(1-b)c}{be-c}\right]^{\frac{\frac{1}{\alpha}-1}{2-\frac{1}{\alpha}}}. \tag{A.45}$$

It follows that the claim rate is given by:

$$l(b) = \frac{-\left[\left[pAK^\alpha(1-\alpha)\right]^{\frac{1}{\alpha}}\frac{r}{e^{\frac{1}{\alpha}-1}}\right]^{\frac{1}{2-\frac{1}{\alpha}}}\left[\frac{be-(1-b)c}{be-c}\right]^{\frac{\frac{1}{\alpha}-1}{2-\frac{1}{\alpha}}}be + \frac{be(be-c)}{be-c(1-b)}}{-\left[\left[pAK^\alpha(1-\alpha)\right]^{\frac{1}{\alpha}}\frac{r}{e^{\frac{1}{\alpha}-1}}\right]^{\frac{1}{2-\frac{1}{\alpha}}}\left[\frac{be-(1-b)c}{be-c}\right]^{\frac{\frac{1}{\alpha}-1}{2-\frac{1}{\alpha}}}c(1-b) + \frac{be(be-c)}{be-c(1-b)}}. \tag{A.46}$$

Differentiating (A.46) w.r.t. b shows that $\frac{dl}{db} > 0$ if

$$\frac{\frac{1}{\alpha}-1}{2-\frac{1}{\alpha}} \frac{c^2\big[be-c(1-b)\big]}{\big[eb-c\big]^2} > \frac{\big[e+c\big]\big[eb-c(1-b)\big]}{eb-c}. \tag{A.47}$$

This inequality is satisfied if α is sufficiently close to $\frac{1}{2}$.

Proof of Lemma 6. Let $b > \frac{\rho(0)}{1+\rho(0)}$. I know that the optimal wage rate w^* lies in the interval $[w_c(b), w_d(b)]$ for each given b and each given $s \geq 0$. This follows from the fact that there is zero expected labor provision for $w < w_c$ and $\Pi(w)$ is decreasing in w for $w > w_d$. Moreover, $w_c < w < w_d$ cannot be optimal. Setting $w_d > w > w_c$ such that $\rho c > (bw-c)(1-\rho)(1-\theta(s))$ is not optimal, as $\Pi(w)$ is decreasing in w for given s if labor provision stays constant. I also know that

$$\frac{\theta(0)(1-\rho)}{w_c\big[b+(1-b)(1-\rho)\theta(0)\big]} > \frac{\Big(1-\rho\frac{bw}{bw-c}\Big)}{w\Big[b+(1-b)\Big(1-\rho\frac{bw}{bw-c}\Big)\Big]} \tag{A.48}$$

holds for any $w > w_c$ such that $\rho c < (bw-c)(1-\rho)(1-\theta(0))$. I observe that the RHS of (A.48) stays constant in s whereas the LHS of (A.48) is increasing in s. This shows that setting $w_d > w > w_c$ such that $\rho c \leq (bw-c)(1-\rho)(1-\theta(s))$ is also not optimal. I am therefore left with w_c and w_d. Furthermore, I assume

$$\frac{\big[pAK^\alpha(1-\alpha)(1-\rho)^{1-\alpha}\big]^{\frac{1}{\alpha}} m w_c b}{\big[bw_c\big]^{\frac{1}{\alpha}}} < 1 \;\forall b \geq \frac{\rho}{1+\rho}. \tag{A.49}$$

Let s_c^* be the optimal level of investment in injury prevention given that $w = w_c$ and let s_d^* be the optimal level of investment in injury prevention given that $w = w_d$. It follows that $s_d^* = 0$ for all α and $s_c^* = 0$ for $\alpha \leq \frac{1}{2}$. Then the profit for $w = w_c$ is given by:

$$\Pi^*(w_c) = \frac{\alpha}{1-\alpha}\left[\frac{pAK^\alpha(1-\alpha)\big(\theta(s_c^*)(1-\rho)\big)^{1-\alpha}}{\big[w_c b + \big(1-\rho\big)\theta(s_c^*)w_c(1-b)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}} - s_c^*. \tag{A.50}$$

The corresponding profit for $w = w_d$ is given by:

$$\Pi^*(w_d) = \frac{\alpha}{1-\alpha}\left[\frac{pAK^\alpha(1-\alpha)\big((1-\rho)+\gamma\rho(1-\theta(0))\big)^{1-\alpha}}{\big[w_d b + \big(1-\theta(0)\rho\big)w_d(1-b)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}}. \tag{A.51}$$

For $\alpha \leq \frac{1}{2}$, the claim follows from the Proof of Proposition 1. Let $\alpha > \frac{1}{2}$. Applying the Envelope Theorem shows that $\Pi^*(w_c)$ and $\Pi^*(w_d)$ are decreasing in b. With $\theta(s_c^*) = \theta^*$, I obtain the following:

$$\frac{d\Pi^*(w_c)}{db} = -\frac{\left[pAK^\alpha(1-\alpha)\right]^{\frac{1}{\alpha}}}{e^{\frac{1}{\alpha}-1}}(1-\rho)^{\frac{1}{\alpha}}(1-\theta^*)(\theta^*)^{\frac{1}{\alpha}-1}\frac{\left[b+(1-b)(1-\rho)\right]^{\frac{1}{\alpha}-2}}{\left[b+(1-b)(1-\rho)\theta^*\right]^{\frac{1}{\alpha}}} \tag{A.52}$$

and

$$\frac{d\Pi^*(w_d)}{db} = -\frac{\left[pAK^\alpha(1-\alpha)\right]^{\frac{1}{\alpha}}}{e^{\frac{1}{\alpha}-1}}\left[1-\rho+\rho\gamma(1-\theta(0))\right]^{\frac{1}{\alpha}-1}\frac{\left[1-b\right]^{\frac{1}{\alpha}-2}}{\left[b+(1-b)(1-\theta(0)\rho)\right]^{\frac{1}{\alpha}}}. \tag{A.53}$$

It follows that $\frac{d\Pi^*(w_c)}{db} - \frac{d\Pi^*(w_d)}{db} > (<)\ 0$ iff

$$\begin{aligned} &-(1-\rho)^{\frac{1}{\alpha}}(1-\theta^*)(\theta^*)^{\frac{1}{\alpha}-1}\left[\frac{b+(1-b)(1-\theta(0)\rho)}{b+(1-b)(1-\rho)\theta^*}\right]^{\frac{1}{\alpha}}\left[\frac{1-b}{b+(1-b)(1-\rho)}\right]^{2-\frac{1}{\alpha}} \\ &+\left[1-\rho+\rho\gamma(1-\theta(0))\right]^{\frac{1}{\alpha}-1} > (<)\ 0. \end{aligned} \tag{A.54}$$

Let

$$f(b) := (1-\rho)^{\frac{1}{\alpha}}(1-\theta^*)(\theta^*)^{\frac{1}{\alpha}-1}\left[\frac{b+(1-b)(1-\theta(0)\rho)}{b+(1-b)(1-\rho)\theta^*}\right]^{\frac{1}{\alpha}}\left[\frac{1-b}{b+(1-b)(1-\rho)}\right]^{2-\frac{1}{\alpha}}. \tag{A.55}$$

It follows that $f'(b) = \frac{\partial f}{\partial b} + \frac{d\theta^*}{db}\frac{\partial f}{\partial \theta^*}$. A simple calculation shows that $\frac{\partial f}{\partial b} < 0$. Moreover, the sign of $\frac{\partial f}{\partial \theta^*}$ is given by the negative sign of $\frac{d\theta^*}{db}$ (See Proof of Proposition 4 for the sign of $\frac{d\theta^*}{db}$). Therefore, I obtain $f'(b) < 0$. Consequently, $\frac{d\Pi^*(w_c)}{db} - \frac{d\Pi^*(w_d)}{db}$ is either positive for all $b \geq \frac{\rho}{1+\rho}$ or there exists $1 > b_3 > \frac{\rho}{1+\rho}$ such that $\frac{d\Pi^*(w_c)}{db} - \frac{d\Pi^*(w_d)}{db} < 0$ for $b < b_3$ and $\frac{d\Pi^*(w_c)}{db} - \frac{d\Pi^*(w_d)}{db} > 0$ for $b > b_3$. As $\Pi^*(w_c) > \Pi^*(w_d)$ for $b = 1$ and $\Pi^*(w_c) < \Pi^*(w_d)$ for $b = \frac{\rho}{1+\rho}$ (due to $\gamma > 1-\rho$), there exists a unique $1 > \bar{b} > \frac{\rho}{1+\rho}$ such that $\Pi^*(w_c) = \Pi^*(w_d)$ for $b = \bar{b}$. It follows that the firm sets $w = w_d$ for $b < \bar{b}$ and $w = w_c$ for $b \geq \bar{b}$.

Proof of Proposition 4. I denote the wage rate by $w(b)$ and omit the argument if not necessary. For $s \geq 0$, the firm's profit function is given by:

$$\Pi(s,N) = pAK^\alpha\Big[N\Big[\theta(s)(1-\rho)\Big]\Big]^{1-\alpha} - wN\Big[\theta(s)(1-\rho)\Big] - wNb\Big[1-\theta(s)(1-\rho)\Big] - s. \tag{A.56}$$

The function $\Pi(s,N)$ is defined over $[s^0,s^1]\times[0,N^{max}]$ with $\theta(s^0)=0, \theta(s^1)=1$, and $N^{max} > 0$ large. In contrast to injury prevention, the wage rate w does not depend on the investment level, as θ has no impact on the expected utility of non-strategic workers. Thus, the FOC w.r.t. s is given by:

$$\begin{aligned}
\frac{\partial \Pi}{\partial s} &= pAK^{\alpha}\Big[N(1-\rho)\Big]^{1-\alpha}\Big[\theta(s)\Big]^{-\alpha}(1-\alpha)m - wN(1-\rho)m + wNb(1-\rho)m - 1 \overset{!}{=} 0\\
&\Leftrightarrow \Big[pAK^{\alpha}(1-\alpha)N^{-\alpha}\Big[\theta(s)(1-\rho)\Big]^{-\alpha} - w(1-b)\Big]mN(1-\rho) = 1\\
&\Leftrightarrow \theta(s) = \frac{1}{N(1-\rho)}\left[\frac{pAK^{\alpha}(1-\alpha)mN(1-\rho)}{1+w(1-b)N(1-\rho)m}\right]^{\frac{1}{\alpha}}.
\end{aligned} \tag{A.57}$$

Furthermore, the FOC w.r.t. N is given by:

$$\begin{aligned}
\frac{\partial \Pi}{\partial N} &= pAK^{\alpha}(1-\alpha)N^{-\alpha}\Big[\theta(s)(1-\rho)\Big]^{1-\alpha} - w\Big[\theta(s)(1-\rho)\Big] - wb\Big[1-\theta(s)(1-\rho)\Big] \overset{!}{=} 0\\
&\Leftrightarrow \Big[pAK^{\alpha}(1-\alpha)N^{-\alpha}\Big[\theta(s)(1-\rho)\Big]^{-\alpha} - w(1-b)\Big]\Big[\theta(s)(1-\rho)\Big] - wb = 0\\
&\Leftrightarrow \frac{\theta(s)}{Nm} = wb \Leftrightarrow \theta(s) = Nmwb.
\end{aligned} \tag{A.58}$$

Equating (A.57) and (A.58) yields

$$\begin{aligned}
\Big[N^2mwb(1-\rho)\Big]^{\alpha} &= \frac{pAK^{\alpha}(1-\alpha)mN(1-\rho)}{1+w(1-b)N(1-\rho)m}\\
\Leftrightarrow \Big[Nmwb\Big]^{\alpha}\Big[1+w(1-b)N(1-\rho)m\Big] &= pAK^{\alpha}(1-\alpha)m\Big[N(1-\rho)\Big]^{1-\alpha}.
\end{aligned} \tag{A.59}$$

The number of solutions to equation (A.59) depends on the term $f(N) := N^{2\alpha-1}\big[1+w(1-b)N(1-\rho)m\big]$. I obtain:

$$f'(N) = N^{2\alpha-1}\Big[(2\alpha-1)N^{-1} + 2\alpha w(1-b)(1-\rho)m\Big]. \tag{A.60}$$

It follows that (A.59) has at most two solutions N_x, N_y (only one solution N_y if $\alpha \geq \frac{1}{2}$) with

- $(2\alpha-1)N_x^{-1} + 2\alpha w(1-b)(1-\rho)m < 0$ and
- $(2\alpha-1)N_y^{-1} + 2\alpha w(1-b)(1-\rho)m > 0$.

The solutions N_x, N_y entail some s_x and s_y with $\theta(s_x) = N_xmwb$ and $\theta(s_y) = N_ymwb$. The entries of the Hessian matrix are given by the following expressions:

$$\begin{aligned}
\Pi_{ss} &= -\alpha pAK^{\alpha}(1-\alpha)N^{1-\alpha}(1-\rho)^{1-\alpha}\Big[\theta(s)\Big]^{-\alpha-1}m^2,\\
\Pi_{NN} &= -\alpha pAK^{\alpha}(1-\alpha)\Big[\theta(s)(1-\rho)\Big]^{1-\alpha}N^{-\alpha-1},\\
\Pi_{sN} = \Pi_{Ns} &= \Big[pAK^{\alpha}N^{-\alpha}(1-\alpha)^2\Big[\theta(s)(1-\rho)\Big]^{-\alpha} - w(1-b)\Big]m(1-\rho).
\end{aligned} \tag{A.61}$$

For the tuples (s_x, N_x) and (s_y, N_y), I obtain

$$\Pi_{NN}\Pi_{ss} - \Pi_{Ns}\Pi_{sN} = \frac{1}{N^2}\Big[(2\alpha - 1) + 2\alpha w(1-b)N(1-\rho)m\Big]. \tag{A.62}$$

It follows that (s_x, N_x) is a saddle point and (s_y, N_y) is a local maximum. I denote by s_m the local maximum on $[s^0, s^1]$. Furthermore, I assume that

$$\frac{\big[pAK^\alpha(1-\alpha)(1-\rho)^{1-\alpha}\big]^{\frac{1}{\alpha}} mwb}{\big[bw\big]^{\frac{1}{\alpha}}} < 1 \;\forall b. \tag{A.63}$$

This condition guarantees that $\theta(s_m(b)) = \theta(0) + ms_m(b) < 1$ for all b. Moreover, there exists a unique optimum $N^*(s)$ for each given $s \in [s^0, s^1]$ as $\frac{\partial^2\Pi}{\partial N^2} < 0$. I can therefore reduce the two-dimensional optimization problem $\max_{s,N} \Pi(s, N)$ to a one-dimensional optimization problem $\max_s \Pi(s) := \max_s \Pi(s, N^*(s))$. Thus, I have:

$$\Pi(s) = \frac{\alpha}{1-\alpha}\left[\frac{pAK^\alpha(1-\alpha)\big(\theta(s)(1-\rho)\big)^{1-\alpha}}{\big[wb + \theta(s)\big(1-\rho\big)w(1-b)\big]^{1-\alpha}}\right]^{\frac{1}{\alpha}} - s. \tag{A.64}$$

It follows that

$$\frac{\partial\Pi}{\partial s} = \frac{\big[pAK^\alpha(1-\alpha)\big]^{\frac{1}{\alpha}}\big(\theta(s)\big)^{\frac{1}{\alpha}-2}(1-\rho)^{\frac{1}{\alpha}-1}mwb}{\big[wb + \theta(s)\big(1-\rho\big)w(1-b)\big]^{\frac{1}{\alpha}}} - 1 \tag{A.65}$$

and

$$\frac{\partial^2\Pi}{\partial s^2} = \frac{\big[pAK^\alpha(1-\alpha)\big]^{\frac{1}{\alpha}}(1-\rho)^{\frac{1}{\alpha}-1}mwb\big[\theta(s)\big]^{\frac{1}{\alpha}-2}\Big[\Big(\frac{1}{\alpha}-2\Big)mwb - 2\theta(s)(1-\rho)mw(1-b)\Big]}{\theta(s)\big[wb + \theta(s)\big(1-\rho\big)w(1-b)\big]^{\frac{1}{\alpha}+1}}. \tag{A.66}$$

For $\alpha \geq \frac{1}{2}$, $\Pi(s)$ is concave in s for given b implying that there exists a unique global maximum $s_m \in [s^0, s^1]$. For $\alpha < \frac{1}{2}$, $\Pi(s)$ is either first convex and then concave, or entirely convex on $[s^0, s^1]$. If

$$\left(\frac{1}{\alpha} - 2\right)mwb - 2(1-\rho)mw(1-b) > 0, \tag{A.67}$$

holds, it follows that $\Pi(s)$ is entirely convex in s and therefore $s_m = 0$. If (A.67) does not hold, $\Pi(s)$ is first convex and then concave in s. Thus, there either exists a local maximum $s_2 > 0$ (which might be as well the global maximum on $[s^0, s^1]$) or $\Pi(s)$ is strictly decreasing in s implying that $s_m = s^0$. In particular, $\Pi(s)$ is increasing for some s implying that a local maximum exists iff

$$\frac{\big[pAK^\alpha(1-\alpha)\big]^{\frac{1}{\alpha}}\Big[\frac{(1-2\alpha)b}{2\alpha(1-b)(1-\rho)}\Big]^{\frac{1}{\alpha}-2}(1-\rho)^{\frac{1}{\alpha}-1}mwb}{\Big[\frac{wb}{2\alpha}\Big]^{\frac{1}{\alpha}}} > 1, \tag{A.68}$$

and $\left[\frac{(1-2\alpha)b}{2\alpha(1-b)(1-\rho)}\right] < 1$. Due to condition (A.63), it follows that this cannot be the case. Consequently, $s_m = s^0$ if $\alpha < \frac{1}{2}$ and therefore $s^* = 0$. I now focus on the case $\alpha \geq \frac{1}{2}$. I already know that $\Pi(s)$ has a unique optimum s_m on the interval $[s^0, s^1]$. If $s_m > 0$ it follows that $s^* = s_m$ and if $s_m \leq 0$ it follows that $s^* = 0$. The sign of $\frac{ds_m}{db}$ depends on the sign of $\frac{\partial^2 \Pi}{\partial b \partial s}$. Given risk neutrality of workers, I obtain:

$$\begin{aligned}\frac{\partial^2 \Pi}{\partial b \partial s} = & \frac{\left[pAK^\alpha(1-\alpha)\right]^{\frac{1}{\alpha}}\left(\theta(s)\right)^{\frac{1}{\alpha}-2}(1-\rho)^{\frac{1}{\alpha}-1}mw^2}{\left[wb+\theta(s)\left(1-\rho\right)w(1-b)\right]^{\frac{1}{\alpha}+1}(1-\rho+\rho b)} \\ & \times \left[(1-\rho)\left[b+\theta(s)(1-\rho)(1-b)\right] - \frac{1}{\alpha}(1-\rho)b(1-\theta(s))\right].\end{aligned} \tag{A.69}$$

It follows that $\frac{ds_m}{db} > 0$ if $\theta(s) > (1-\alpha)$ for all b, which is the case if

$$\frac{\left[pAK^\alpha\right]^{\frac{1}{\alpha}}\left(1-\alpha\right)^{\frac{2}{\alpha}-2}(1-\rho)^{\frac{1}{\alpha}-1}mwb}{\left[wb+(1-\alpha)\left(1-\rho\right)w(1-b)\right]^{\frac{1}{\alpha}}} > 1. \tag{A.70}$$

Condition (A.63) and (A.70) can hold simultaneously if $\frac{1}{1-\alpha} > pAK^\alpha\left[\frac{1-\rho}{bw}\right]^{1-\alpha}m^\alpha > 1$ and α sufficiently close to 1. Conversely, $\frac{ds_m}{db} < 0$ if θ is below a certain threshold for all b, which is the case if the term $pAK^\alpha m^\alpha$ is sufficiently small.

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