Firm Age and Firm Performance in the Labor Discipline Model

Johann K. Jaeckel*
Global Liberal Studies
New York University
Email: jj94@nyu.edu

September 2016

Abstract

(...) on endogenous effort enforcement and, thereby, extends the literature on efficiency wages and labor discipline. (...) a baseline model of labor discipline based on contingent contract renewal and introduces idiosyncratic firm closure risk as an additional informational asymmetry. The paper argues that the effectiveness of the effort enforcement strategy is determined, *inter alia*, by the workers' expectation of future employment rents and the distribution of information about firm closure risk. (...) the paper investigates the relation between firm age and firm performance. Given that agents cannot credibly verify the idiosyncratic closure risk of a firm, but information about the previous lifespan of individual employers is public, workers estimate the future life expectancy of firms and adjust their effort response. The model predicts that, absent exogenous technical change, firms register continuous labor productivity growth as they age. This insight parallels the learning-by-doing hypothesis, but results from the strategic interaction between employers and employees.

Keywords: efficiency wages, labor discipline, effort, firm closure, learning by doing, principle-agent problem

1 Introduction

This paper extends the labor discipline model with a specific focus on the role of firm age. It investigates the implications of endogenous effort enforcement by means of contingent contract renewal assuming that the closure risk of an employer is a parameter in the worker's effort response function. The paper starts from the premise of a labor market with firms that are characterized by a

*Prepared for the Third Conference of the World Interdisciplinary Network for Institutional Research (WINIR), September 2016, Boston, MA. Work in progress. Do not cite without the permission of the author. This document last updated on August 30, 2016.

distinct life expectancy which is unknown to workers. The subsequent argument shows how, in this setting of asymmetric information, workers may discriminate between different firms based on their age.

A key assumption of the model is that, while agents cannot verify the idiosyncratic closure risk of an individual principal, information about the previous lifespan of employers is public. Workers estimate the future life expectancy of a firm based on its age and adjust their effort response accordingly. Thus, the following question arises: What is the effect of a firm's age – via the effort enforcement strategy - on its performance? The model predicts that, absent technical change, firms register ongoing labor productivity growth as they age. Seasoned employers are able to discipline labor more effectively than recently established firms.

The remainder of the paper is structured as follows. The next section presents a baseline version of an endogenous effort enforcement model based on contingent contract renewal. Section 3 introduces idiosyncratic closure risk as a firm characteristic in terms of a survival function and investigates the population shares in the steady states. Sections 4 and 5 examine the worker's effort response and the contract offer in equilibrium given imperfect information about firm closure risk. The results are discussed vis-à-vis the literature about the relation of firm age and performance in Section 6. The final section concludes by summarizing the key insights of the model.

2 Baseline Labor Discipline Model

This section develops a baseline model of endogenous effort enforcement. It follows Bowles (2004) labor discipline model based on contingent contract renewal. The model highlights the strategic interaction between firms and workers in the determination of the wage, the effort level, and the hours of labor hired in equilibrium.

2.1 The Workers' Decision

The workers' instantaneous utility (u) is a function of the wage (w) and the effort level (e).

$$u = u(w, e) \quad e \in [0, 1] \tag{1}$$

Let the function in Equation (1) be linear in the wage, decreasing and concave in the effort level, and additively separable in its arguments.[1] The marginal utility of providing effort is negative at an increasing rate. Changes in the wage have no effect on the disutility of providing effort, and *vice versa*.

Firms offer employment contracts which specify the wage level and an *ex ante* probability of contract termination, respectively contract renewal, contingent on effort provision. Assuming the cost of monitoring and replacing workers are zero,

[1] Expressed formally, the assumptions on the instantaneous utility function in Equation (1) are: $\partial u/\partial w > 0$, $\partial^2 u/\partial w^2 = 0$, $\partial u/\partial e < 0$, $\partial^2 u/\partial e^2 < 0$, and $\partial^2 u/\partial w \partial e = 0$.

the probability of contract termination (τ) is a function of the workers' effort level.

$$\tau = \tau(e) \tag{2}$$

Let the termination schedule be linear and decreasing in the effort level. Increasing the level of work intensity reduces the probability of contract termination at a constant rate.[2]

For any contract offer workers chooses the effort level which maximizes the value of being employed over an infinite future horizon (v). The workers' present value function can be written as the sum of three terms: the present utility of being employed, the value of continued employment weighted by the probability of contract renewal, and the value of being unemployed in the future weighted by the probability of contract termination. The value of the fallback position (z) in the case of job loss and the wage level are exogenous to the workers' choice.[3]

$$v(e, w, z) = u(e, w) + \big(1 - \tau(e)\big)v + \tau(e)z \tag{3}$$

Given the transaction is stationary, the workers' objective function is the sum of termination weighted utility and the value of the fallback position.

$$v(e, w, z) = \frac{u(e, w)}{\tau(e)} + z \tag{4}$$

The first term on the right-hand side of Equation (4) illustrates the twofold role of effort provision in the workers' decision. On the one hand, increased work intensity reduces the utility of being employed, on the other hand, a higher effort level reduces the probability of contract termination.

The effort level which solves the workers' optimization problem is given by the following first-order condition.

$$\frac{\partial v(e)}{\partial e} = \frac{\partial u}{\partial e} - \frac{\partial \tau}{\partial e}\frac{u(w, e)}{\tau(e)} = 0 \tag{5}$$

Rearranging the solution to Equation (5) demonstrates that the best-response function requires workers to chooses the effort level that equates the marginal cost of providing effort to its marginal benefit

$$\frac{\partial u}{\partial e} = \frac{\partial \tau}{\partial e}\left(v(e^{\star}) - z\right) \tag{6}$$

where $e^{\star} = e(w, z)$ denotes the solution to the optimization problem. The difference between the present value of being employed and the value of the fallback position occurs as an employment rent to workers; it constitutes a necessary condition for effective endogenous effort enforcement. Absent this

[2] The termination schedule is assumed to be exogenous to the firms' choice of a profit-maximizing contract. Formally, the assumptions on (2) are $\partial\tau/\partial e < 0$ and $\partial^2\tau/\partial e^2 = 0$.

[3] As it bears no crucial implications for the subsequent analysis, the model abstracts from discounting of future periods and assumes the rate of time preference is zero.

rent, workers provide the reservation effort level, which is assumed not be profit-maximizing for firms.

By implicit differentiation of Equation (6) the change in the optimal effort level in response to a change in the wage can be determined.

$$\frac{\partial e^\star}{\partial w} = -\frac{\partial^2 v(e^\star)/\partial e \partial w}{\partial^2 v(e^\star)/\partial e^2} > 0 \tag{7}$$

Increases in the wage, *ceteris paribus*, are associated with increased effort. Similarly, it is easy to show that $\partial e^\star/\partial z < 0$, i.e., changes in the value of the fallback position are inversely related to the optimal effort level.

2.2 The Firms' Decision

Let firms produce a single good using labor (L) and a certain amount of fixed capital ($\bar{K}$). Labor input is expressed in terms of effective labor units, i.e., the product of the hours of labor hired (h) and the effort level (e). The price of output is given exogenously and normalized to one. Output per period (Q) is determined by a production function with decreasing returns to scale.

$$Q = f(L, \bar{K}) = f(he, \bar{K}) \tag{8}$$

Assuming the best-response function of workers is known to employers and non-labor inputs are acquired at a given unit cost (r), firms set the wage and the level of employment (h) such as to maximize per-period profits (π).

$$\pi(w, h) = f\big(he(w, z)\big) - wh - r\bar{K} \tag{9}$$

The first-order conditions to the firms' optimization problem determining the wage and the amount of labor hired are as follows.

$$\frac{\partial \pi}{\partial w} = f' h \frac{\partial e}{\partial w} - h = 0 \tag{10}$$

$$\frac{\partial \pi}{\partial h} = f' e - w = 0 \tag{11}$$

Equations (10) and (11) imply two properties of the equilibrium transaction of the model. First, the effort level per dollar of expenditure on labor is equal to the marginal impact of changes in the wage level on the effort level.

$$\frac{e^\star(w^\star, z)}{w^\star} = \frac{\partial e}{\partial w} \tag{12}$$

Second, the marginal productivity of effort is equal to the cost of an effort unit at the profit-maximizing wage.

$$f' = \frac{w^\star}{e(w^\star, z)} \tag{13}$$

Firms enter into the market as long as profits of enterprise, i.e., net revenue minus the opportunity cost of capital, are positive and exit from the market when profits are negative. Given unrestricted capital mobility, the price of a unit of capital (r) correspond to the equalized profit rate. In equilibrium the number of firms is determined by the following zero-profit condition.

$$\pi(w,h) = f\big(he(w,z)\big) - wh - r\bar{K} = 0 \tag{14}$$

Equilibrium in the baseline model is defined by the levels of $w^\star$, $e^\star$ and $h^\star$ that jointly fulfill the first-order conditions to the firms' and the workers' optimization problems. Table 1 summarizes the equilibrium conditions.[4] The number of firms in the market, and thus total employment, is determined by the zero profit condition for a given level of the fixed capital requirement and the average profit rate rate in the economy.

Table 1: Equilibrium Conditions of the Baseline Model

$\frac{\partial u}{\partial e} = \frac{\partial \tau}{\partial e}\frac{u(w^\star,e^\star)}{\tau(e^\star)}$
$w^\star = \frac{e^\star(w^\star,z)}{\partial e/\partial w}$
$f' = \frac{w^\star}{e^\star(w^\star,z)}$

The baseline model produces several of the standard results of the efficiency wage literature.[5] First, the workers' best-response function implies a positive relation between compensation and productivity; the optimal effort level is increasing in the wage. Second, since firms solve their optimization problem subject to the workers' incentive compatibility constraint – instead of the participation constraint – the equilibrium wage does not clear the labor market. Workers face quantity constraints, there is involuntary unemployment. Third, firms pay an enforcement rent in order to induce effort provision above the reservation level. Workers are not indifferent to the possibility of costly job loss and try to avoid contract termination by complying with the effort enforcement strategy. Fourth, the equilibrium is not Pareto efficient. There exist sufficiently small increases in the equilibrium wage and the effort level that would be Pareto improving.[6]

[4] Sequentially, the equilibrium conditions for the baseline model can be solved as follows. Given the workers' effort response schedule in Equation (6), firms select the profit maximizing wage level according to Equation (12). Substituting the equilibrium values of the effort level and the wage into Equation (13) determines the amount of hours of labor hired by an individual firm.

[5] For a parallel discussion of these results, refer to Bowles (2004, Chap. 8).

[6] The effort level set by workers does not satisfy $\partial\pi(w,h,e^\star)/\partial e = 0$ and the wage set by firms does not satisfy $\partial v(e,w^\star,z)/\partial w = 0$.

3 Firm Closure Risk & Life Expectancy

Assume in the market under consideration there are two types of firms which are distinct only in terms of their idiosyncratic risk of firm closure. Firm closure may occur due to bankruptcy, merger and acquisition, or any other event which does not allow the firm to independently renew existing employment contracts. Firm closure, from the perspective of workers, is synonymous with contract termination. Suppose that type one firms have a lower per-period closure rate (λ) than type two firms.

$$0 \leq \lambda_1 < \lambda_2 \leq 1 \tag{15}$$

The following subsections introduce firm survival functions and investigate the steady state population shares.[7]

3.1 The Firm Survival Function

Let firm closure follow a Poisson process with a constant average failure rate $\lambda_i(t) = \lambda_i$ for each firm type i and the corresponding survival functions (S_i).

$$S_i(t) = \exp\{-\lambda_i t\} \qquad i = 1, 2 \tag{16}$$

The type-specific probability of firm survival is exponentially distributed with parameter λ. The survival function is strictly decreasing over time and lies between one at the start of the spell and zero at infinity:

$$\begin{aligned} &\partial S(t)/\partial t < 0, \qquad && 0 \leq S(t) \leq 1, \\ &S(0) = 1, && \lim_{t\to\infty} S(t) = 0. \end{aligned}$$

For the subsequent analysis it is crucial to note that the survival probability is decreasing in the closure rate.

$$\partial S(t)/\partial\lambda = -\exp\{-\lambda_i t\}t < 0 \tag{17}$$

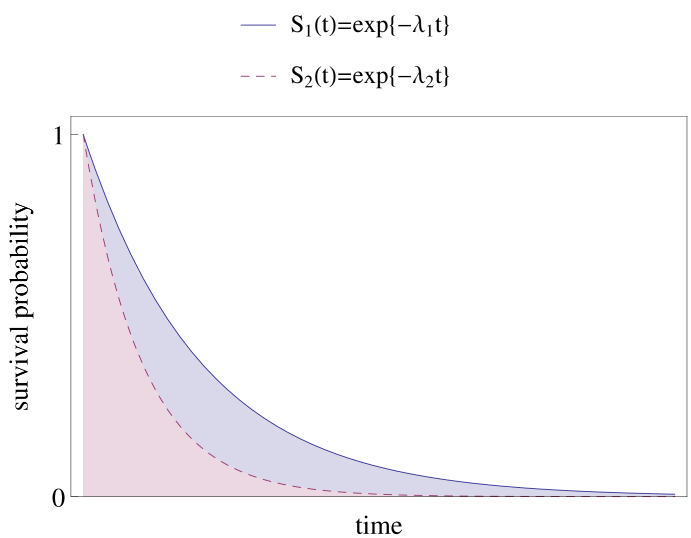
The density function (f_i), i.e., the type-specific rate of firm closure per unit of time, is the product of the failure rate and the survival function.

$$f_i(t) = \lambda_i \exp\{-\lambda_i t\} \qquad i = 1, 2 \tag{18}$$

The average life expectancy of a firm, i.e., the mean of the survival distribution, is $1/\lambda$. Plotting the survival function for the two firm types as described in Equation (16) illustrates that type one firms are more likely to be alive than type two firms at any given point in time (Figure 1).

[7] While the terminology of survival analysis might not be appropriate when speaking about entities such as firms, the subsequent analysis adopts the conventional vocabulary of duration analysis for the sake of convenience.

Figure 1: Firm-Specific Survival Function For $\lambda_1 < \lambda_2$



3.2 Steady State Population Shares

Let the firm birth process ensure that the firm population stays constant over time. This requires that for every firm that dies at the end of a period a new firm with age zero is reborn in the subsequent period. Assume firm rebirth has no memory, in the sense that the type assigned to newborn firms follows a binomial distribution with parameter p. The number of type one firms ($n_1(t)$) and type two firms ($n_2(t)$) in the market at time t is determined by the following laws of motion,

$$\partial n_1/\partial t = p(n_1(t)\lambda_1 + n_2(t)\lambda_2) - n_1(t)\lambda_1 \tag{19}$$
$$\partial n_2/\partial t = (1-p)(n_1(t)\lambda_1 + n_2(t)\lambda_2) - n_2(t)\lambda_2 \tag{20}$$

where the first and the second term in each equation capture the number of type-specific firm births and deaths, respectively. Setting Equations (19) and (20) equal to zero, and denoting the total firm population as $N = n_1 + n_2$, allows to solve for the steady state shares.

$$\frac{n_1}{N} = \frac{\lambda_1}{\lambda_1 + \lambda_2} \tag{21}$$
$$\frac{n_2}{N} = \frac{\lambda_2}{\lambda_1 + \lambda_2} \tag{22}$$

In the steady state the population shares are determined exclusively by the type-specific failure rates.

4 The Workers' Decision

Assume that workers are aware of the existence of the two firm types and know their respective closure rates. The idiosyncratic closure risk of any particular firm is private information. While workers cannot identify the true type of an employer, however, they know the age of any individual firm. The next subsection introduces a Bayesian inference process which allows workers to form a probability estimate of facing a certain firm type. The second subsection explores the implications of this process with regard to the relation between estimated firm closure risk and effort provision.

4.1 Estimated Firm Closure Risk

Following Bayes' theorem, the conditional probability of an individual firm of age t being type i is given by the ratio of the conditional probability of a type i firm surviving to age t to the total probability of a firm surviving to age t weighted by the probability of encountering a type i firm in the market.

$$P(i \mid t) = \frac{P(t \mid i)}{P(t)} \, P(i) \qquad i = 1, 2 \tag{23}$$

Put differently, the posterior probability $P(i \mid t)$, i.e., the workers' degree of belief that a firm is of a certain type is the product of two terms: first, the support provided by the age of a firm for it being of a certain type and, second, the prior probability, i.e., the initial degree of belief, in dealing with a certain firm type. The total survival probability of a firm $P(t)$ is an average of the type-specific survival probability weighted by the type shares.

$$P(t) = P(t \mid i = 1)P(i = 1) + P(t \mid i = 2)P(i = 2) \tag{24}$$

In the given context, $P(t \mid i)$ is synonymous with the survival function in Equation (16).[8] In equilibrium the workers' prior beliefs $P(i)$ correspond to the steady state shares in Equations (21) and (22). The posterior probabilities of a firm of age t being of either type are determined by the ratio of the type specific survival functions to the average survival probability of a firm.

$$P(i = 1 \mid t) = \frac{S_1(t)}{S_1(t)(n_1/N) + S_2(t)(n_2/N)} \, \frac{n_1}{N} \tag{25}$$

$$P(i = 2 \mid t) = \frac{S_2(t)}{S_1(t)(n_1/N) + S_2(t)(n_2/N)} \, \frac{n_2}{N} \tag{26}$$

The posterior probabilities in the above equations are determined by the type-specific firm survival functions and the steady state population shares.

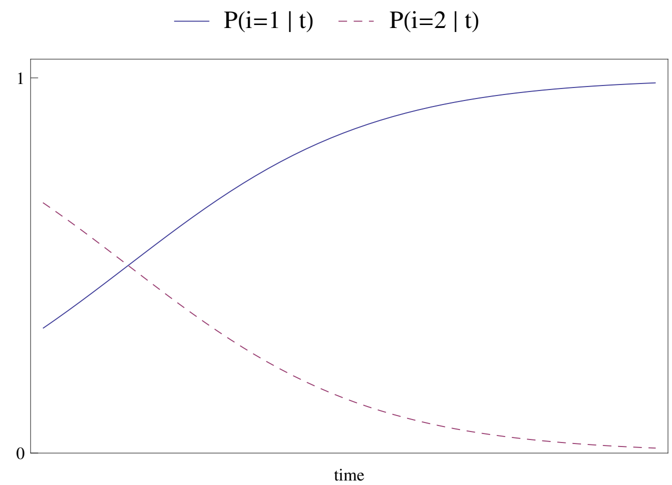
$$\frac{\partial P(i = 1 \mid t)}{\partial t} > 0 \tag{27}$$

$$\frac{\partial P(i = 2 \mid t)}{\partial t} < 0 \tag{28}$$

[8] Recall that workers are assumed to know the firm type specific failure rates.

With increasing firm age the posterior probability of dealing with a type one firm increases; conversely, the probability of dealing with a type two firm decreases. This dynamic is illustrated in Figure 2. Put simply, the older a firm, the more likely it is to be of type one.

Figure 2: Posterior Probability Estimates For $\lambda_1 < \lambda_2$



Based on this process of Bayesian inference, workers compute a probability estimate of the closure risk of an individual firm (Λ) of age t as the sum of the idiosyncratic closure rates, each weighted by the posterior degree of belief in facing either type of firm.

$$\Lambda(t) = P(i = 1 \mid t)\lambda_1 + P(i = 2 \mid t)\lambda_2 \tag{29}$$

Thus, the workers' belief about the closure risk of an individual firm (Λ) with increasing age asymptotically approaches the failure rate of type one firms (Figure 3).

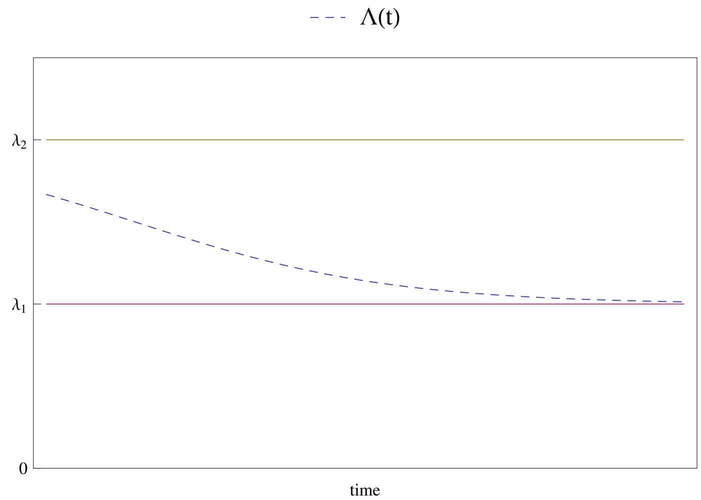
4.2 Effort Response & Firm Age

From the workers' perspective firm closure is synonymous job loss. Therefore, workers take the probability estimate of idiosyncratic firm closure risk (Equation 29) into account in the determination of their optimal effort response. The fact that contract renewal, in addition to effort provision, is contingent on Λ is expressed in the following augmented present value function.

$$v\big(e, w, z, \Lambda(t)\big) = u(e, w) + \big(1 - \Lambda(t)\big)\big((1 - \tau(e))v + \tau(e)z\big) + \Lambda(t)z \tag{30}$$

The value of the employment relationship is the sum of three terms: the present utility of being employed, the combined value of contract renewal and termination due to effort provision weighted by the probability estimate of firm survival, and the value of being unemployed in the future due to firm closure.

Figure 3: Estimated Individual Closure Risk For $\lambda_1 < \lambda_2$



Assuming the transaction is stationary and rearranging the above equation, gives the workers' present value function as the sum of the present employment utility weighted by the probability of job loss, due to firm closure as well as contract termination, and the fallback option.

$$v(e, w, z, \Lambda(t)) = \frac{u(w, e)}{\Lambda(t)\big(1 - \tau(e)\big) + \tau(e)} + z \tag{31}$$

The workers' best-response function, as in Equation (6), requires the marginal disutility and the marginal benefit of providing effort to be equal. In contrast to the baseline model, the marginal benefit of effort is weighted by the estimated probability that the firm will be able to renew its existing contracts.

$$\begin{aligned} \frac{\partial u}{\partial e} &= \frac{(1 - \Lambda(t))(\partial\tau/\partial e)u(w, e^\star)}{\Lambda(t)\big(1 - \tau(e^\star)\big) + \tau(e^\star)} \\ &= (1 - \Lambda(t))\frac{\partial\tau}{\partial e}(v(e^\star, w, z, \Lambda(t)) - z) \end{aligned} \tag{32}$$

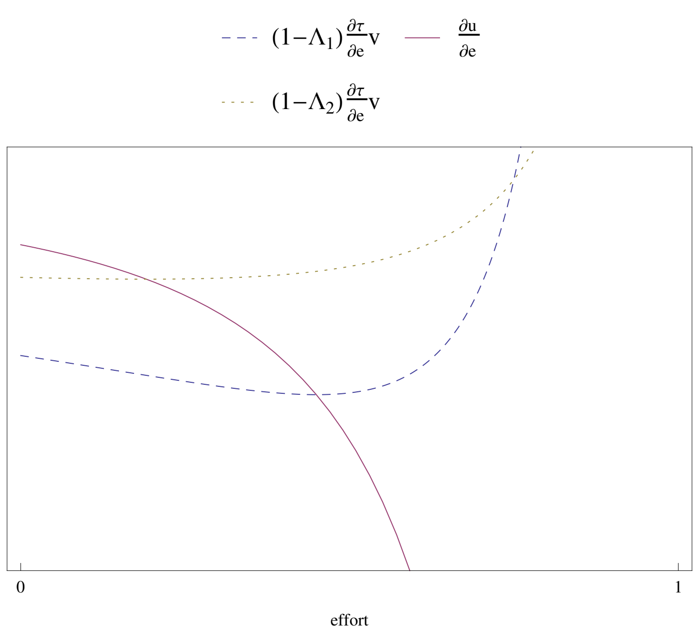
Equation (32) illustrates the role of the firm closure risk estimate in the workers' optimization problem. In case workers expect certain firm survival, $\Lambda = 0$, the equilibrium transaction is identical to the baseline model. Expecting job loss at the end of the period due to certain firm closure, $\Lambda = 1$, workers provide the reservation effort level.

Two implications of this effort response under uncertainty are of particular importance. First, as effort provision is based on the probability estimate of idiosyncratic firm closure risk, workers do not discriminate between type one and type two firms. Regardless of the true firm type, workers provide identical effort levels for firms of identical age. Second, the best-response effort level is decreasing in firm closure risk. Implicit differentiation of the first-order condition in Equation (32) with respect to Λ yields a negative sign for the change in the equilibrium effort.

$$\frac{\partial e^{\star}(w, z, \Lambda(t))}{\partial \Lambda(t)} = \frac{(\partial u/\partial e)}{(\Lambda(t)-1)\big(\Lambda(t)+\tau(e)-\Lambda(t)\tau(e)\big)(\partial^2 u/\partial e^2)} < 0 \tag{33}$$

It follows that firms of either type obtain a stronger effort response for a given contract as they age and the risk of firm closure inferred by workers decreases. Figure 4 illustrates this result by plotting the marginal cost of providing effort and the marginal benefit of providing effort for different probability estimates of firm closure risk with $\Lambda_1 > \Lambda_2$.[9] Note that while the marginal cost of providing effort is the same as in the baseline model, changes in the workers' probability estimate of firm closure risk are inversely related with the marginal benefit of providing effort.

Figure 4: Marginal Cost and Marginal Benefits Of Effort For $\Lambda_1 < \Lambda_2$



[9]The functional specifications in Figure (4) are $u(w, e) = w - 1/(1-e)$ for the utility function and $\tau(e) = 1 - e$ for the termination function. The wage offer is set as $w = 4$, the value of the fallback option is set as $z = 0$, and the probability estimates of firm closure risk are $\Lambda_1 = 0.1$ and $\Lambda_2 = 0.5$ respectively.

5 The Firms' Decision

Given the worker's effort response, the firms' per-period optimization problem determines the contracts offered by employers of a certain age. In next subsection changes in the optimal contract offer as firms age are analyzed and the relation between firm age and profits is investigated. The second subsection distinguishes a monomorphic and a polymorphic equilibrium depending on the moment when firms learn about their type.

5.1 Per-Period Profit Maximization

Firms anticipate the workers' effort response to a contract offer and set the wage level and the amount of hours labor hired such as to maximize per-period profits. Given employment contracts are renegotiated for every period t, i.e., every firm can optimize its contracts according to its age, the firms' per period objective function is

$$\pi(w, h) = f\big(he(w, z, \Lambda(t))\big) - wh - r\bar{K} \tag{34}$$

with the first-order conditions from Equation (10) and (11) augmented by the workers' probability estimate of idiosyncratic firm closure risk.

$$\frac{e^\star\big(w^\star, z, \Lambda(t)\big)}{w^\star} = \frac{\partial e}{\partial w} \tag{35}$$

$$f' = \frac{w^\star}{e\big(w^\star, z, \Lambda(t)\big)} \tag{36}$$

While the qualitative effects of changes in Λ on the optimal contract offer are ambiguous, differentiating the profit function in Equation (34) with respect to the workers' estimate of firm closure risk yields an unambiguous result.

$$\frac{\partial \pi}{\partial \Lambda} = f' \frac{\partial e}{\partial \Lambda} < 0 \tag{37}$$

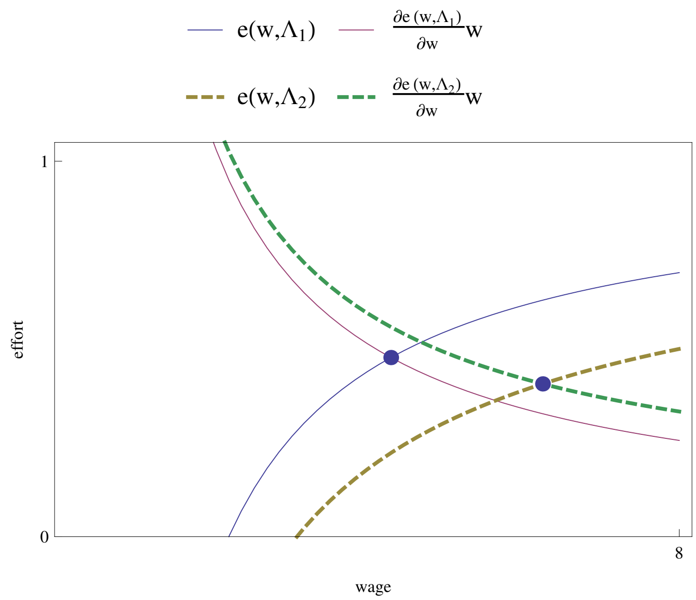
Profits are inversely related to the workers' belief in the closure probability of an individual firm. This is due to the stronger effort response associated with lower estimates of firm closure risk. Figure (5) illustrates this key feature of the model by plotting the first-order condition in Equation (35). For $\Lambda_1 < \Lambda_2$, type one firms face lower unit effort costs than type two firms and, thus are able to realize a higher profit.[10]

5.2 The Firms' Entry Decision

Recall that in equilibrium the number of firms operating in the market is subject to the zero profit condition. As market entry requires a one-time investment of

[10]Figure 5 uses the same functional specifications as Figure 4.

Figure 5: Best-Response Effort for For $\Lambda_1 < \Lambda_2$



fixed capital ($\bar{K}$) in the first period and firms face an idiosyncratic closure risk, entry and exit decisions are determined by the expected sum of profits ($E[\Pi]_i$) accumulated over the life span of a firm. Assume, as above, that the effort, the wage and the amount of hours of labor hired are at their optimal levels for every period t, and denote these per-period equilibrium levels by $e^\star$, $w^\star$, and $h^\star$, respectively.

$$E[\Pi]_i = \sum_{t=1}^{1/\lambda_i} \big(f(h^\star e^\star, z, \Lambda(t))) - w^\star h^\star \big) - r\bar{K} = 0 \quad i = 1, 2 \tag{38}$$

Accumulated profits are the difference between per period net revenues summed over the expected firm life span and the cost of the fixed capital requirement at a given interest rate. [11]

The equilibrium condition in Equation (38) expresses two crucial aspects of the entry decision. First, market entry is associated with an irreversible commitment to the fixed capital investment. Second, the expected payoffs of entering the market are, *inter alia*, a function of firm type. As a consequence, different equilibria exist depending on whether firms obtain the information about their type before (*ex ante*) or after (*ex post*) taking the entry decision.

First, consider the scenario in which firms know their type before taking the decision to enter the market, and thus before having to commit to the initial

[11] Recall that the life expectancy of a firm is determined by the mean of the type specific survival distribution and that type two firms on average have a shorter life span than type one firms.

fixed capital investment. Due to their comparatively longer life expectancy, type one firms on average accumulate revenue net of labor costs for more periods than type two firms. Expected life span profits for type one firms exceed those of type two firms.

$$E[\Pi]_1 > E[\Pi]_2 \tag{39}$$

Type one firms enter into the market as long as positive profits can be made in the sense of Equation (38), which is possible as long as there are type two firms in the market. Conversely, type two firms do not enter the market, as the life expectancy required to realize the average profit rate is $1/\lambda_1$. If the information about idiosyncratic closure risk is available to the principals *ex ante*, a monomorphic equilibrium, in which only type one firms operate, emerges.

In a complete strategic equilibrium workers are aware of the timing of the firm type lottery and, thus, can anticipate the monomorphic equilibrium. As workers know that every firm in the market is of type one, they no longer provide their effort response under uncertainty. Instead of a probability estimate of closure risk based on observed firm age, effort provision is determined by the actual closure rate of type one firms. This equilibrium is stable, since market entry for a type two firm is not rationale given the informational environment.

Second, and by contrast, consider the *ex post* scenario in which firms learn their type only after taking the entry decision. Market entry requires firms to commit to the initial fixed capital investment before learning about their type. Firms have to estimate their actual closure risk as an average of the type specific closure rates weighted by the parameter of the firm type distribution.

$$E[\lambda] = p\lambda_1 + (1-p)\lambda_2 \tag{40}$$

In this informational environment both types of firms operate in the market. The number of firms in equilibrium follows the condition in Equation (38) and the anticipated profitability of firm is determined by the average life expectancy $1/E[\lambda]$. In this polymorphic equilibrium both firm types offer employment contracts. Recall that contracts are heterogeneous across firm age and homogeneous across firm type. The workers' effort response follows the process described in the previous section.

Once types have been assigned, however, firms of different types operate under different conditions. Since the actual life expectancies differ from the estimated life expectancy, $1/\lambda_2 < 1[E/\lambda] < 1/\lambda_1$, the average type one firm realizes a profit rate in excess of of r, while the average type two firm fails to recover $r\bar{K}$ from its accumulated net revenue. Thus a regret equilibrium, in which type two firms are worse off for having entered the market, emerges.

6 Review & Discussion of Related Literature

Modern growth theory, starting with Solow (1957) and Abramovitz (1956), has long acknowledged that increasing per capita output cannot be exclusively attributed to a rising capital-labor ratio.[12] This line of research has led to the formulation of endogenous growth models, which aim to account for continuous labor productivity growth in the absence of technical change. The model at hand presents a novel explanation for this phenomenon in terms of labor discipline. The next two sections review and discuss the results of the model concerning the relation between firm age and performance with respect to the theoretical and empirical literature.

6.1 Theoretical Work

Previous theoretical contributions on the relation between firm performance, particularly, in terms of (labor) productivity, and firm age can be organized according to three separate effects.[13] First, selection effects occur when competitive pressures continuously eliminate the weakest firms in the market. In a model put forward by Jovanovic (1982) heterogeneous firms are assumed to maintain fixed productivity levels. Over time, low productivity firms are forced to exit the market while firms with high productivity remain in business. As a result of this selection, the cohort's average productivity continuously increases, even as the productivity levels of individual firms remain constant.

Second, learning-by-doing effects (Arrow 1962) focus on productivity increases due to discoveries of more efficient techniques and their successive incorporation in the production process. The positive relation between current output per worker and measures of past activity is assumed to occur as "labor learns through experience" (Vassilakis 2008). In a similar vein, Romer's (1986) model generates endogenous growth by including knowledge in the production function as a factor with increasing marginal productivity. Some authors, for instance Garnsey (1998), point out that this effect is particularly relevant to young firms accumulating experience. Learning-by-doing constitutes an adaptation internal to the firm, as opposed to an external selection by the market.

Third, inertia effects account for the opposite scenario of declining productivity with increasing firm age. This phenomenon is caused by an evolutionary process which may prevent firms from keeping up with the pace of change in their environment (Hannan & Freeman 1984). In addition to such a "liability of obsolescence", Barron, West & Hannan (1994) suggest "liability of senescence", i.e., the idea that older firms may become ossified by accumulated routines, rules and organizational structures, as a complimentary aspect of inertia effects.

Selection, adaptation, and inertia effects are likely to be operating simultaneously. Learning-by-doing and senescence in particular, rather than being thought of as mutually exclusive moments, are fundamentally interdependent processes. As Levinthal (1991, p. 140) states: "On the one hand, organizational learning contributes, in part, to organizational inertia, which, in turn, is the basis of selection processes. On the other hand, far from being incompatible with adaptive learning, inertial forces are a prerequisite for intelligent adaptation."

[12] Similarly, Verdoorn (1956) observed a positive relationship between past cumulative output and current labor productivity at the aggregate level.

[13] This classification follows the literature review in Coad (2010).

Likewise, the complex interplay of external and internal forces, i.e., selection and adaptation, determines the relation between firm age and performance at the individual as well as at the aggregate level (Sorensen & Stuart 2000).

The present model provides a novel explanation for the positive relation between firm age and productivity levels. Similar to the adaptation effect, the model predicts continuous productivity growth in the absence of technical change. This result, however, is not due to changes in the production process *per se*. Instead, it is caused by the combination of the endogenous effort enforcement and the dynamics of the workers' probability estimate of firm closure risk.

It is important to note that learning-by-doing and labor discipline constitute similar but distinct explanations for the same phenomena. The first framework accounts for continuous productivity growth by means of the accumulation of experience and the implementation of new knowledge. Here, the focus of the explanation lies with the adaptation of organizational routines and structures in the production process. In the second framework, by contrast, successive productivity increases are made possible by the contractual incompleteness of the employment relationship. While learning (updating) does occurs on part of the workers, however, this does not concern any aspect of the production process *proper*, but rather the workers' beliefs in the life expectancy of the firm.

The model at hand foregrounds three elements of the social relation between firms and workers: the employment contract, the effort enforcement strategy of the firm, and the updating process of workers' effort provision. The key prediction is a consequence of the dynamics of effort provision under the assumption of asymmetric information regarding the idiosyncratic closure risk of an employer. As the workers' belief about the life expectancy of an employer rises with firm age, effort enforcement becomes more effective over time.

Note that there is no selection process at work in the model. Firm exit is not contingent on performance, but determined exogenously by the idiosyncratic closure risk. One way to integrate this feature into the model, would be to endogenize the probability of market exit by making part of a firm's closure risk a function of its performance.

Inertia, i.e., a lack of adaptation inside the firm, is relevant in the given framework as employers may not always know the exact form of the workers' best-response function. Moreover, the existence of medium or long term contracts may prevent firms from continuously optimizing their employment contracts according to their age. While the present model abstracts from these issues, extensions of this research may relax the assumption that firms have knowledge of the effort provision function for every time period and are able to adjust their contracts immediately.

6.2 Empirical Work

Starting with Gibrat (1931) the industrial organization investigates the firm size distribution on the one hand and the relation between firm size and growth rate on the other hand.[14] Early contributions to this research program tend to consider firm size and firm age as alternative measures of identical underlying phenomena. Greiner's (1972) growth model of organizational change, for instance, assumes that for growing firms size is linearly related to age. Although these two characteristics are closely connected, it is likely that there are considerable differences between their relation to different measures of firm performance. Comprehensive empirical research on the role of firm age, however, often faces the impediment of a lack of firm age data. As Headd & Kirchhoff (2009, p. 548) comment, there is "(...) a dearth of information by business age. Simply stated, industrial organization and small business researchers are deprived of firm-age data."

Given these data constraints, a number of authors investigate the nexus between firm age and growth rates with ambiguous empirical results. While most studies observe a negative effect (Evans 1987*a*, Evans 1987*b*, Rodríguez, Molina, Pérez & Hernández 2003, Farinas & Moreno 2000), studies by Das (1995) and Shanmugam & Bhaduri (2002) identify a positive effect of age on firm growth. Teruel-Carrizosa (2010), using panel data for manufacturing and service industries in Spain during the period 1994–2002, finds an inverted U-shaped relation. A study by Lotti, Santarelli & Vivarelli (2009) finds a negative effect of age on growth for young firms, which becomes insignificant as the cohort matures.

Some of the studies cited in the above paragraph also investigate the relation between firm age and survival; again, without arriving at clear-cut results. Stinchcombe's (1965) early contribution explains a lower probability of survival for younger firms in terms of a "liability of newness". More recent work, on the other hand, accounts for evidence of an initial honeymoon period, i.e., low exit rates experienced by young firms, in terms of a "liability of adolescence" (Bruderl & Schussler 1990, Fichman & Levinthal 1991).

Another strand of the recent empirical literature focuses on differences in a number of performance indicators in relation to firm age, such as post-entry growth rates (Bartelsman, Scarpetta & Schivardi 2005), wage levels (Brown & Medoff 1989, Brown & Medoff 2003), firm survival (Bellone, Musso, Nesta & Quéré 2008), and the probability of innovation and productivity growth (Huergo & Jaumandreu 2004*a*, Huergo & Jaumandreu 2004*b*). A recent empirical study by Coad, Segarra & Teruel (2013, p. 1) summarizes the complex relation between firm age and performance as follows: "We find evidence that firms improve with age, because ageing firms are observed to have steadily increasing levels of productivity, higher profits, larger size, lower debt ratios, and higher equity ratios. (...) On the other hand, we also found evidence that firm performance deteriorates with age. Older firms have lower expected growth rates of sales, profits and productivity, and they have lower profitability levels (when other variables such as size are controlled for (...)". A study by Lane, Haltiwanger & Spletzer (1999), which is of particular relevance to the model, suggest that

[14] Refer to Sutton (1997) and Coad (2009) for extensive survey articles of the industrial organization literature investigating the role of firm size.

the age of a firm is positively related to its productivity levels.

The present model suggests two additional contributions to the existing empirical literature. First, to scrutinize the available data about the relation between labor discipline and labor productivity at the firm level.[15] From an econometric point of view this exercise is equivalent to testing the learning-by-doing hypothesis. It requires an estimation of the effect of firm age on unit labor output while controlling for the effect of new capital investment, respectively changes in the capital-labor ratio over time. The second extension consists in analyzing firm panel data regarding the relation between effort enforcement and profitability predicted by the model. In addition to testing the hypothesis whether firms achieve higher profit rates as they age, constructing profit-age schedules for different industries may indicate whether there are differences in idiosyncratic closure risk at the sectoral level.

7 Conclusion

The labor discipline framework foregrounds the incompleteness of the employment contract and the strategic interaction between firms and workers. The particular focus of the present model lies with the role of firm age in determining the effectiveness of endogenous effort enforcement. To investigate this question the model adds two key assumptions to the baseline labor discipline framework. First, in addition to the classic principal-agent problem of effort provision, it introduces idiosyncratic firm closure risk as a further informational asymmetry. Second, the model lets workers make use of an updating process to estimate the life expectancy of individual employers based on the respective age of the firm.

The key prediction of the model states that a firm's per-period profitability increases over its lifespan. This result is driven by the link between increasingly effective effort enforcement and continuous labor productivity growth as firms age. In contrast to the baseline model, effort provision is not just determined by the firm's decision to renew or terminate employment contracts, but also by the workers' confidence in the life expectancy of an employer.

The analytical framework adds a novel contribution to the existing literature on productivity growth absent exogenous technical change. It provides an alternative explanation for this phenomenon, which is not based on mechanisms of firm adaptation or market selection, but, instead, on the dynamics of endogenous effort enforcement given idiosyncratic firm closure risk.

The distinctive insight provided by the labor discipline framework is particularly evident vis-à-vis the learning-by-doing hypothesis. The two approaches differ crucially in their treatment of the relation between employers and employees and their characterization of the production process. According to the learning-by-doing hypothesis, productivity gains occur smoothly, without

[15] The COMPUSTAT database contains the data required for these empirical extensions. Due to proprietary, institutional constraints the dataset was not available during the work on this thesis.

conflict and are determined solely by the ability of firms to translate their experience into more efficient production routines. Within the labor discipline framework, on the other hand, the exchange of labor power for a money wage and the incompleteness of the employment contract are a source of fundamental and continuous conflict. Labor discipline requires institutional enforcement by means of credible threats and sanctions, in particular the existence of involuntary unemployment. The possibility of firm closure and the existence of informational asymmetries between employers and employees, however, undermines the effectiveness of endogenous effort enforcement by means of contingent contract renewal. At the same time, the resulting strategic interaction between firms and workers sets into motion a process of endogenous productivity growth by means of increasingly stricter labor discipline.

References

Abramovitz, M. (1956), Resource and output trends in the United States since 1870, *in* 'Resource and Output Trends in the United States Since 1870', NBER, pp. 1–23.

Arrow, K. J. (1962), 'The economic implications of learning by doing', *Review of Economic Studies* **29**(3), 155–173.

Barron, D. N., West, E. & Hannan, M. T. (1994), 'A time to grow and a time to die: Growth and mortality of credit unions in New York City, 1914-1990', *American Journal of Sociology* **100**(2), 381–421.

Bartelsman, E., Scarpetta, S. & Schivardi, F. (2005), 'Comparative analysis of firm demographics and survival: evidence from micro-level sources in oecd countries', *Industrial and Corporate Change* **14**(3), 365–391.

Bellone, F., Musso, P., Nesta, L. & Quéré, M. (2008), 'Market selection along the firm life cycle', *Industrial and Corporate Change* **17**(4), 753–777.

Bowles, S. (2004), *Microeconomics: Behavior, Institutions, and Evolution*, Princeton University Press, Princeton, NJ.

Brown, C. & Medoff, J. (1989), 'The employer size-wage effect.', *Journal of Political Economy* **97**(5), 1027–1059.

Brown, C. & Medoff, J. L. (2003), 'Firm age and wages', *Journal of Labor Economics* **21**(3), 677–697.

Bruderl, J. & Schussler, R. (1990), 'Organizational mortality: The liabilities of newness and adolescence', *Administrative Science Quarterly* **35**(3), 530–547.

Coad, A. (2009), *The Growth of Firms: A Survey of Theories and Empirical Evidence*, Edward Elgar Publishing.

Coad, A. (2010), 'Investigating the exponential age distribution of firms', *Economics: The Open-Access, Open-Assessment E-Journal* **4**, 1–30.

Coad, A., Segarra, A. & Teruel, M. (2013), 'Like milk or wine: Does firm performance improve with age?', *Structural Change and Economic Dynamics* **24**, 173–189.

Das, S. (1995), 'Size, age and firm growth in an infant industry: The computer hardware industry in India', *International Journal of Industrial Organization* **13**(1), 111–126.

Evans, D. S. (1987*a*), 'The relationship between firm growth, size, and age: Estimates for 100 manufacturing industries', *Journal of Industrial Economics* **35**(4), 567–581.

Evans, D. S. (1987*b*), 'Tests of alternative theories of firm growth', *Journal of Political Economy* **95**(4), 657–674.

Farinas, J. C. & Moreno, L. (2000), 'Firms' growth, size and age: a nonparametric approach', *Review of Industrial Organization* **17**(3), 249–265.

Fichman, M. & Levinthal, D. A. (1991), 'Honeymoons and the liability of adolescence: A new perspective on duration dependence in social and organizational relationships', *Academy of Management Review* **16**(2), 442–468.

Garnsey, E. (1998), 'A theory of the early growth of the firm', *Industrial and Corporate Change* **7**(3), 523–556.

Gibrat, R. (1931), Les inegalites economiques, applications: aux inegalites des richesses, a la concentration des entreprises, aux populations des villes, aux statistiques des familles, etc., d'une loi nouvelle, la loi de l'effet proportionnel, PhD thesis.

Greiner, L. E. (1972), 'Evolution and revolution as organizations grow', *Harvard Business Review* **50**(4), 27–46.

Hannan, M. T. & Freeman, J. (1984), 'Structural inertia and organizational change', *American Sociological Review* **49**(2), 149–164.

Headd, B. & Kirchhoff, B. (2009), 'The growth, decline and survival of small businesses: An exploratory study of life cycles', *Journal of Small Business Management* **47**(4), 531–550.

Huergo, E. & Jaumandreu, J. (2004*a*), 'Firms' age, process innovation and productivity growth', *International Journal of Industrial Organization* **22**(4), 541–559.

Huergo, E. & Jaumandreu, J. (2004*b*), 'How does probability of innovation change with firm age?', *Small Business Economics* **22**(3-4), 193–207.

Jovanovic, B. (1982), 'Selection and the evolution of industry', *Econometrica* **50**(3), 649–670.

Lane, J., Haltiwanger, J. & Spletzer, J. (1999), 'Productivity differences across employers: The roles of employer size, age, and human capital', *American Economic Review* **89**(2), 94–98.

Levinthal, D. A. (1991), 'Organizational adaptation and environmental selection-interrelated processes of change', *Organization Science* **2**(1), 140–145.

Lotti, F., Santarelli, E. & Vivarelli, M. (2009), 'Defending Gibrat's Law as a long-run regularity', *Small Business Economics* **32**(1), 31–44.

Rodríguez, A. C., Molina, M. A., Pérez, A. L. G. & Hernández, U. M. (2003), 'Size, age and activity sector on the growth of the small and medium firm size', *Small Business Economics* **21**(3), 289–307.

Romer, P. M. (1986), 'Increasing returns and long-run growth', *The Journal of Political Economy* pp. 1002–1037.

Shanmugam, K. & Bhaduri, S. N. (2002), 'Size, age and firm growth in the indian manufacturing sector', *Applied Economics Letters* **9**(9), 607–613.

Solow, R. (1957), 'Technical change and the aggregate production function', *The Review of Economics and Statistics* **39**(3), 312–320.

Sorensen, J. B. & Stuart, T. E. (2000), 'Aging, obsolescence, and organizational innovation', *Administrative Science Quarterly* **45**(1), 81–112.

Stinchcombe, A. L. (1965), 'Social structure and organizations', *Handbook of organizations* **142**, 193.

Sutton, J. (1997), 'Gibrat's Legacy', *Journal of Economic Literature* **35**(1), 40–59.

Teruel-Carrizosa, M. (2010), 'Gibrat's Law and the learning process', *Small Business Economics* **34**(4), 355–373.

Vassilakis, S. (2008), Learning-By-Doing, *in* S. N. Durlauf & L. E. Blume, eds, 'The New Palgrave Dictionary of Economics', Palgrave Macmillan, Basingstoke.

Verdoorn, P. J. (1956), 'Complementarity and long-range projections', *Econometrica* **24**(4), 429–450.