

NORWEGIAN SCHOOL OF MANAGEMENT BI

FINAL MASTER THESIS

Industry Dynamics and Productivity:
The Effect of Productivity Change
on Worker Reallocation

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Date of submission:

09.08.2010

Examination code:

GRA 19003

MSc in Business and Economics, Double Degree in Economics

"This master thesis is part of the Master program at Norwegian School of Management BI. The school takes no responsibility for the methods

used, results found and conclusions drawn."

Abstract

The purpose of this study is to investigate to what extent it is the most productive firms who attract workers. Using the microeconomic models of general equilibrium, Cournot and Hotelling competition, search models and related empirical studies we postulate an econometric model. We use a unique dataset on Norwegian manufacturing firms from the years 2000 to 2008. We find that more productive firms have a higher average annual worker growth. This does not necessarily mean that more productive firms are larger. However, given enough time a faster growing but small firm is expected to be larger than a large but slow growing firm. We also find that firm growth decreases with size, rejecting Gibrat's Law. Our findings give suggestive evidence to the theories of competitive search models, which state that more productive firms offer higher wages, have more vacancies and attract workers faster. These results survive several robustness checks, including alternative productivity measure and an alternative structural form. In addition, we find that our data confirms a collection of stylized facts often found in the literature.

Preface

This paper is written as a Master of Science thesis at BI Norwegian School of Management. We would like to thank our supervisor Espen Moen for valuable guidance, counseling and flexibility. He provided us with the initial topic for this thesis. We would also thank the Center of Corporate Governance Research for providing the data used in our study.

Barcelona, 9th of August, Jonas Momkvist and Øyvind Nilsen Aas.

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1 Introduction

We investigate the relationship between productivity and worker reallocation of Norwegian manufacturing firms. Understanding the determinants of worker reallocation is important since reallocation of resources as a result of creative destruction, is an important factor in economic growth [57] [6] [45]. Advances in productivity, that is the ability to produce more with the same or less input, is a significant source of increased potential national income [47]. The process of creative destruction leads to job destruction and creation which leads to shifts in resources. The process is driven by different types of innovations and improvements, which could be summarized as productivity [57].

The purpose of this study is to investigate to what extent it is the most productive firms who attract workers. In more specific terms, our research question is "*How is the flow of workers affected by productivity?*" We look at the microeconomic models of general equilibrium, Cournot and Hotelling competition and competitive search. These models predict that more productive firms will attract more workers. We then postulate an econometric model based on the theory and related empirical literature. We find that more productive firms have a higher average annual growth rate, meaning that they attract more workers. This finding does not necessarily mean that the more productive is larger. However, given sufficient time a small fast growth firm will be larger than a larger slow growing.

According to OECD the world economy have experienced a formidable economic growth since the industrial revolution [47]. Joseph Schumpeter presented the ideas that economic growth is not necessarily driven by competition, but by creative destruction. In Schumpeter's *Capitalism, Socialism and Democracy* the author postulates a theory of capitalism which is "*by nature a form or method of economic change and not only never is but never can be stationary.*" ([57], p. 82). According to Schumpeter, the driving force of economic growth and increasing standard of living in the capitalist system is the process of creative destruction. Creative destruction is industrial mutation that constantly destroys the old structure and instantly creates a new one.

Our main focus is on changes in employment demand, so our econometric strategy is to estimate the growth-productivity relationship using regression estimation. The elasticities of interest are those of productivity, wage, size and age. In addition, we estimate a collection of stylized facts often found in the literature. We take advantage of a unique panel data set of 2 942 manufacturing firms in Norway for the years 2000 to 2008. Our

data is provided by the Center of Corporate Governance Research at BI Norwegian School of Management.

Related studies are Baily et. all. [6] which studies the connection between worker growth and productivity growth at the plant level. Using data collected from the Longitudinal Research Database, from the Bureau of Census, on U.S. manufacturing firms from 1977 to 1987 they find that increases in employment and productivity contributes almost as much as increases in productivity on the expense of employees to overall industry productivity. Evans [28] investigates the relationship between worker growth, probability of survival and variability of worker growth with the use of size, age and number of plants as explanatory variables. Using a sample of 100 manufacturing industries from 1976 to 1989. He finds that worker growth, probability of failure and variability of worker growth all declines with size, age and number of plants. Dunne et. all. [25] examines the pattern of postentry worker growth and failure for 200 000 U.S. manufacturing firms from 1967 to 1977. They find that failure rates and growth rates declines with size and age. Our study differs from Baily since we look at the relationship between growth rates and productivity at firm level, instead of plant level. With respect to the studies of Dunne et. all [25] and Evans [28] we look at the productivity, wage and rental rate of capital in addition to size and age.

The structure of the thesis is the following. The next section presents the definitions, related literature and previous empirical research. The third section introduces the theoretical foundation for our analysis with a presentation of the different microeconomic models. The fourth section describes our method and approach, while the fifth section is the estimation of stylized facts and the estimation of our research question. Section 6 concludes.

2 Definitions and related literature

The purpose of this section is to present the terminology of our paper, related studies and some of the established stylized facts about industry dynamics. We define¹ a job as *”an employment position filled by a worker”*. The discipline of Labor economics refer to *”job destruction and creation as job reallocation or job flows, because it entails the reshuffling of job opportunities across locations.”*([23] p. 2717)

Definition 1 *Job flows at time t is the sum of all business units employment gains and losses that occur between $t-1$ and t .*

The terminology we will use is the following. Following Definition 1, job flows is represented by the following equation

$$JF_{it} = S_{it} - S_{it-1} \quad (1)$$

where S_{it} is employment level at the i -th employer at time t and job reallocation is the absolute value of job flows

$$JR_{it} = |JF_{it}| \quad (2)$$

Job flows will either take a positive form, referred to as job creation (JC) or a negative form referred to a job destruction (JD).

$$JF_{it} = \begin{cases} JC_{it} & \text{if } JF_{it} \geq 0 \\ JD_{it} & \text{if } JF_{it} < 0 \end{cases} \quad (3)$$

As employment opportunities shift across locations, workers move within firms and from firm to firm. In addition workers switch employers or change employment status for other reasons as well. We therefore need to distinguish job flow from worker flow, which is defined as

Definition 2 *Worker flows at time t equals the number of persons who changed place of employment or employment status between $t-1$ and t .*

Burgees et all. [15], set total worker flows to be the sum of hires, H , and departures in the period, D ².

$$WF_{it} = H_{it} + D_{it} \quad (4)$$

¹All these definitions are from Ch. 41 Gross Job Flows, Volume 3B, in the Handbook of Labor Economics [23]

²For a more detailed description of the model see Burgees et all.[15]

Following these notations, we can write job flows as

$$JF_{it} = H_{it} - D_{it} = S_{it} - S_{it-1} \quad (5)$$

Combining the worker flow definition with the notion of job flows and we obtain the following relationship

$$WF_{it} = JR_{it} + CF_{it} \quad (6)$$

where CF denotes the level of excess worker flows, here denoted churning. From Equation (6) we see that worker flows is a function of job flows and churning. Churning represent other various reasons for a worker changing jobs. JR is the job reallocation component that will be studied by us. Related studies of job reallocation are Dunne, Roberts and Samuelson [26], Davis and Haltiwanger [22] [21], Leonard [46] and Anderson and Meyer [4].

Dunne, Roberts and Samuelson [26] investigated the role of plant construction, expansion, contraction and closing on net and gross changes in U.S. manufacturing from 1963 to 1982. They find that 70 percent of reallocation of job flows occur across plants within the same industry and region. Davis and Haltiwanger [21] investigate the creation, destruction and reallocation rate of jobs across plants in U.S. manufacturing sector from 1972 to 1986. They find average gross job creation and destruction rates of 9.2 percent and 11.3 percent per year. Job reallocation rate is defined as the sum of gross job creation and destruction rates. According to the authors, " *the high rates of job reallocation found indicate that the reshuffling of employment opportunities across plans is one of the most important reasons that workers change employers.* " ([21], p. 820).

Research on dynamics of firm and industries have found some statistical regularities, known as stylized facts. We have selected a few of the most relevant for our study, which are the following.

1. *Size distribution of firms and plants are highly skewed.* Studies of size distributions in the U.S. [56], [60], [44] and the U.K. [18], [20] concentrate on the lognormal and Pareto distributions. These generally support size distributions of firms and plants which are highly skewed. According to Curry and George [19] the distributions fail to describe at least some industries well. Neither the lognormal nor the Pareto consistently outperforms the other distribution.
2. (a) *The probability of survival increases with firm size.* (b) *The proportional rate of growth of a firm conditional on survival is decreasing in size.* (c) *For any given size*

of firms, the proportional rate of growth is smaller according as the firm is older, but its probability of survival is greater. Several studies [28], [34], [25], have found that mean growth rates decline with firm size, rejecting Gibrat's Law. This is also the case with the probability of failure. Using data of four-digit SIC codes from the Small Business Data Base Evans [28] finds that worker growth decreases with firm size and firm age and that the probability of firm survival increases with firm size and firm age. The study also found that worker growth decreases with firm size and firm age.

3. *Across different industries, there is a positive correlation between gross entry rates, and gross exit rates.* According to Caves [17] entry and exit are intimately involved in growth-size relations. Entry is more likely to occur into smaller size classes, and the likelihood of a unit's exit declines with its size. The entry barriers affect both the number of entries and their survival rate. These entry barriers can become entry gateways for lucky entrants. Lastly Caves found that "*productivity growth for an industry as whole depends on the redistribution of shares toward the more productive units and not just the growth of the units' individual productivity.*" ([17], p. 1976).
4. *Productivity levels are quite dispersed,* meaning some firm are more productive than others. Davis and Haltiwanger [29] found considerable heterogeneity both in plant level as well as firm level data. According to Nelson [53] one suggestion to why productivity dispersion is so large and how it evolves, is that productivity differences reflect the differences in the outcomes of technological bets. Even if firms make the same bets, they may not reap the same rewards. Several models of industry dynamics have formalized these concepts. Jovanovic [42] develop a model which imply that firm's productivity will vary initially but then settle down to a constant value. Ericson and Pakes [27] extended Jovanovic's model so that efficiency is more stochastic. Unlike the Jovanovic-model, negative shocks can cause very productive firms to have losses in efficiency. Furthermore Lentz and Mortensen [45] found that productivity dispersion across firms is large and persistent, and worker reallocation among firms is an important source of productivity growth. Even though the reason for the observed phenomenon is not fully understood, economic principles could suggest that the presence of productivity heterogeneity induce worker reallocation from less to more productive firms as well as from exiting and entering firms.
5. *There are tremendous heterogeneity in worker flows among firms and industries.* Davis and Haltiwanger [22], using annual-level of employment changes, calculate that manufacturing rates of job creation and destruction average 9.2 percent and

11.3 percent. The heterogeneity is a result of large rates of job creation and job destruction.³ Haltiwanger [35] found that worker flows are closely connected to firm outcomes, reflecting in large part the ongoing shift in resources from less productive to more productive employers.

6. *Entry and exit of plants with different productivity levels is an important source of productivity growth.* A large portion of aggregate productivity growth can be attributed to resource reallocation. The manufacturing sector is characterized by large shifts in employment and output across establishments every year. These large shifts are a major force contributing to productivity growth, resurrecting the Schumpeterian idea of creative-destruction [17]. John Baldwin explains the pattern of productivity and output as the following. In general, entrants are smaller than the average incumbent, and about half die within the first decade. If the entrant survive, they reach average productivity in about a decade, they are however still smaller than the average firm. Essentially the pattern is survival of the fittest, the process of weeding out the unsuccessful entrants and nurturing the successful ones [8].

³This is also found in Albaek and Sorensen [2] and Burgess et all. [15]

3 Microeconomic theory

In this section we will review the general equilibrium model, Cournot and Hotelling competition and search theory. The predictions of these models is the basis of our hypothesis.

3.1 General equilibrium

Consider an economy with perfect competition. Each firm is a small player in the industry. The price of the product is unaffected by the quantity of output produced by the individual firm, and the price of inputs are also unaffected by the individual firm's factor demand. All products and inputs are homogeneous. We will first address the optimal decisions by the firms in short term and later in long term.

By short term, we mean a sufficiently short period such that capital is fixed. Consider a Cobb-Douglas production function with two inputs and decreasing returns to scale in labor⁴. The firms set labor to minimize the following cost function given the levels of capital and quantum.

$$C(w, r, q) = r \cdot K + w \cdot L$$

such that $AK^\alpha L^\beta = q, \quad \alpha + \beta < 1$

r is the rental rate of capital, K is the amount of capital, w is the wage, L is the amount of labor, q is the quantity produced, A is the technology parameter and α, β are the elasticities. Solving the constraint for L as a function of q and K , which is fixed, yields

$$L^* = \left(\frac{q}{AK^\alpha} \right)^{1/\beta} \tag{7}$$

Equation (7) gives the optimal demand for labor as a function of output and fixed capital endowments. It is important to note that the q is a function of the technology parameter as well. The combination of Equation (7) with the cost function yields the following

$$C(w, r, q) = r \cdot K + w \cdot \left(\frac{q}{AK^\alpha} \right)^{1/\beta} \tag{8}$$

⁴**Decreasing returns to scale** Let $f(\mathbf{x}) = AK^\alpha L^\beta$. A technology exhibits decreasing returns to scale if $f(t\mathbf{x}) < tf(\mathbf{x}) \quad \forall t > 1$ The most natural case of decreasing returns to scale is the case where we are unable to replicate some inputs. In addition, it is assumed that decreasing returns to scale is due to the presence of fixed capital.

Suppose that $q = AK^\alpha L^\beta$. Then $f(tK, tL) = (tK)^\alpha (tL)^\beta = t^{\alpha+\beta} K^\alpha L^\beta = t^{\alpha+\beta} f(K, L)$ Hence, $f(tK, tL) = tf(K, L)$ if and only if $\alpha + \beta = 1$. Similarly, $\alpha + \beta > 1$ implies increasing returns to scale, and $\alpha + \beta < 1$ implies decreasing returns to scale [63].

and the short term marginal cost thus becomes

$$\frac{d}{dq}(C(w, r, q)) = C'(w, r, q) = \frac{w}{\beta} \left(\frac{q^{1-\beta}}{AK^\alpha} \right)^{1/\beta} \quad (9)$$

The firms maximize the following profit function.

$$\max_q \pi = p \cdot q - C(w, r, q) \quad (10)$$

According to the principles of maximizing behavior the producers will choose a quantity such that $p = C'(w, r, q)$. Using the short term marginal cost function the relationship is the following.

$$p = \frac{w}{\beta} \left(\frac{q^{1-\beta}}{AK^\alpha} \right)^{1/\beta} \quad (11)$$

Suppose the different firms capital endowment and technology parameter are distributed on different levels. A firm with higher AK^α will chose to have a larger q in order to satisfy the optimality condition in Equation (11), than a firm with a lower AK^α . As a result, the firms with a higher AK^α will demand a higher number of workers. The firm will hire new workers until the marginal productivity of labor is equal to the marginal cost. However, in equilibrium the marginal product of labor in all firms are the same, since the wage is equal for all firms. Since there is decreasing returns to scale in labor we can in the short run have firms with different AK^α levels existing together. If there is a change in productivity, the demand for labor change immediately.

The firms which are most productive, highest A , are the only ones which want to increase their K . The reason is that increased K will allow for a larger production volume yielding a lower price than the one offered in short term, enabling firms with the highest productivity level to capture the market.

In the long run, the firms are able to adjust both labor and capital input in production. However, only the most productive firms will allocate more capital and labor. Suppose that the economy moves from a short run equilibrium with different A_i levels ranging from $A_1 > A_2 > \dots > A_n$. There exists sufficiently many firms on each level to ensure perfect competition. Since capital is no longer fixed, the technology production is assumed to be constant returns to scale. The firms now face a different cost function,

namely the long run cost function with is derived in the following way [63].

$$C(w, r, q) = \min_{K, L} r \cdot K + w \cdot L$$

$$\text{such that } A_i K^\alpha L^{1-\alpha} = q$$

Where $A_i > 0$ is a level specific production technology. Solving the optimization we obtain the optimal demand for K and L

$$K^* = q \cdot \frac{1}{A_i} \left(\frac{\alpha}{1-\alpha} \frac{w}{r} \right)^{1-\alpha} \quad (12)$$

$$L^* = q \cdot \frac{1}{A_i} \left(\frac{1-\alpha}{\alpha} \frac{r}{w} \right)^\alpha \quad (13)$$

The cost function is defined as:

$$C(w, r, q) = r \cdot K^* + w \cdot L^* \quad (14)$$

Combining (12), (13) and (14), yields the following cost function

$$C(w, r, q) = \frac{1}{A_i} \left[\left(\frac{\alpha}{1-\alpha} \right)^{1-\alpha} + \left(\frac{\alpha}{1-\alpha} \right)^{-\alpha} \right] r^\alpha w^{1-\alpha} \cdot q \quad (15)$$

$$C'(w, r, q) = \frac{1}{A_i} \left[\left(\frac{\alpha}{1-\alpha} \right)^{1-\alpha} + \left(\frac{\alpha}{1-\alpha} \right)^{-\alpha} \right] r^\alpha w^{1-\alpha} \quad (16)$$

We see from equation (16) as A_i increases the marginal cost will go down. As a result, the firms with the highest productivity level, will have the lowest marginal cost. The firms optimize in the same way as in the short run, solving Equation (10), setting price equal to marginal cost given by

$$p = \frac{1}{A_i} \left[\left(\frac{\alpha}{1-\alpha} \right)^{1-\alpha} + \left(\frac{\alpha}{1-\alpha} \right)^{-\alpha} \right] r^\alpha w^{1-\alpha} \quad (17)$$

In short run, firms with different productivity levels coexisted. According to Equation (17) the equilibrium price for the firms on different levels will vary. The firms on the level with the highest productivity, will have the lowest marginal cost and therefore the equilibrium price will be lowest. The firms which produce at the lowest marginal cost (highest A_i) will be the only ones selling the product and the only ones that want to allocate more capital and labor. As a result only the most productive firms will stay and the less productive will exit. Since the total number of firms in the economy is reduced,

the remain firms are larger relative to when there where many level. Since the optimal labor demand is a function of both A and q , $(d/dA)(q) > 0$ there exists a trade off for the firm. An increase in productivity increases optimal quantum produced (quantum effect) and reduces the workers needed since the firms are more productive (utilization effect). The total effect will depend on which of these two effects are the dominating.

Using the notion of different productivity levels the firms with productivity level A_1 are the ones which will survive. Let $A_1 - A_2 = \epsilon$ and let $\epsilon > 0$. The firms with level 1 will always undercut the firms with level 2. However, since there is sufficiently many firms on each level, the price will still be equal to marginal cost. The result is that only firms with the same productivity level can exist in the market.

In conclusion, in the short term there can exist firms with different AK^α levels, since there is decreasing returns to scale due to fixed capital. In the long run, only the most productive firms will produce, such that all firms in the economy have the same productivity level. If there is a difference in long run, there will be a reallocation of inputs from the low productivity firms to the high productivity firms. A productivity change leads to a reallocation of inputs from the low productive to the high productive firms. So a more productive firm is expected to have a larger work force.

3.1.1 Adjustment cost

In the model of general equilibrium firms immediately adjust their capital and labor when productivity changes, leading to an instant flow of inputs. However, in the real economy there is considerable lag in demand for inputs [37]. One explanation for the observed phenomenon could be adjustment costs related to changes in input. In the Cobb-Douglas production function there may be adjustment costs related to changes in the work force and capital.

The literature investigating adjustment costs has two approaches, namely convex and non-covex costs of adjustment. Holt et all [38] found a quadratic specification of adjustments costs to be a suitable first approximation in certain industries. To avoid the increasing costs the firm will adjust their input often by small amounts, causing distributed lags [5]. According to Doms-Dunne [24] non-convex cost of adjustment focus either on fixed or proportional costs of adjustment, making characteristics of optimal behavior hard to outline. The implications may be certain number of periods without adjustments, and at selected times sizable adjustments [5]. These implications are contradicting to those of the quadratic adjustment cost which yield small and continuous

adjustments.

Labor adjustment costs will directly affect labor demand. A productivity shock may create a lag in convergence to its new long run equilibrium if there is convex adjustment cost. But if the the adjustment costs are non convex there may be a immediate jump to the new long run equilibrium, or the firm can maintain its old employment level if the shock is not large enough [36]. The cost related to capital adjustment play an important role in determining the labor demand. If a positive productivity shock occur, the firm demand more of both inputs. If the adjustment cost of capital is convex there will be a slow transition towards the long run equilibrium level of capital. On the other hand if there is a non-convex adjustment cost, adjustments occur as a jump.

In conclusion, convex adjustment cost may create a lag in convergence to the new long run equilibrium after a productivity shock. However if adjustment cost are non-convex there may be a immediate jump to the new long run equilibrium, or unchanged behavior if the the shock is not large enough [36].

3.2 Cournot

Consider an economy with a finite number of homogeneous firms competing in the final goods market, and infinite many agents supplying the input factors. There is free competition in the input market, such that all prices are marginal prices. In the final good, the firms compete on quantity, here represented by a repeated game of Cournot with infinite many periods, or uncertainty about when the last period will be. All agents maximize the profit function in Equation (18), taking into consideration the other firms actions. Consider a symmetric case with linear demand and a Cobb-Douglas cost function $C(w, r, q)$ yields the following profit function⁵

$$\Pi^i = q_i \cdot (1 - q_i - q_j) - c_i \cdot q_i \quad (18)$$

where c_i is the unit cost for the i -th firm, defined as

$$c_i = A_i^{-1} \left[\left(\frac{\alpha}{1 - \alpha} \right)^{1-\alpha} + \left(\frac{\alpha}{1 - \alpha} \right)^{-\alpha} \right] r^\alpha w^{1-\alpha} \quad (19)$$

where q_i is the quantity produced by firm i , q_j the quantity by firm $j \neq i$, A_i is a firm specific production technology, α is the capital share, and r and w are the input prices.

⁵See Appendix A for the derivations of the model

By taking the first order conditions w.r.t. q_i and q_j , and solving the reactions functions with respect to the optimal action by the other firm we get that

$$q_i = \frac{1 - 2c_i + c_j}{3} \quad (20)$$

$$q_j = \frac{1 - 2c_j + c_i}{3} \quad (21)$$

Equation (20) show the optimal quantum produced by firm i to be a function of the marginal cost of its own production and its competitor. Firm i which minimizes the cost of production for a given quantity has the following factor demand

$$K^* = q_i \cdot \frac{1}{A_i} \left(\frac{\alpha}{1 - \alpha} \frac{w}{r} \right)^{1-\alpha} \quad \text{and} \quad L^* = q_i \cdot \frac{1}{A_i} \left(\frac{1 - \alpha}{\alpha} \frac{r}{w} \right)^\alpha \quad (22)$$

Where demand for inputs is a function of the quantity produced, the firm specific technology, factor intensities and the price of the two inputs. It is important to note that by Equation (20), q_i is a function of the technology parameter as well. This relationship will have a profound effect on the demand when productivity change is introduced.

After the first period is over, right before the next period starts, the firms may experience a productivity shock, such that $A' \neq A$. Resulting either in the firm becoming more productive or less productive. The probability of experiencing a productivity shock is non-negative for all firms. By looking at the derivative of Equation (20) and (22) with respect to the technology, A_i , we can define what the theory suggest is the effect of productivity change.

$$\frac{\partial q_i}{\partial A_i} = \frac{2}{3} \frac{1}{A_i^2} \left[\left(\frac{\alpha}{1 - \alpha} \right)^{1-\alpha} + \left(\frac{\alpha}{1 - \alpha} \right)^{-\alpha} \right] r^\alpha w^{1-\alpha} > 0 \quad (23)$$

$$\frac{\partial L}{\partial A_i} = \left(\underbrace{\frac{2}{3} \frac{1}{A_i^3} \left[\left(\frac{\alpha}{1 - \alpha} \right)^{1-\alpha} + \left(\frac{\alpha}{1 - \alpha} \right)^{-\alpha} \right]}_{\text{q-effect}} \underbrace{\frac{1}{A_i^2} q_i}_{\text{u-effect}} \right) \left(\frac{1 - \alpha}{\alpha} \frac{r}{w} \right)^\alpha \quad (24)$$

By Equation (23) the effect of an increase in productivity increases the optimal quantum of the final good. Equation (24) however is less clear since the effect of a productivity increase depends on two effects, the quantum effect and utilization effect. The quantum effect suggest that an increase in productivity leads to more quantum being produced such that more input is needed. The utilization effect, on the other hand, suggest less inputs for a given output since the firm is more productive. It is not clear by Equation

(24) which of these effects are the strongest because it depends on the parameter α , the input prices r, w and the quantity produced, q .

The Cournot model predicts that if a firm experiences a positive productivity shock there will be a change in inputs, but the exact sign is not clear. However, there is a link between productivity and input allocation. In addition, we see firms with different productivity levels coexisting in the economy under the condition that the difference in productivity is sufficiently small. There exists an interval $A_i - A_j = \varepsilon$, ($A_i \neq A_j$), where $\varepsilon > 0$, such that for value of A_i within this interval there will be at least two firms with different productivity levels.

3.3 Hotelling

We consider the model of horizontal differentiation given by Hotelling [39][62]. Consider an economy with two firms located at different points of a city, represented by a $[0, 1]$ interval on \mathbb{R} . The unit cost of the two firms is given by c_i , where $i = 1, 2$ for the two firms. Firm 1 is more productive, so $c_1 < c_2$. The unit cost is the same as before, given by the following equation

$$c_i = A_i^{-1} \left[\left(\frac{\alpha}{1-\alpha} \right)^{1-\alpha} + \left(\frac{\alpha}{1-\alpha} \right)^{-\alpha} \right] r^\alpha w^{1-\alpha} \quad (25)$$

The two firms are located at the two ends of the city, and sell the same products. The location of firm 1 is $x = 0$ and firm 2 $x = 1$. Let p_1 and p_2 denote the prices charged by the two firms. The price of going to firm 1 for a consumer with coordinate x on the $[0, 1]$ interval, is $p_1 + tx$ and to firm 2 it is $p_2 + t(1 - x)$. If the price difference between the two firms does not exceed the transport cost t along the whole line segment, there exists a consumer located at x^m who is indifferent between the two options. To determine the market shares, we equate the respective utilities from buying from the two firms of the indifferent consumer.

$$p_1 + tx^m = p_2 + t(1 - x^m) \quad (26)$$

Taking into consideration the best response of the other firm to its own price, the optimal prices for the two goods are

$$\begin{aligned} p_1^* &= \frac{3t + c_2 + 2c_1}{3} \\ p_2^* &= \frac{3t + c_1 + 2c_2}{3} \end{aligned} \quad (27)$$

where $p_2 > p_1$. The respective market shares of the two firms then become

$$\begin{aligned} x^m &= \frac{1}{2} + \frac{c_2 - c_1}{6t} \\ (1 - x^m) &= \frac{1}{2} + \frac{c_1 - c_2}{6t} \end{aligned} \tag{28}$$

We see that if the two firms were identical ($c_1 = c_2$), the result would be to split the market. However, since $c_1 < c_2$ firm 1 obtains a larger market share than firm 2. These are the optimal market shares from the two firms point of view. However, this is not necessary what is optimal for society. We look at the objective function for society as a whole

$$W = V - c_1 \cdot y^* - c_2(1 - y^*) - \frac{t \cdot y^{*2}}{2} - \frac{t(1 - y^*)^2}{2} \tag{29}$$

By maximizing the social wealth function W , with respect to y^* we find the socially optimal market shares

$$\begin{aligned} y^* &= \frac{1}{2} + \frac{c_2 - c_1}{2t} \\ 1 - y^* &= \frac{1}{2} + \frac{c_1 - c_2}{2t} \end{aligned} \tag{30}$$

Comparing Equations (28) and (30) we see that the optimal market share for society of the most efficient firm (firm 1) is larger than the equilibrium market share ($y^* > x^m$). The opposite is true for the less efficient firm.

When firm 1 has a cost advantage, it obtains a larger market share and become less aggressive when setting the price. The differences between the two firms are therefore smaller than the differences in costs. The high-cost firm obtains a larger market share than what is socially optimal. The reason is the higher costs of firm 2 leads firm 1 slacks off and not press the price as much as it would under perfect competition. Once again we can have firms with different productivity levels in the same market. The argument is the same as Cournot, given that the differences are not too large, there will exist firms with different productivity levels in the same market. The empirical predictions by this model is that firms which are more productive will obtain a larger market share, resulting in an increased demand for workers.

3.4 Search models

Search models are characterized as equilibrium models with frictions in information, recruitment and turnover costs. Here unemployment, job spell duration and wage offers

are treated as endogenous variables. These models provide a richer equilibrium framework in contrast to the frictionless competitive models [52]. The most used model of wage posting is the model by Burdett and Mortensen [14]. The model postulates an equilibrium where firms posts wages unilaterally and workers are randomly searching for a higher paid job, so there is no matching function. The Burdett-Mortensen model is the main focus of the following section. We will look at two scenarios, first one where all firms and employees are identical and one with heterogeneous productivity levels of firms and identical workers⁶.

3.4.1 Homogeneous firms and employees

We start by looking at the behavior by the workers. A worker can be employed or unemployed. The worker has one objective and that is to maximize his expected discounted lifetime income. The employed and the unemployed both search for a job. This condition is essential to generate wage dispersion⁷. The employers send "help wanted ads" to the workers at random and each worker chooses among the different offers within a specific period. *"Given that offers arrive continuously over the week at frequency λ , the number of received offers is a random Poisson variable."* ([52] p. 2612).

Suppose the employed worker receives offers at arrival rate $\lambda_1 > 0$ which is different from the arrival rate for the unemployed $\lambda_0 > 0$. According to Mortensen and Neumann [51] the unemployed accept any wage offers which exceeds the reservation wage R and the employed accepts any offer greater than the current wage. This condition is the following

$$R - b = (\lambda_0 - \lambda_1) \int_R^\infty \left(\frac{1 - F(x)}{r + \delta + \lambda_1[1 - F(x)]} \right) \quad (31)$$

where b is the unemployment income, r is the interest rate, δ is the turnover rate and $F(x)$ is the wage offer distribution. Since jobs are identical except for the wage, employed workers move from lower to higher paying jobs. In addition, they move from employment to unemployment and back again. Given the reservation wage, the flow of workers can be specified. Equality of the flow of workers into employment $\lambda_0[1 - F(x)]u$ and the flow out of employment $\delta(m - u)$ yields the steady state unemployment rate.

$$u = \frac{m}{1 + k_0[1 - F(x)]} \quad (32)$$

⁶For the details on the derivations see Mortensen and Neuman [51] and Burdett and Mortensen [14].

⁷If some positive strict fraction receive two or more offers and another fraction receives only one, the unique equilibrium is characterized by a non-degenerate offer distribution [52]

where $k_0 = \lambda_0/\delta$ represent the ratio of the arrival rate to the job separation rate and m represent the number of workers per employer. In the case of differentiable wage offer distribution, the measure of workers per firm earning a wage w can be expressed as

$$l(w|R, F) = \frac{mk_0[1 + k_1(1 - F(R))]/[1 + k_0(1 - F(R))]}{[1 + k_1(1 - F(w))][1 + k_1(1 - F(w^-))]} \quad (33)$$

where $k_1 = \lambda_1/\delta$ represent the ratio of employed arrival rate to the job separation rate. So, Equation (33) specifies the steady-state number of workers available to firms offering any particular wage conditional on the wage offered by other firms ($F(\cdot)$) and the reservation wage R .

Firm behavior is now considered. Let p denote the flow of revenue generated per employed worker. Hence, an employer's steady-state profit is given by the wage offer, w . Conditional on R and F , each employer is assumed to post a wage such that profit is maximized. Optimal wage offers solves the following

$$\pi = \max_w (p - w)l(w|R, F) \quad (34)$$

An equilibrium solution to the search and wage-posting game can be described by (R, F, π) such that R , the common reservation wage of unemployed workers, satisfies (31), π satisfies (34), and F is such that

$$\begin{aligned} (p - w)l(w|R, F) &= \pi && \text{for all } w \text{ on support of } F \\ (p - w)l(w|R, F) &\leq \pi && \text{otherwise} \end{aligned} \quad (35)$$

Given Equations (33), (34) and $\underline{w} = R$, Equation (35) implies a single candidate for the offer distribution function

$$F(w) = \left[\frac{1 + k_1}{k_1} \right] \left[1 - \left(\frac{p - w}{p - R} \right)^{1/2} \right] \quad (36)$$

combining (36) with (31) gives an expression for the equilibrium reservation wage. This is a weighted average of the unemployment benefits and worker productivity.

$$R = \frac{(1 + k_1)^2 b + (k_0 + k_1)k_1 p}{(1 + k_1)^2 + (k_0 - k_1)k_1} \quad (37)$$

Since there exists a strictly positive fraction which is offered two or more jobs and another fraction which only is offered one, the unique equilibrium is characterized by a non-degenerate offer distribution. The unique equilibrium solution generates wage dis-

person because offering a wage equal to a mass point is not profit maximizing in the sense of equation (35).

A critical feature of the model is the positive relationship between the wage offer and employers labor force size it implies. As the voluntary quit rate, $\lambda_1 F(w)$, decreases with the wage offer, larger firms experience lower quit rates. Because workers only switch employers in response to a higher wage offer, workers with either more experience or tenure are more likely to be earning a higher wage.

3.4.2 Job Productivity Differentials

We will now look at what happens if we introduce heterogeneity among employers, specifically two types of employers. One of the employers is more productive than the other and earn a higher revenue flow per workers such that $p_2 > p_1$. The fraction of employers of type 2 is denoted σ . The model is identical to the one above in all other aspects such that an equilibrium can be described by $(F_1, F_2, R, \pi_1, \pi_2)$, where the reservation wage satisfies equation (31) and F_1, F_2 represent an offer distribution of the two types of employers and

$$\begin{aligned} (p_i - w)l(w|R, F) &= \pi_i \quad \text{for all } w \text{ on support of } F \\ (p_i - w)l(w|R, F) &\leq \pi_i \quad \text{otherwise} \end{aligned} \tag{38}$$

where the market offer distribution, \mathbf{F} , is the following mixture:

$$\mathbf{F}(w) = (1 - \sigma)F_1(w) + \sigma F_2(w) \tag{39}$$

The result of this unique equilibrium yield the case where more productive employers offer higher wages. Formally, we can show $w_2 \geq w_1$ if w_i is on the support of F_i , $i=1,2$. This follows as

$$\begin{aligned} \pi_2 &= (p_2 - w_2)l(w_2|R, F) \geq (p_2 - w_1)l(w_1|R, F) \\ &> (p_1 - w_1)l(w_1|R, F) = \pi_1 \geq (p_1 - w_2)l(w_2|R, F) \end{aligned} \tag{40}$$

where the first inequality and the last inequality are implied by (38). Comparing the difference between the first and last terms of (40) with the difference between the middle two yields the inequality $(p_2 - p_1)l(w_2|R, F) \geq (p_2 - p_1)l(w_1|R, F)$. This inequality and the fact that $l(\cdot|R, F)$ is increasing in w imply $w_2 \geq w_1$ as claimed. It follows that F_1

and F_2 can be written as

$$F_i(w) = \left[\frac{k_1}{1+k_1} \right] \left[1 - \left(\frac{p_i - w}{p_i - \underline{p}_i} \right)^{1/2} \right] \quad (41)$$

on its support $[\underline{w}_i, \bar{w}_i)$, $i=1,2$.

$$\begin{aligned} \underline{w}_i &= R, \quad \text{where } R \text{ satisfies (31)} \\ \bar{w}_1 &= \underline{w}_2, \text{ where } p_1 - \bar{w}_1 = (p_1 - \underline{w}_1)/(1+k_1)^2 \\ p_2 - \bar{w}_2 &= (p_2 - \underline{w}_2)/(1+k_1)^2 \end{aligned}$$

So as the more productive employers offer higher wages, they have larger workforces, make more profit, and keep workers longer than less productive firms.

3.4.3 Alternative models of wage determination

Moen [50] and Shimer [58] have constructed models of wage formation which generate the socially optimal allocation of resources, as derived by the Hosios condition ⁸. *"In these models firms post wages to minimize search and waiting cost and the labor market is endogenously separated into sub-markets"* ([31] p. 343). The markets are competitive in the sense that all agents are price takers and maximize utility subject to a set of market parameters.

Garibaldi and Moen [31] derive an extension of the competitive search model by Moen [50] where they introduce convex costs of maintaining vacancies and efficient labor market contracts. The predictions by the model is firms with higher productivity can offer a wage strictly larger than the one offered by a low productivity firm and thereby filling their vacancies faster. The higher wage would yield higher growth rates and larger profit for the high productivity firm. In equilibrium workers and firms of different productivity levels search in different sub-markets.

⁸Hosios' efficiency condition characterizes the solution to a utilitarian social planner's problem.

4 Method and Approach

In our paper we will take an empirical approach. The combination of microeconomic general equilibrium, Cournot, Hotelling, search theory and empirical studies of firm dynamics are used to identify factors affecting worker allocation between firms. The theory driven model will be estimated using data from the Center for Corporate Governance Research (CCGR). The CCGR dataset is an unbalanced panel containing accounting data for Norwegian firms with limited liability in the period 1994 to 2008. The scope of our investigation will be the manufacturing industry, classified according to the OECD NACE codes. A lot of the research on productivity and firm dynamics are conducted on the manufacturing industry, which makes it easier to relate to previous literature.

The econometric estimation will start with an investigation of well-established stylized facts. The reason for this query is to see if our data have similar properties to those found in previous studies. Next, we estimate our model using OLS regression analysis. In addition, we test the results for misspecification, heteroskedasticity and multicollinearity to determine the most efficient estimator. Lastly we will run a least square dummy variable (LSDV) to allow for the intercept to vary across different sectors of the manufacturing industries. We end our empirical analysis with robustness tests on our estimates using an alternative measure of productivity and an alternative structural form. All econometric tests and regressions are performed using STATA 9.0 and STATA 10.

5 Econometric Strategy

5.1 Model of estimation

The objective of this paper is to investigate the relationship between worker reallocation and productivity. In more specific terms, how is the flow of workers affected by productivity. According to a long run cost minimization where both labor and capital can be adjusted, the optimal labor demand is

$$L^* = q_i \cdot \frac{1}{A_i} \left(\frac{1 - \alpha r}{\alpha w} \right)^\alpha \quad (42)$$

where q_i is model specific, meaning that it depends on the model and it is a function of the technology parameter. According to (42) there is a trade off between the utilization effect and the quantum effect. One way to measure the effect of productivity on worker reallocation is to look at the average worker growth of firms. As an illustrative example suppose there are two identical firms in size in the beginning period, with different average growth rates. Then, after one period the firm with the highest average growth will be larger than the other. In addition, if there is one large firm with a low average growth rate and a small firm with a high average growth rate, the small firm will become the largest over time⁹. In conclusion, the most productive firms will attract more workers than less productive firms. However, this does not necessarily mean the the more productive are larger. According to Evans [28] and Baily et. all [7] the change in workers can be define as

$$Growth = \ln[S_{t'}/S_t]/[t' - t] \quad (43)$$

were S is the number of employees, $t' = 2008$ and $t = 2000$. Worker growth is therefore average annual growth in employees.

Previous empirical studies investigating worker growth have found a relationship between worker growth and size and age [28] [46]. By combing the variables from the optimal labor demand by Equation (42), the growth definition by Equation (43) and the empirical literature the relationship between productivity and worker reallocation can be expressed by the following equation.

$$[\ln S_{it'} - \ln S_{it}]/d = F(A_{it}, w_{it}, r_{it}, q_{it}, \alpha, Age_{it}, S_{it}) + \epsilon_{it} \quad (44)$$

where the subscript i indicate the firm and the subscript t indicate beginning period. $d = t' - t$, $A_{it} = (R_{it} - m_{it})/S_{it}$, is value-added per employee, where R_{it} is revenue and

⁹See Appendix B for a graphical representation.

m_{it} is material cost, w_{it} is the average wage rate, r_{it} is capital cost, q_{it} is the quantum produced for each firm, α is the capital share, Age_{it} is the age of the firm, S_{it} is number of employees and ϵ_{it} is a random error term. The variable construction will be discussed later. $\ln S_{it'} - \ln S_{it}$ is the logarithmic version of Equation (1). $F(\cdot)$ is a growth function which we will approximate by taking a first-order logarithmic expansion such that we can calculate the respective elasticities. For example, a positive and significant productivity coefficient imply that more productive firms grow faster and attract more workers than less productive firms. Our equation is expressed as the following

$$\begin{aligned} [\ln S_{it'} - \ln S_{it}]/d = & \beta_1 + \beta_2 \cdot \ln A_{it} + \beta_3 \cdot \ln w_{it} + \beta_4 \cdot \ln r_{it} \\ & + \beta_5 \cdot \ln q_{it} + \beta_6 \cdot \ln \alpha + \beta_7 \ln Age_{it} + \beta_8 \cdot \ln S_{it} + \epsilon_{it} \end{aligned} \quad (45)$$

The search theory models of Garibaldi and Moen [31] and Moen [50] states that more productive firm offer a higher wage and have more vacancies which they fill faster. In the short term general equilibrium, there exists firms with different productivity and capital levels. Only the most productive firms wish to expand labor. As the economy moves toward long term general equilibrium, the most productive firms (highest A) wish to increase capital and then increase labor. In the long run general equilibrium there can only exist players with the same productivity level. According to a two-player Cournot game, the firm with the highest productivity level, will have a smaller marginal cost and will produce more than the low productivity firm. The demand for labor depends on the parameters of the economy, where there is a tradeoff between the quantum-effect and the utilization effect. In Cournot game there can exist firms with different productivity levels in the economy at the same time, if the difference is sufficiently small. In a Hotelling game with two players, the most productive firm, will have the lowest marginal cost and get a larger market share. Once again, there is a quantum effect and utilization effect. Furthermore, in Hotelling two firms with different productivity level can coexist given that the difference is sufficiently small.

The econometric model above suggest that over time the firm with the highest average growth rate will become the largest. Our period spans over 9 years, so it could be that larger firms with a low growth rate are still the largest since it may be that 9 years is a too short time period to capture the element of differences in beginning period size. A positive and significant β_2 indicate that more productive firms hire employees at a higher rate than less productive ones. This does not necessarily mean that they are larger in size. However the illustrative example above show that given enough time ($time \rightarrow \infty$) the fast growing firms will also be the largest.

Alternatively, we could have modeled the relationship between firm size in period t (S_t) and $F(\cdot)$ in period t . As a part of the initial decision process regarding econometric method and model, this was tested but yielded non-significant results when correcting for violations of the OLS (unpublished results). We therefore choose to use the method described above. In addition, we could have used profitability instead of productivity. The econometric model would then become

$$[\ln S_{it'} - \ln S_{it}]/d = \beta_1 + \beta_2 \cdot P_{it} + \beta_3 \cdot \ln Age_{it} + \beta_4 \cdot \ln S_{it} + \epsilon_{it} \quad (46)$$

where $P_{it} = EBIT/S_{it}$. Where $EBIT$ is equal to earnings before interest. A firm which is more productive could be expected to be more profitable. According to Haltiwanger [30] more profitable firms are not necessarily more productive, due to for example market power.

5.2 Data collection

The data is collected from the Center of Corporate Governance (CCGR) at BI Norwegian School of Management. The dataset is a panel dataset from 1994 to 2008 which include data on revenue, acquisition cost of goods sold, payroll expense, operating income, income before tax, total fixed assets, total current assets, industry codes, industry codes at level two, number of employees and company age. In addition, we have calculated rental rate of capital¹⁰ based on data from Norwegian Central Bank, Oslo Stock Exchange and the Norwegian Tax Law. The calculation is described later.

The raw data from CCGR contains 2 304 743 annual firm observations. Our paper focus on the relationship between productivity and employment, so firms where employment is missing is removed. This deleted 1 579 605 annual observations. We are looking at the manufacturing industries in Norway. We first remove those that have missing values on industry codes (2 510), then we remove all that are outside the industry codes 17 – 37. This deleted 652 182 annual observations. We now have 70 446 annual observations.

We make sure that we have no reporting mistakes, so we delete those firms which have negative revenue and assets and those who have positive costs of goods sold and payroll expenses. This deleted 1 078 annual observations. We now have 69 368 annual observations. We need two types of data set, one which is balanced where we will calculate the worker growth, variability of growth and the rest of the stylized facts. We also need an unbalanced panel such that we can map those who went bankrupt in the period and look

¹⁰See appendix D for reference

at the relationship between bankruptcy risk and age and size.

The first data set containing 69 368 annual observations or 13 799 firm observations is cleaned in the following way. First we need a balanced data set, so we delete those firms that are not present in the whole period, which removed 10 547 firms. The removal of firms which go bankrupt or disappear reduces much of our variability and could leave to survival bias. This potential problem is discussed more thoroughly after the results are presented. We have not controlled for this problem in our estimation. In order to estimate our equation we need the variables on log form. When creating logs we remove those 310 observations that become missing values due to the log operation. Now we have 2 942 firm observations or 26 478 annual (9 years) observations.

This second data set is cleaned in the following way. We first need to find out which firms that is present in the beginning of the period and the end. We start with 69 368 annual observations or 13 799 firm observations. We then remove all that are not present in 2000. This removed 5 742 firm observations. We create a survival variable which is coded 1 if they are present in 2000 and 2008 and 0 if they are present in 2000 but not in 2008. We generate the variables by taking log of employment and age. We now have 8 057 firm observations.

Due to the extensive screening process, we do not have a random sample. Our balanced dataset consist of firms which are present in the whole period, have not failed to report correct accounting data and does no have values which are conflicting with log operation. This is sample can therefore not be seen as a random sample. We have not corrected for this problem.

5.3 Variable construction

The variables of interest in our model are the following: number of employees, wage, capital cost, quantum produced and capital share, productivity and company age.

The wage rate was constructed by dividing the payroll expenses by the number of employees. This provides a proxy for the wage rate in the company. There is a measurement problem with this variable. Payroll expenses take into consideration differences in the indirect wage costs across different regions of Norway. Differences in the indirect wage cost across counties in Norway is due to a discriminatory employer tax. The country is divided into different zones, and in some areas the tax is lower than in others. It is a way for the Norwegian government to reduce the cost of employment in some areas and

promoting the use of labor instead of capital [1]. Further more, there is a problem regarding the assumptions of exogeneity of the wage variable. In free competition the prices of input and outputs are set on the industry level. For each firm, the price is given, such that the individual firm is a price taker. Hence, prices of inputs are assumed exogenous. However, suppose that the entire industry of a long run general equilibrium is hit by a positive productivity shock. As a result, the marginal cost of production is reduced and the optimal quantum is increased. Furthermore, every firm will demand more capital and hire more workers. The price of capital and wages would increase and there could be an inflow of workers and capital from other sectors. In this example, the wage and price of capital has become endogenous. The inclusion of an endogenous variable as an explanatory variable, could potentially disrupt the estimates. We assume for simplicity that the wage is exogenous for the individual firms, but fully acknowledge that if the industry demand is changed, the prices of inputs and outputs will change. We have only included the wage on firm level and assumed that it is exogenous.

Next, we address our productivity measure. According to Barelsmann and Doom [10] the main choice productivity researchers make is whether to analyze labor productivity or total factor productivity (TFP). Secondly they must choose whether the output is in physical terms, or in gross production [10].

We will use labor productivity, defined as Q/L where Q is output and L is number of employees. We use labor productivity since our data is on firm level and we want to compare productivity units across firms. Furthermore, it is one of the most common measure of productivity [30]. However, our data is disaggregated but not on physical output level. Due to the data constraint we have not obtained physical output, Q , nor the prices of the output so we will focus on a gross production measure. It would be more precise to calculate the gross production per hour worked, but such a measure is not available in our data. However it would not take into consideration people working unpaid overtime nor people on fixed week.

We choose to use value added as our output variable. Value added is constructed as revenue subtracted by cost of materials. Value added was divided by number of employees. The value added measure is the following

$$\frac{Q}{L} = \frac{\text{Revenue} - \text{material cost}}{\text{Employees}} = \frac{R_{it} - m_{it}}{S_{it}} \quad (47)$$

Which is value added per employee. R_{it} is revenue, m_{it} is material costs and S_{it} is number of employees.

Our measure is not without limitations. Our value added measure does not include purchased services related to production. The measure will capture increases in outsourcing if it is the form of intermediate physical input but will not capture changes in the role of purchased services like back-office and other support activities [6]. Siegler and Griliches [59] investigated the measurement problem of purchased services and concluded that there was not much effect on the measurement of manufacturing productivity for the period 1977-82. This could provide some reassurance that the measurement concerns are not likely to have a serious impact on our estimates. However, this study focus on a period long before our panel data so the argument should be taken with a grain of salt.

Lastly, we treat the capital cost. The rental rate of capital, r_{it} , is defined by the Norwegian Ministry of Finance as; *"the firms actual cost of utilizing the capital in one period"*. Accordingly, it can be represented as the following

$$r_{it} = k_{it} + \delta_{it} \quad (48)$$

where k_{it} the financing cost of capital and δ_{it} is the depreciation. We have not included inflation, since all our values are deflated using the indexes given in Appendix C. According to Miller and Modigliani [49] the total capital cost depends only on the risk of the project, not the way the project is financed. Suppose the world is without tax to simplify. Using the capital asset pricing model, the financing cost of capital is the following.

$$k_{it} = r_f + \beta [E(r_m) - r_f] \quad (49)$$

where r_f is the risk-free interest rate, β measures the systematic risk of the individual firm in relation to the market portfolio, and $[E(r_m) - r_f]$ the risk premium. The beta of the market portfolio¹¹, β_m , is equal to 1. The project beta, β_I , of a firm is according to Bøhren and Michalsen [11] defined as

$$\beta_I = \beta_E \cdot w_E + \beta_L \cdot w_L \quad (50)$$

where β_I is the weighted average of the equity beta and liability beta, and w_E, w_L are the weights of the equity and liability of total market value.

¹¹ $\beta_m = \frac{\sigma_m^2}{\sigma_m^2} = 1$ where σ_m^2 is the std.dev.

We have obtained the risk free interest rate as the 3 year government bond issued by the Norwegian government, collected from the Norwegian Central Bank¹². We do not know the identity of our companies. We are therefore unable to obtain an individual β for each firm. Because of the loss of information regarding the identity of our firms we assume that the average firm in our sample will have the same risk as the average firm on Oslo Stock Exchange. By definition, the average beta of a stock exchange is the beta of the market portfolio, equal to 1. According to the Norwegian Ministry of Finance the risk premium has been 6 percent in the period 1971-1997 [41].

According to the Norwegian Tax law the depreciation rate depends on the type of asset. We only have the aggregate total fixed assets so we are unable to separate the different depreciation groups. We have therefore chosen to make a weighed average of the depreciation rate. According to the law, there are ten different groups of assets, of whom five being the most relevant for a manufacturing firm. The rates vary from 2 percent to 30 percent. We have divided the five into two groups. The first is office appliances and commercial property, the second is trucks, trailers, machines, tools, buildings and constructions. The average of the first groups is 16 percent and the average of the second is 14.67 percent. Suppose that a manufacturing firm has 20 percent of its assets from the first groups and 80 percent of its assets from the second group. The weighted average depreciation rate then become 14.9 percent.

Due to lack of data there is a problem with our rental rate of capital. Since we do not have the individual β_I and since we do not have the individual depreciation rates the rental rate of capital will be the same for all firms. As a consequence, when running the regression analysis the treatment of a constant variable will lead to exclusion from the regression. As a results, we will not be able to include the rental rate of capital in our estimation. Alternatively we could have used the total assets in the firm, K , and multiplied by the rental rate of capital in order to produce a proxy. However, we would then include a variable which could endogenous in the long run, (K) , so our estimates could be distorted. In addition, we would have inconsistency in the treatment of our wage and capital cost, since our wage is per unit while the capital cost would be the product of the price per unit and the total amount of capital. In conclusion, we do not use the potential proxy. In addition, we have not been able to obtain data on quantum produced and the capital share. As a results, capital cost, quantum and capital share are excluded

¹²See Appendix D for source

from our regression. Our equation in its final form will be the following.

$$\begin{aligned} [\ln S_{it'} - \ln S_{it}]/d &= \beta_1 + \beta_2 \cdot \ln A_{it} \\ &+ \beta_3 \cdot \ln w_{it} + \beta_4 \ln Age_{it} + \beta_5 \cdot \ln S_{it} + \epsilon_{it} \end{aligned} \tag{51}$$

Table 1: Summary Statistics

Variable	Obs. ^a	Mean	Std. Dev.	Min	Max
Employees	26478	31.01	110.98	1	3534
Productivity	26478	0.72	3.37	-5.75	380.65
Wage	26478	0.33	2.20	0	254.74
Age	26478	15.98	12.13	1	166

^a All variable are average of their 2000 to 2008 observations.

5.4 Descriptive statistics

We will in this section describe the numerical properties of our data¹³ We start with the summary statistics of our variables as well as a description of how key variables have developed over time. The summary statistics is presented in Table 1. In order to make the data more presentable the respective accounting variables are given in million NOK (MNOK). In addition, we have used the PPI for Norway, collected from OECD ¹⁴, to deflate revenue and material costs. Furthermore, we have used the hourly wage index for manufacturing in Norway, collected from OECD.

The summary statistics are collected from the balanced dataset used to calculate worker growth, variability in worker growth and the stylized facts. All the variables have 9 annual observations per firm. We see that the mean number of employees per firm is 31.01, with the smallest firm at 1 and the highest at 3 354 employees. For productivity the mean value-added is 0.72, which is interpreted as the mean firm generates 720 000 per employee after material cost is subtracted from revenue. This means that there is 720 000 per employee left to be split between the employees and the owners. The minimum value of productivity is -5.75. This indicate that the firm has larger material cost than revenue. The mean wage for the period is 330 000. The mean firm in our sample is 15.98 years old and the oldest firm in the sample is 166 years old.

¹³For the logarithmic values, see Appendix C.

¹⁴See Appendix C for the respective indices's

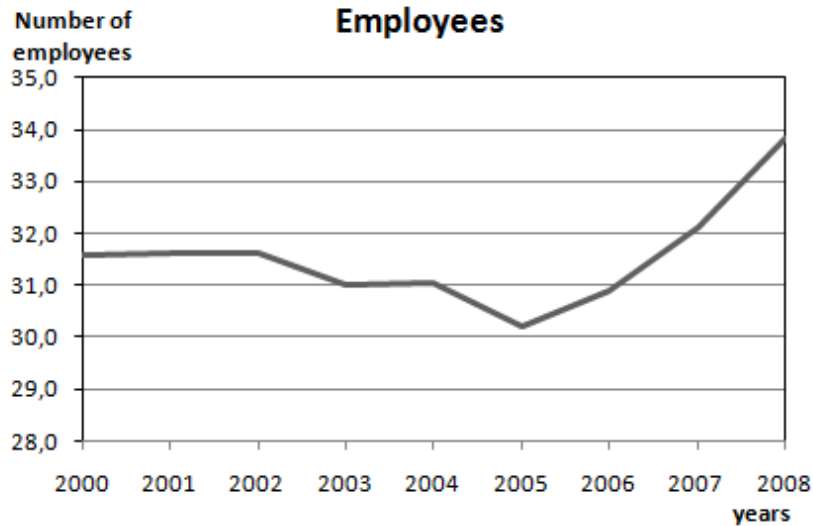


Figure 1: Employment *Notes*. The figure shows the the mean employment per year.

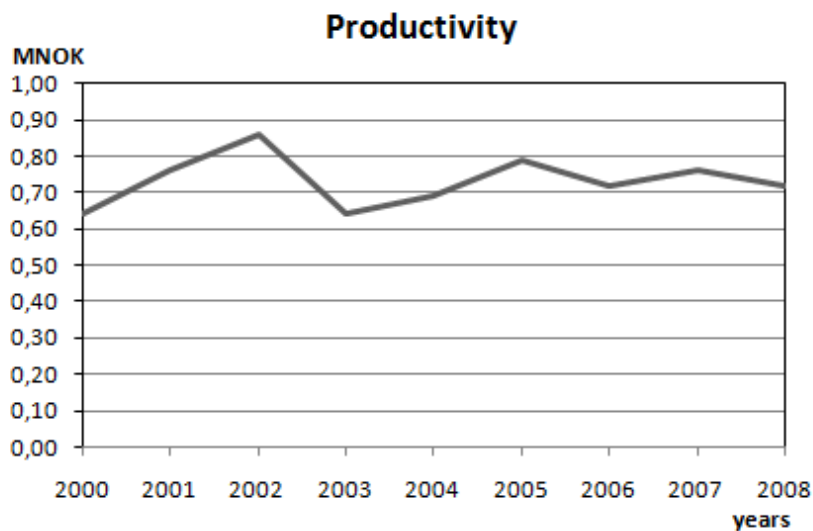


Figure 2: Productivity *Notes*. The figure shows the annual mean value-added per employe.

We will only describe the movement of our variables, and not discuss the underlying reasons for the observed movement. We choose to do this because there are many possible explanations and any proposed suggestions would at best be a result of an educated guess. Figure 1 display the annual number of employees for the mean firm. As the graph displays, the number of employees is stable from 2000 to 2002 and it decreases until 2005 where it turned and increased for the rest of the period.

Figure 2 show how our productivity measure has developed over time. The produc-

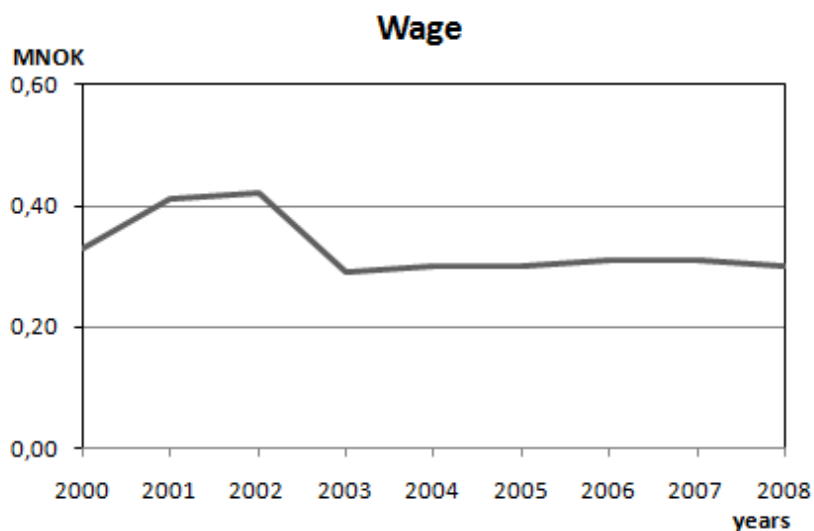


Figure 3: Wage. *Notes.* The figure shows the mean value for the average wage per employee.

tivity measure is value added per employee. From the graph we see that it varies between 0.60 and 0.90 meaning that it varies between 600 000 to 900 000 NOK in value added per employee for the mean firm in our sample. Productivity peaked in 2002 and has been relatively stable in the interval 0.7 – 0.8 from 2004 to 2008. Figure 3 show the average wage per employee. Average wage increases up until 2002 before it decreases in 2003. From 2003 to 2008 the wage is fairly stable at approximately 300 000 NOK.

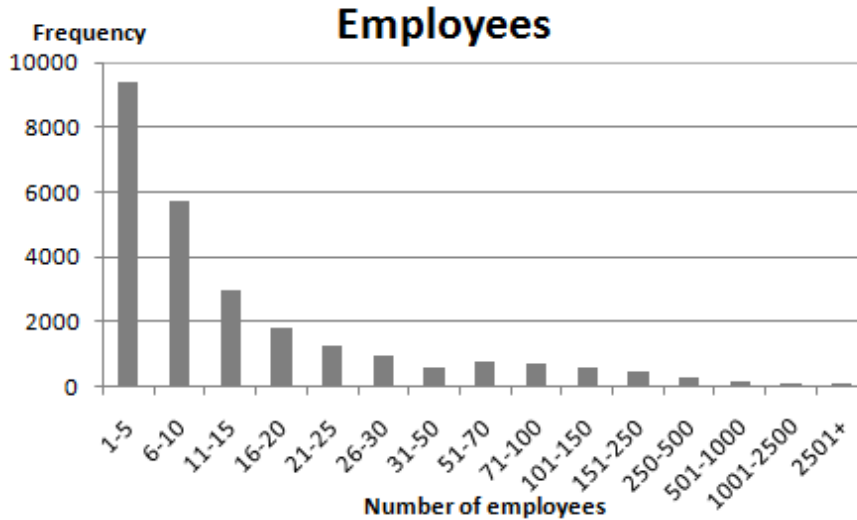


Figure 4: Employees per firm. *Notes.* The figure shows the frequency of annual firm observations in the particular intervals of number of employees.

5.5 Stylized facts

In this section we will show how well our data match some stylized facts found in the literature. We begin by looking at the distribution of size, the dispersion in productivity levels and the relationship between wage and productivity. We then estimate the relationship between probability of survival and size and age. Finally we estimate the relationship between variability in firm growth rates and size and age. These results are meant as suggestive evidence to how our data relates to other studies of firm dynamics. A reasonably good match could indicate that our results can be used to draw inferences about other populations.

5.5.1 Size distribution

We investigate the size distribution of the firms in our data, defined as number of employees. Figure 4 is a bar-chart of the size distribution. The chart has size on the x-axis and the frequency of annual firm observations on the y-axis. The bar chart displays that the highest proportion of observations has 1 to 5 employees. The frequency decreases as we move to the right in the chart, so our data contains more small than large firms. As expected, this chart suggests that the size distribution of firms is highly skewed, here towards smaller firms. This is in line with the stylized fact postulated in our literature review.

5.5.2 Dispersion in productivity levels

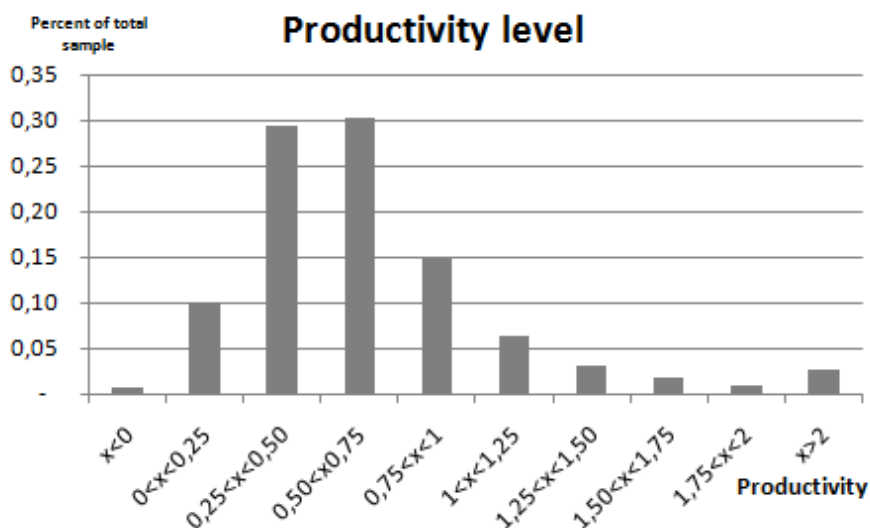


Figure 5: Productivity level. *Notes.* The figure show the percentage of firm of the total sample which lies in a particular productivity level interval. The y-axis is the percent of companies of the total sample. The x-axis is the productivity level intervals

The bar chart of the productivity dispersion is illustrated in Figure 5. The chart has intervals of value added per worker on the x-axis and percentage of firms from the total sample on the y-axis. We see that approximately 30 percent of our firms lie in the productivity interval 0.25 – 0.50. Meaning that 30 percent of our companies have a value-added which lie between 250 000 and 500 000. We also see that approximately 85 percent of our firms lie in the productivity interval 0 – 1. Furthermore, the bar chart shows that there is some dispersion in productivity levels. This is in line with the stylized facts in our literature review.

5.5.3 Productivity and wage

The scatter plot of the relationship between productivity and wage is shown in Figure 6. We use the mean of each firm's productivity on the x axis and mean wage on the y-axis to illustrate the relationship. We interpret the scatter plot as displaying a positive relationship between productivity and wage. As the mean productivity for a firm increases, the wage seems to increase. The plot does not show this relationship accurately because some firms have a low mean productivity and pay high wages, but the overall trend from the graphical illustration suggest a positive relationship. This is also supported by stylized facts found by Oi et all. [54]

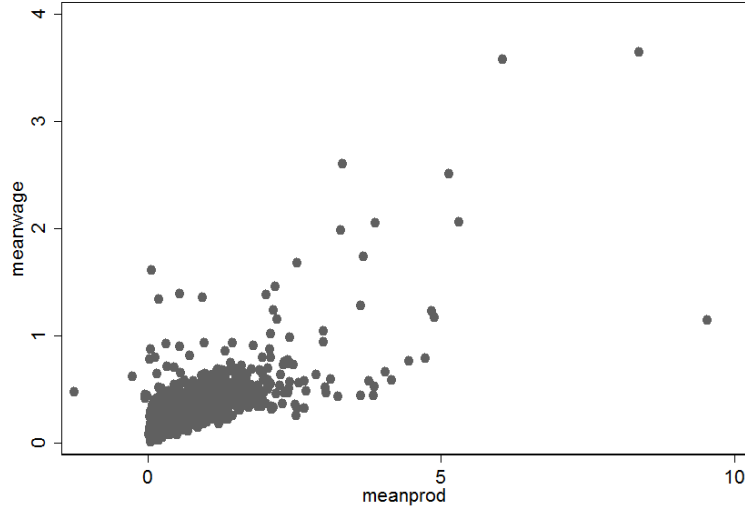


Figure 6: The relationship between mean wage and mean productivity *Notes*. The figure shows a scatter plot of mean wage on the y-axis and mean productivity on the x-axis.

5.5.4 Survival

Jovanovic's [42] theory of firm growth states that as time progresses, the firm will uncover their true efficiency level. Based on this efficiency level, they are able to evaluate the prospect value of remaining in business. If this value is negative, the firm will chose to go bankrupt or be dissolved. As part of our investigation of the stylized facts, we want to see how the probability of survival is affect by the firm age and size. The probability of survival-variable is based on whether the firm is present in the beginning period and in the ending period. If the firm survives (present all years) we code the survival-variable with $I = 1$ and if the firm is only present in the beginning and not in the end (dissolved) we code with $I = 0$. According to Evans [28] the regression can be represented by the following equation.

$$E[I|A_{it}, S_{it}] = Pr[e_{it} > -V(A_{it}, S_{it})] = \Phi[V(A_{it}, S_{it})] \quad (52)$$

"where V can be thought of as the value of remaining in business, e_t is a normally distributed disturbance with unit variance and Φ is the cumulative normal distribution function with unit variance" ([28], p. 573). We take a first-order logarithmic expansion of the growth function and estimated our equation using probit regression. According to Cameron and Trivedi [16], there is little difference between a logit and a probit model when the focus is on the marginal effects at the mean of the sample. According to Amemiya [3] Equation (52) estimated with a maximum likelihood estimator will be consistent. In addition we adjust the error terms according to White [64].

Table 2: Firm Survival and Variability of Growth

Dependent variable	Survival	Variability of Growth
Size	0.1577* [0.0107]	0.7697* [0.0130]
Age	0.0486** [0.0158]	-0.1528* [0.0192]
Constant	-0.3470* [0.0647]	-1.2477* [0.0517]
Observations	8057	2942

*Significant at the 1 percent level. **Significant at the 5 percent level

The results of the estimation are presented in Table 2. We have used a probit model which is non-linear. We therefore need to calculate the marginal effects at the mean. These results are presented in Table 3. From Table 2 we see that the probability of survival increases with size and age. Table 3 show that at the sample mean, a 1 percent increase in size leads to 0.0627 percent increase of the probability of survival. A 1 percent increase in age leads to a 0.0193 percent increase of the probability of survival. These results are in line with the empirical results from Evans [28] and are consistent with the predictions by the learning model of Jovanovic [42]. Hence, they satisfy the stylized facts summarized in our literature review.

5.5.5 Variability in growth

Lastly we want to estimate the variability of firm growth as a function of age and size. We first calculate the growth rates from 2000-2002, 2002-2004, 2004-2006 and 2006-2008. We then calculate the standard deviation of these four growth rates. A large number of observations should be able to *"predict reasonably precise estimates"*, even though the variability of the individual firms growth is imprecise ([28], p. 571) Variability of growth may be defined as [61]

$$\ln StdDev(F) = \ln h(A_{it}, S_{it}) + w_{it} \quad (53)$$

where $StdDev(F)$ is the estimate of the standard deviation of firm growth described by Equation (43), h is a regression function approximated by a first-order logarithmic

Table 3: The Effect of Firm Size and Age on Firm Dynamics

Partial Derivative of with Respect to ^a	Survival	Variability
Size		
Mean	0.0627	0.7697
Standard Deviation	0.0042	0.0129
Age		
Mean	0.0193	-0.1527
Standard Deviation	0.0063	0.0192

^aPartial derivative of the regression function on the horizontal with respect to the logarithmic value of the variable on the vertical.

expansion and w is the error term. We use maximum likelihood and white adjusted error terms. The results from the estimation are presented in Table 2.

The results from estimation should be viewed with caution. The dependent variable is based on four growth observations and may be imprecise. The results shows that the variability of growth increases with size and decreases with age. At the sample mean, a 1 percent increase in size leads to 0.77 percent increase in the standard deviation of firm growth. A 1 percent increase in age leads to a 0.1527 percent decrease in the standard deviation of firm growth. The second result is in line with earlier studies by Evans [28] and Sutton [61].

5.6 Results

This section outlines the statistical tests and estimations. We will, as discussed in Section 5.1, estimate the relationship between worker reallocation and productivity using the following equation

$$\begin{aligned}
 [\ln S_{it'} - \ln S_{it}]/d &= \beta_1 + \beta_2 \cdot \ln A_{it} \\
 &+ \beta_3 \cdot \ln w_{it} + \beta_4 \ln Age_{it} + \beta_5 \cdot \ln S_{it} + \epsilon_{it}
 \end{aligned}
 \tag{54}$$

This regression equation is estimated using the balanced panel dataset and ordinary least square (OLS) as estimator. The problem of autocorrelation is not present in our data since we only use data from the base year, 2000, as explanatory variables. Heteroskedasticity can be caused by omitted variables, incorrect functional form or skewness in the

distribution of regressors [33]. We decide to check for heteroskedasticity by running the Breusch-Pagan-Godfrey (BPG) test [13] [32].

The BPG tests the null hypothesis of homoskedasticity. It is a Chi-Square test based on an auxiliary regression. This implies that the null hypothesis is rejected if the chi-square exceeds the critical chi-square at the given level of significance. This translates into the decision rule; reject the null hypothesis if the p-value of the test is below the significance level. We reject the null hypothesis of homoskedasticity ($P < 0.05$) and conclude that we have a problem of heteroskedasticity.

Notice that in presence of heteroskedasticity the OLS estimators are still linear and unbiased as well as consistent, but they are no longer efficient (i.e. minimum variance) [33]. As a consequence the OLS estimators is not the best linear unbiased estimator (BLUE). The problem of heteroskedasticity is a serious potential problem and one cannot rely on the conventionally computed confidence intervals and the t-test, f-test and chi-square test may not be valid. Hence it should not be used for conclusions or inferences because they might be misleading [33].

There may also be multicollinearity in our estimation. The presence of high multicollinearity give large variance and covariance, making precise estimation difficult. Furthermore, multicollinearity increases the probability of accepting the null hypothesis. It has, however, no effect on the properties of the estimator.

We used a multicollinearity indicator, the VIF test¹⁵, to see if we have a problem of multicollinearity. The VIF test is a measure of collinearity. The larger the VIF value, the more collinear are the variable. A rule of thumb is a VIF value exceeding 10 indicate high collinearity [33]. All of our VIF values are less than 2.32, hence multicollinearity does not seem to be a severe problem in our data.

In addition, we run the Ramsey's regression specification error test (RESET). The Ramsey test is a general test of specification error [33]. The RESET tests the null hypothesis that the model has no specification error, i.e has no omitted variables. The test statistic reject the null hypothesis, no mis-specifications ($P < 0.01$). Hence our model has, according to the RESET, omitted variables. The theoretical models in Section 5.1 suggest an econometric model adding rental rate of capital, capital share and output to the estimated equation. This could yield more precise estimates. Due to lack of data we are

¹⁵See Table 9 in Appendix C

Table 4: Regression results

Variable	(1)	(2)	(3)
Productivity	0.0454* [0.0034]	0.0226* [0.0048]	0.0238* [0.0017]
Wage		0.0361* [0.0087]	0.0367* [0.0030]
Age		-0.0119* [0.0020]	-0.0111* [0.0006]
Size		-0.0149* [0.0015]	-0.0158* [0.0005]
Cons.	0.0363 [0.030]	0.1277 [0.0104]	0.1380 [0.0046]
Industry dummies			Yes
Adjusted R^2	0.1401	0.2165	0.2373

Dependent variable: Annual change in workers, in logs. (1) OLS, (2) OLS (3) Fixed effects. All standard errors are White-adjusted. *Significant at the 1 percent level. **Significant at the 5 percent level

unable to compute this extension of our econometric equation.

Since we have heteroskedasticity in our model, we decided to apply an econometric method to cope with the violations of the OLS assumptions. We apply the White's Heteroskedasticity-Consistent Variance and Standard errors method [64]. This adjustment is appropriate since we have a large sample. The standard errors estimated using White are referred to as robust standard errors, or White-adjusted standard errors. The robust standard errors will according to White be larger than the initial OLS in the presence of heteroskedasticity. The estimated results with robust standard errors are presented in column (1) and (2) in Table 4. Column (1) presents the OLS estimation of a simple regression estimation of our equation. Given by

$$[\ln S_{it'} - \ln S_{it}]/d = \beta_1 + \beta_2 \cdot \ln A_{it} + \epsilon_{it} \quad (55)$$

The productivity coefficient has a positive sign and is significant at the 1 percent level. A 1 percent increase in beginning period productivity leads, on average, to a 0.045 percent change in average annual worker growth. The total variance explained by this equation

is 14 percent.

Column (2) presents the full regression equation, given by Equation (51), estimated using OLS. The productivity and wage coefficients have positive signs and are significant at the 1 percent level. The age and size coefficients have negative signs and are significant at the 1 percent level. A 1 percent increase in beginning period productivity leads, on average, to a 0.0226 percent increase in average annual worker growth. A 1 percent increase in wage leads, on average to 0.0361 percent increase in average annual worker growth. A 1 percent increase in age leads, on average, to a 0.0119 percent reduction in average annual worker growth. A 1 percent increase in size leads, on average, to a 0.0149 percent reduction in average annual worker growth. The total variance explained by the full regression equation is 21.65 percent.

So far we have used the pooled OLS and corrected for problems in our residual. This approach assume that the intercept and slope coefficients are constant across firms. This assumption may distort the true relationship between the dependent and the independent variables [33].

To capture the individual characteristics of each industry we choose to include dummy variables for the industry code, a differential intercept dummy. The inclusion of industry dummies allows each cross sectional unit to have different intercept. We chose to include these dummy variables and adopt a fixed effect regression model to correct for fixed individual differences. We run the least square dummy variable (LSDV) model with robust standard errors. The results are presented in column (3) Table 4. The productivity and wage coefficients have positive signs and are significant at the 1 percent level. The age and size coefficients have negative signs and are significant at the 1 percent level. A 1 percent increase in the respective variable has the same interpretation as above. The total variance explained by the full regression equation is 23.73 percent.

The main difference between column (2) and (3) are the size of the standard errors and the coefficients. Further we see the adjusted R^2 increases as we move from column (1) to column (3).

5.6.1 Discussion

Since the general conclusions regarding the different effects are the same in the LSDV model and the extended linear regression, we focus only on the simple and extended regression equations. Our results indicate that more productive firms, in the beginning

period, have a higher average annual worker growth rate, suggesting that more productive firms, on average, hire worker at a higher rate. In other words, they attract more workers. We see from column (1) that there is a positive relationship between worker growth and productivity in our data. When including wage, size and age, in column (2), the productivity coefficient falls from 0.0454 to 0.0226. According to the search theory-model by Garibaldi and Moen [31], more productive firms offer a higher wage and thereby fill their vacancies faster. Search theory assumes that the wage is an endogenous variable for the firm. The reason for the reduction in the productivity coefficient might be that productivity affects average annual worker growth through wage, as suggested by Garibaldi and Moen. The positive wage coefficient indicate that firms with higher wages have, on average, higher average annual worker growth rates.

Our investigation of the stylized facts offered suggestive evidence for a possibly positive relationship between mean wage and mean productivity. The evidence is not estimated but based on a graphical representation. Another set of interpretations can according to Baily et. all [6] be that wages are related to labor quality. A firm may hire more skilled workers and pay them a higher wage which would lead to higher productivity. Furthermore, there can be rent sharing, meaning that those who increased productivity negotiated an agreement on rent of the productivity increase to the workers. Lastly, an increase in wage may have lead to capital/labor substitution such that there are fewer, but higher paid workers, and more capital in production instead. This finding is in line with Baily et. all [6] and Hulten et. all [7]. Our finding give empirical support for the model of competitive search by Moen [50], which postulates that a more productive firm will pay a higher wage such that they fill their positions faster and increase profit. So productivity may work through wage on the average annual worker growth.

The positive wage coefficient is not in line with cost minimization. In a Cobb-Douglas production function where both inputs are normal goods there exists a substitution effect¹⁶ and a scale effect¹⁷. An increase in wage causes the firm to re-optimize as the wage becomes higher, assuming that cost of capital is held fixed. An increase will cause a negative scale effect since the firm will reduce production, resulting in less demand for both inputs. Given this new output, the firm rearranges its input bundle. The firm substitute away from labor towards capital, because capital is now relatively cheaper [12].

¹⁶ "The substitution effect indicates what happens to the firm's employment as the price of inputs change, holding output constant." ([12] p. 123

¹⁷ "The scale effect indicates what happens to the demand for the firm's inputs as the firm expands production." ([12] p. 123

As discussed in Section 5.1 general equilibrium, Cournot, Hotelling and the Burdett and Mortensen model suggest that there is a link between productivity and number of employees in a firm. Furthermore, the three first models offers a trade off between quantum effect and utilization effect, where the sign of the effect is determined by the parameters of the economy. The Burdett and Mortensen model suggest a positive link. Our illustrative example, measured by the econometric model, suggest that over time, the firm with the highest average annual worker growth rate become the largest firm ($time \rightarrow \infty$). However, our time period is 9 years. 9 years may be a too short time period to allow for a small fast growing firm to catch up with a large slow growing one. Therefore, our results does not necessarily imply that the more productive firm are the largest ones. However, they indicate that a firm which is more productive will, on average, attract a higher average annual number of worker.

Next we look at size. The interpretation of our results is that as size increases the average annual worker growth rate decreases. This result indicate that Gibrat's Law fail, growth is not independent of size. Mansfield [48] finds that Gibrat's Law is reject for small firms. The author suggest the exit of slow growing firms as the reason. Hymer and Pashigian [40], Hall [34], Kumar [43] and Evans [28] reject Gibrat's Law for small firms while accept or weakly reject for large firms. One explanation for our findings could be that we have a sample dominated by small firms.

Lastly, as age increases the average annual worker growth rate decreases. This is also found by Evans [28]. We have included age and size since empirical findings suggest that there is a link between these variables and our worker growth measure. Our initial theory does not suggest any theoretical relationship between size, age and worker growth. However, not including these two variables might lead to omission bias.

5.6.2 Availability of data and properties of the model

From the definitions in Section 2, Equation (6) states that worker flow is a function of job reallocations and churning. We have used number of employees in each firm in first and last period and calculated an average annual worker growth rate. This number does not fully capture the entire picture of worker flows. Equation (4) states that worker flows is the sum of hires and departures. Our measure only show the end result, namely $S_{t'} = S_t + H_t - D_t$. To measure work flows precisely we would ideally have data on the churning component. Churning is a function of hires and departures, and we do not have data on these. Better data would give a better insight on how the workers move, and give us more precise estimates of the reallocation.

Our model of estimation builds on models developed by Evans [28] , Baily et al [7] and microeconomic theories. Even if our model is correctly specified, and all available variables are measured correctly, we do not have data available on all suggested variables. As a direct consequence the model may have a problem with specification bias. We do not have data available on rental rate of capital, capital share or physical output so these variables are not included in our model. This implies that we run the risk of having an error term which look like this $\epsilon'_{it} = \epsilon_{it} + \beta_6 \cdot \ln r_{it} + \beta_7 \cdot \ln \alpha + \beta_8 \cdot \ln q_{it}$ where r_{it} is cost of capital, α is capital share and q_{it} is physical output. If the omitted variables are correlated with one of the explanatory variables there will be nonzero correlation with the error term and the respective explanatory variables.

Specification bias can lead to biased and inconsistent coefficients. The effect of omission is that the usual confidence interval and hypothesis testing will give misleading conclusions about statistical significance [33]. When we run the Ramsey RESET we reject the null hypothesis of no omitted variables this imply that our coefficients may be biased. The lack of precise data is one of the largest shortcomings in this paper. Another shortcoming is we do not know the true functional form of our model. We run a multiple regression, which makes it impossible to create a scatter plot and decide based on the pattern observed [33]. Wrong structural form may give specification bias. We check for this by testing a different structural form in the robustness section later.

5.6.3 Measurement error

According to Pakes and Ericson [55] omitting firms that fail during the period will tend to omit one tail of the distribution. If exit decision is independent of the productivity level observed by the firm, then omitting the firms which leave during the period could lead to an imprecise but not inconsistent description. However, exit decision will, according to Jovanovic [42], be based on whether the firm is able to successfully compete in the market. Consider a market with three identical firms (A, B, C) in the first period. If there is a productivity shock to the industry, which leads to only firm A and B experiencing positive productivity change, firm C will become smaller or exit the industry completely. In the final period, firm C may not be present. Since we have deleted all those firms which are not present in the entire period, we do not capture this dynamic. The exit decision is therefore not likely to be independent of the productivity level. So we will tend to omit one tail of the distribution we study. Since exit and entry account for between 20 – 25% of job creation and destruction [22], the exclusion of these observations could have a profound effect on our results which may lead to inconsistent description. We

have not corrected for this problem in our estimation.

5.7 Robustness checks

To further address the validity of the results we run two alternative regressions. First, we use a different type of productivity measure. Second, we use a different structural form on the estimated equation.

5.7.1 Productivity measure

We perform a robustness test of our productivity measure using a new definition of productivity. According to Bartelsman and Dooms [10] the main choice a researcher make is whether to analyze labor productivity or TFP. Hence it is natural to see if our findings are robust using a TFP measure. If the results are the same it provides support for our findings. Namely, more productive firms have a larger average annual growth rate and hire more workers. Note, this does not necessarily mean that they are larger in number of employees.

Measures of TFP can be calculated by variety of methods. We will use a version of a general decomposition of a TFP index derived by Balk [9]. On its original form it allows for a computation of the contribution of technological change, changes in technology, effects of non marginal pricing and effects of non constant returns to scale [10]. The measure is the following

$$\ln A_{it} = \ln \left(\frac{R_{it}}{C_{it}} \right) = \ln R_{it} - \ln C_{it} \quad (56)$$

where R_{it} is revenue and C_{it} is total costs. Equation (56) states that the revenue over cost is a measure for productivity since it indicates how much output the firm get per input. Column (1) in Table 5 presents the OLS estimates of a simple regression estimation of our equation given by

$$[\ln S_{it'} - \ln S_{it}]/d = \beta_1 + \beta_2 \cdot \ln A_{it} + \epsilon_{it} \quad (57)$$

Based on our findings in Section 5.6 we test for heteroskedasticity. The BPG test rejects the null hypothesis of homoskedasticity ($P < 0.01$) The Ramsey test rejects the null hypothesis that the model has no omitted variables ($P < 0.01$). We correct for heteroskedasticity using white-adjusted error terms. The results are presented in Table 5.

Table 5: Robustness estimates

Variable	Productivity measure (1)	Structural form (2)
Productivity	0.0314* [0.0014]	0.0212* (0.0028)
Wage		0.0863* (0.0056)
Wage ²		0.0148* (0.0011)
Cons.	0.0134* [0.0007]	0.1023* 0.0050)
Adjusted R^2	0.0292	0.1938

Dependent variable: Annual change in workers, in logs. *Significant at the 1 percent level.

**Significant at the 5 percent level

Comparing column (1) in Table 5 and Table 4, we see that the labor productivity measure explains 14.01 percent while the TFP measure explains 2.9 percent of the variance in average annual worker growth. The signs of the coefficient in both table are the same and they are both significant at the 1 percent level. In conclusion, our productivity measure from Section 5.6 seems to be robust.

5.7.2 Structural form

We estimate an alternative model where the growth function $F(\cdot)$ is approximated by a second order logarithmic expansion. In order for our estimator (OLS) to be the best linear unbiased estimator an important factor is that the model is correctly specified, or in other words the model is the true functional form [33]. The hint for investigating this is our low $R^2 = 0.23$ as well as the conclusion from the Ramsey RESET¹⁸. We propose the following equation as an alternative to our main model

$$\begin{aligned}
 [\ln S_{it'} - \ln S_{it}]/d = & \alpha + \beta_1 \ln A_{it} + \beta_2 \ln w_{it} + \beta_3 \ln A_{it}^2 \\
 & + \beta_4 \ln w_{it}^2 + \beta_5 \ln A_{it} \cdot \ln w_{it} + \epsilon_{it}
 \end{aligned} \tag{58}$$

The Ramsey RESET finds that in this equation there is no omitted variables. Since we found heteroskedasticity and multicollinearity in our main estimates we test for these

¹⁸Our model may have omitted variables or wrong structural form

problems. The conclusion from the BPG test is that there is homoskedasticity and the variance-inflating factor (VIF) test suggests there is multicollinearity. We remove the variables $\ln A_{it} \cdot \ln w_{it}$ because of multicollinearity. In addition, we remove $\ln A_{it}^2$ since it is not significant. The resulting VIF-test ¹⁹ states that multicollinearity is no longer a problem and the Ramsey RESET still predict no missing variables.

The results are shown in column (2) in Table 5. We see that all variables are significant at the 1 percent level and the adjusted $R^2 = 0.1938$. These results are almost identical to the ones obtain with a first-order logarithmic expansion. The adjusted R^2 is smaller than for our initial model. These results support our findings.

6 Conclusion

The main objective of this paper is to investigate the relationship between productivity and worker flows. In addition, a brief investigation of selected stylized facts found in the literature is also conducted. We find that the data shows the same stylized facts regarding growth, productivity, size and bankruptcy risk as found in the literature.

We find that the size distribution of firms is highly skewed towards smaller firms. Productivity levels are quite dispersed, meaning that there is productivity differences between firms. We find suggestive evidence for a positive relationship between mean wage and mean productivity in our data. In addition, we find a positive relationship between both the probability of survival ($P < 0.05$) and variability of growth ($P < 0.01$) with size and age as explanatory variables.

Our main finding is that there is a positive relationship between productivity and average annual worker growth ($P < 0.01$). This suggest that more productive firms hire workers faster. However, this does not necessarily suggest that the most productive firm is also the largest firm. But, given enough time this might be the case as well. We also find that there is a positive relationship between wage ($P < 0.01$) and average annual worker growth. The wage-growth relationship is contrary to cost minimization, but in line with competitive search theory. Our results could therefore be seen as supportive evidence for the validity of competitive search models. Furthermore, we find a negative relationship between growth and age ($P < 0.01$). We also find a negative relationship between growth and size ($P < 0.01$), suggesting that Gibrat's Law fails.

¹⁹See Table 10 in Appendix C

The association we identify between productivity and average annual worker growth is robust. To deal with problems of measurement error we test our hypothesis using another measure for productivity, TFP. The use of TFP yields the same results, positive relationship between productivity and average annual worker growth ($P < 0.01$). In order to deal with problems of specification error we run a regression using a different structural form. The use of an alternative structural form yields the same results, positive relationship between productivity and average annual worker growth ($P < 0.01$).

In conclusion, we have found that there is a positive relationship between average annual worker growth and productivity in the Norwegian manufacturing industry suggesting that more productive firms attract workers faster than less productive firms. Given enough time, a fast growing small firm could eventually be larger than a slow growing large firm. Our findings are in line with the microeconomic theories.

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A Mathematical Appendix

A.1 Cournot Competition

The firms have two decisions. First the decision of how much output to produce, and then how to produce this output with the least amount of cost. We start with the output market decision first. The firms compete in quantity in each period. The firms have the following profit function [62]

$$\Pi^i = q_i \cdot (1 - q_i - q_j) - c_i \cdot q \quad (59)$$

where $c_i \cdot q = C(w, r, q)$, just to simplify notation at the moment. The first order condition for the optimization problem are:

$$\frac{\partial}{\partial q_i}(\Pi^i) - 2q_i + 1 - q_j - c_i = 0 \quad (60)$$

$$\frac{\partial}{\partial q_j}(\Pi^j) - 2q_j + 1 - q_i - c_j = 0 \quad (61)$$

By solving (60) and (61) for the respective quantities and substitution in to each other we obtain the following optimal quantities:

$$q_i = \frac{1 - 2c_i + c_j}{3} \quad (62)$$

$$q_j = \frac{1 - 2c_j + c_i}{3} \quad (63)$$

Equation (62) and (63) state that the optimal quantity is a function of the firms own production cost and the cost of the competition. The profit of the firms are given by the following

$$\Pi^1 = \frac{(1 - 2c_i + c_j)^2}{9} \quad (64)$$

The firms know what quantity to produce and need to decide how to produce this given amount of output for the least amount of resources. Suppose a long run cost minimization.

$$C(w, r, q) = \min_{K, L} r \cdot K + w \cdot L$$

$$\text{such that } A_i K^\alpha L^{1-\alpha} = q$$

Where $A_i > 0$ is a level specific production technology. Solving the optimization we obtain the optimal demand for K and L

$$K^* = q \cdot \frac{1}{A_i} \left(\frac{\alpha}{1-\alpha} \frac{w}{r} \right)^{1-\alpha} \quad (65)$$

$$L^* = q \cdot \frac{1}{A_i} \left(\frac{1-\alpha}{\alpha} \frac{r}{w} \right)^\alpha \quad (66)$$

The cost function is defined as:

$$C(w, r, q) = r \cdot K^* + w \cdot L^* \quad (67)$$

combining the optimal demands with the cost function, we obtain

$$C(w, r, q) = \frac{1}{A_i} \left[\left(\frac{\alpha}{1-\alpha} \right)^{1-\alpha} + \left(\frac{\alpha}{1-\alpha} \right)^{-\alpha} \right] r^\alpha w^{1-\alpha} \cdot q \quad (68)$$

$$C'(w, r, q) = \frac{1}{A_i} \left[\left(\frac{\alpha}{1-\alpha} \right)^{1-\alpha} + \left(\frac{\alpha}{1-\alpha} \right)^{-\alpha} \right] r^\alpha w^{1-\alpha} \quad (69)$$

By combining equation (62), (63) and the marginal cost, derived above, we get

$$q_i = \frac{1 + (A_j^{-1} - 2A_i^{-1}) \left[\left(\frac{\alpha}{1-\alpha} \right)^{1-\alpha} + \left(\frac{\alpha}{1-\alpha} \right)^{-\alpha} \right] r^\alpha w^{1-\alpha}}{3} \quad (70)$$

$$q_j = \frac{1 + (A_i^{-1} - 2A_j^{-1}) \left[\left(\frac{\alpha}{1-\alpha} \right)^{1-\alpha} + \left(\frac{\alpha}{1-\alpha} \right)^{-\alpha} \right] r^\alpha w^{1-\alpha}}{3} \quad (71)$$

Which means that q_i is a function of A_i, A_j, α, r, w . We now see that the demand for input K and L is a function of q, A_i, α, r, w , such that we can write the demand for inputs as:

$$K = F(q(A_i, A_j), A_i, \alpha, r, w) \quad (72)$$

$$L = F(q(A_i, A_j), A_i, \alpha, r, w) \quad (73)$$

B Model Appendix

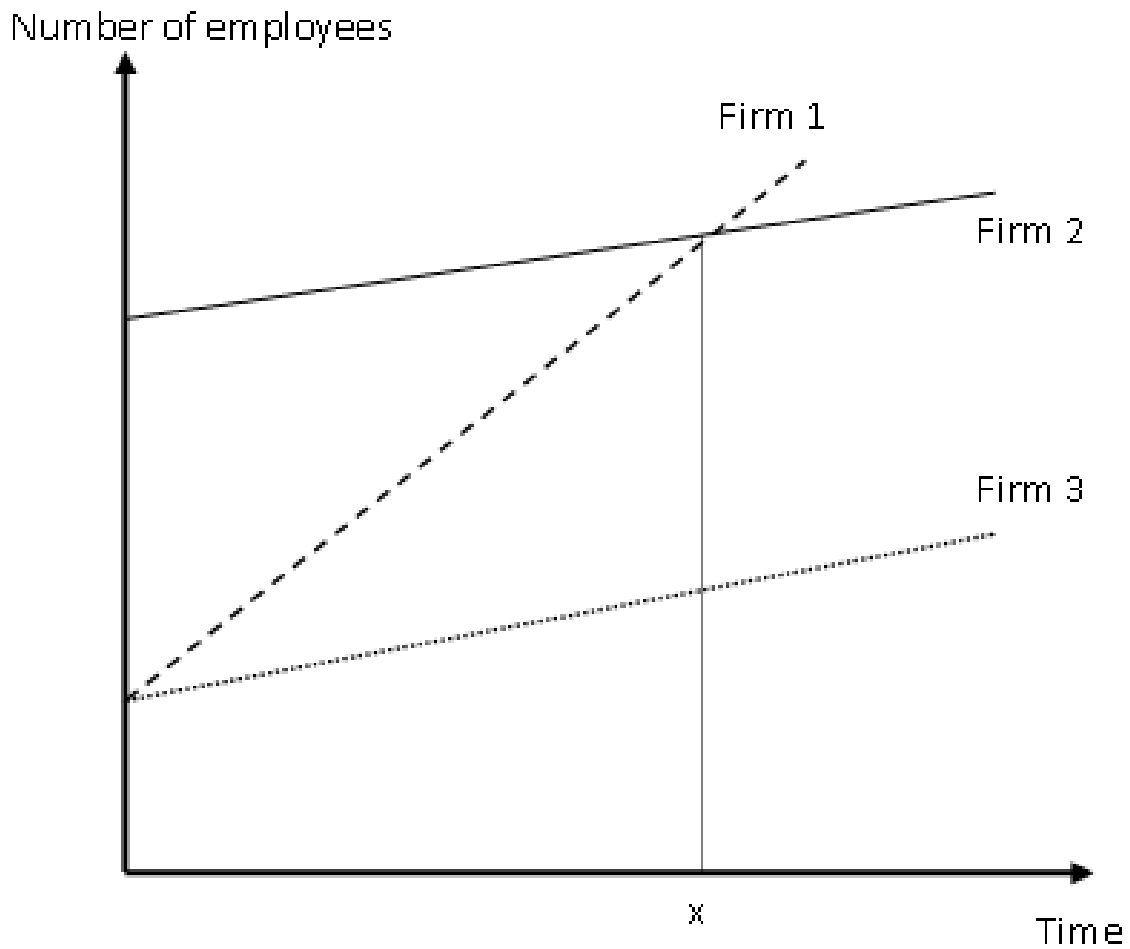


Figure 7: Employment and growth rate. *Notes.* The model show the development in number of employees over time. Firm 1 and Firm 3 are identical but have different growth rates (slope coefficients), while Firm 2 is larger but have a smaller growth rate than Firm 1. X is some point in time where the small fast growing Firm 1 becomes equal to the large slow growing firm 2.

C Tables Appendix

Table 6: Summary Statistics of Logarithmic Variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Survival:					
Survival	8057	0.53	0.50	0	1
Log[Size]	8057	28.62	154.18	1	9094
Log[Age]	8057	13.62	13.94	1	158
Growth/var./reall.:					
Growth	2942	0.003	0.10	-0.52	0.83
Log[Std. of Gro.]	2942	0.21	1.25	-1.39	5.60
Log[Size]	2942	2.32	1.29	0	8.17
Log[Age]	2942	2.14	0	0	5.06
Log[Prod]	2942	-0.75	0.78	-6.45	4.98
Log[wage]	2942	-1.34	0.59	-7.7	4.47

The table presents the logarithmic values used in the estimation

Table 7: Deflation indexes

Year	PPI	Manufacturing
2000	100	100
2001	101.9	104.7
2002	97.8	110.6
2003	99.2	115.4
2004	102.3	120.2
2005	105.8	124.8
2006	109.0	130.0
2007	113.8	138.2
2008	122.7	145.9

The table show the deflation indexes collected from the OECD. PPI is producer price index.

Table 8: Calculation of user price of capital (capital cost)

Year	3 year gov. bond	β -coeff.	Risk prem.	CAPM	Depr.	User price
2000	6.61	1	6	12.61	14.9	27.51
2001	6.44	1	6	12.44	14.9	27.34
2002	6.39	1	6	12.39	14.9	27.29
2003	4.24	1	6	10.24	14.9	25.14
2004	2.95	1	6	8.95	14.9	23.85
2005	2.90	1	6	8.9	14.9	23.8
2006	3.74	1	6	9.74	14.9	24.64
2007	4.79	1	6	10.79	14.9	25.69
2008	4.53	1	6	10.53	14.9	25.43

Table 9: Variance-inflating factor (VIF) test from the initial estimation

Variable	VIF	1/VIF
ln_size	1.10	0.9110
ln_prod	2.32	0.4305
ln_wage	2.30	0.4351
ln_age	1.07	0.9381
Mean VIF	1.70	

The table show the VIF values of our independent variables.

Table 10: Variance-inflating factor (VIF) test for alternative structural form

Variable	VIF	1/VIF
ln_wage	5.46	0.1833
ln_wage2	3.63	0.2758
ln_prod	2.22	0.4511
Mean VIF	3.77	

The table show the VIF values of our independent variables.

Table 11: Regression results from the fixed effects model

Variable	Coefficients	Robust Std. Error	t-statistic	Prob.
ln_prod	0.0238	0.0017	14.21	0.000
ln_wage	0.0367	0.0030	12.28	0.000
ln_age	-0.0111	0.0006	-17.10	0.000
ln_size	-0.0158	0.0005	-32.51	0.000
D2	-0.0130	0.0044	-2.95	0.003
D3	-0.0274	0.0073	-3.74	0.000
D4	0.0112	0.0029	3.84	0.000
D5	-0.0492	0.0057	-8.61	0.000
D6	-0.0274	0.0030	-9.21	0.000
D7	0.0183	0.0031	5.99	0.000
D8	-0.0206	0.0054	-3.85	0.000
D9	-0.0029	0.0032	-0.89	0.375
D10	0.0018	0.0033	0.55	0.582
D11	0.0198	0.0058	3.39	0.001
D12	-0.0074	0.0029	-2.53	0.011
D13	-0.0130	0.0030	-4.27	0.000
D14	-0.0285	0.0154	-1.85	0.065
D15	0.0015	0.0035	0.44	0.658
D16	0.0320	0.0078	4.09	0.000
D17	-0.0042	0.0038	-1.12	0.265
D18	-0.0138	0.0052	-2.67	0.008
D19	0.0009	0.0036	0.25	0.802
D20	-0.0144	0.0031	-4.61	0.000
D21	0.0056	0.0066	0.85	0.395
Constant	0.1379	0.0046	29.67	0.000

Dependent variable: Annual change in workers, in logs. D1 is the reference industry, NACE 17.

D Data Appendix

D.1 Source of government bond

Norges Bank:

Statsobligasjoner. Annual average of daily quotations. The basis is the 3 year.

http://www.norges-bank.no/templates/article____55495.aspx