Strike Models

Strike Activity and Cost Determination

BMI Paper

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Preface

A part of the Business Mathematics and Informatics program is to write a BMI paper, in which at least two of the three aspects of the program; Business, Mathematics and/or Informatics should be contained.

The topic of this BMI paper is strikes; recently there have been a lot of strikes in the Netherlands; bus drivers, police men, farmers, truck drivers and others have struck the past few years. These recent strikes made me curious about strikes and the mathematical models on strikes, this curiosity is the reason I chose the topic for my paper.

Summary

In this paper we study some quantitative aspects of strikes. To be able to study these quantitative aspects we first describe the concepts of strikes in general and related literature.

A strike is a group's refusal to work in protest against low pay or bad work conditions (dictionary.die.net). There have been a lot of strikes through history, in the Netherlands the first reported strikes were in the 14^{th} century. Strikes have been illegal in most (western) countries until the end of the 19^{th}/ beginning of the 20^{th} century.

In several papers models to give quantitative insights in strikes are discussed. In this paper models from Van der Velden (Velden, 2000), Skeels and McGrath (Skeels & McGrath, 1991), Leigh (Leigh, 1984), Buck (Buck, 1984) and Mauleon and Vannetelbosch (Mauleon & Vannetelbosch, 1998) are studied.

The first four models calculate strike activity and show the relations between certain variables and the strike activity. Many variables are used, including future variables, to form the models. The influence of these variables on the strike activity is calculated by regression analysis. From this analysis it seems that present variables perform better than future variables. Furthermore it seems that wage and unemployment are important variables in calculating the strike activity.

The last model, the Mauleon and Vannetelbosch model, uses concepts from game theory to determine the influence of profit-sharing on the strike activity. The introduction of a profit-sharing scheme increases the strike activity if the bargaining between the union and the employer takes place at industry level, but reduces the strike activity if the bargaining takes place at firm level.

Although there are some models on strikes, lots of research can still be done to give more quantitative insight in strikes. We are also interested in the actual costs of a strike. Since there is no literature available about these costs, we made a cost model that can be applied in the transportation industry. We applied this model to the case study Connexxion.

From this case study we can conclude that there are many costs involved in a strike. The savings in e.g. wages does not compare to the loss in profit during a strike.

Overall we conclude there is still an urgent need for more research on strikes. With more knowledge about the influence of certain variables to the strike activity, better decisions to prevent strikes and/or reduce costs can be made.

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1. Introduction

High school students could not get to school to do their final exams because the bus drivers were on strike; a big soccer game was cancelled, because the safety of the players and spectators could not be guaranteed, because of a strike by policemen; the supermarkets were running out of milk because the farmers were on strike; these are some examples of strikes in the Netherlands during the past few years. All those strikes raise questions about their impact.

1.1 Goal

There is a lot of literature available about the social aspects of strikes. Lots of strikes through history are described and strikes can be categorized in many different ways. Data about the number of strikes, number of workers involved, duration of strikes and the industry the strikes were in is available. Despite the massif amount of information there is about the social aspect of strikes, little can be found about quantitative research of strikes.

In this paper our aim is to give an overview of models that give quantitative insight in strikes, answering questions such as: Are there quantitative measures for strikes? With what frequency do strikes occur? What influences the strikes? What do strikes cost?

1.2 Literature

To be able to answer the questions presented above, we first describe the concept of strikes in general and related literature.

A strike is a group's refusal to work in protest against low pay or bad work conditions (dictionary.die.net). In the Netherlands the first reported strikes were in the 14th century (focusing at the modern society, with the contradictions between wage work and capital). Strikes became an issue during the industrial revolution (late 18th/beginning 19th century) because during this period mass labor became important. The industrial revolution also gave a big impulse to capitalism. While strikes became an issue, strikes were often made illegal because the employers power in politics was greater than the workers power in politics. However in the end of 19th/beginning of the 20th century most western countries made it legal, the laws about strikes were brought about by labor unions.

In 1811 the Netherlands had the French Code Penal, in this code was stated that strikers were punishable by law, workers who went on strike risked some months in jail and the leaders of the strike risked years in jail. In 1872 this code was abolished, which was good for unions and made it easier to strike. The first union in the Netherlands was the “Algemene Nederlandsche Typografenbond (ANTB)”, founded in 1866. With the introduction of unions a contradiction between the needs of the members of the unions and the needs of the unions raised to the surface. In 1869 for example, around 200 workers wanted to strike, but the ANTB did not want to support them. The union did not agree to the strike, and therefore the workers had no right to receive money from the union, usually unions give some percentage of the worker's salary to the workers when they are on strike, because otherwise it is not affordable to strike for many workers.

There have been a lot of big strikes through history, and as illustration we only mention a few important strikes, note that this is a small selection of all strikes in recent history. We first mention some important strikes in the history of the Netherlands: The textile strike in 1902, on its peak it has 45000 workers without a job, being on strike or being excluded[1]; The big railway strikes in 1903 and 1944, the strike of 1903 will be described later on in this section. We now mention some important strikes in other countries: In the United States in the 1880s a strike forced a work day to be eight hours; The May strike in 1968 in France, started with student strikes and was followed by a general strike in which roughly two-thirds of the French workforce participated. In 1980, in Poland, there was a strike in the Lenin-shipyard in Gdansk, which forced the government to allow strikes.

To give a better understanding on strikes we will describe two strikes in more detail. The first one is the railway strike of 1903.

The cause of the strike in 1903 was a conflict between two businesses in the harbor of Amsterdam. In one company, "Muller & Co", the workers were obliged to be members of a union, "Federatie van Handel en Nijverheid", while in the other company, "Blauwhoedenveem", the workers were not allowed by the company to be members of a union. The "Federatie van Handel en Nijverheid" did not allow members to work with unorganized workers. When some workers from Blauwhoedenveem had to trade with Muller and wanted to receive some load, the workers from Muller did not provide the load, which was what the union wanted. But the workers from Muller were fired because of this and the organization replaced them with unorganized workers. The rest of the workers of Muller did not want to work with the newly hired unorganized workers and got fired to. Soon strikes were called over the whole harbor. All workers from Blauwhoedenveem and Muller were blacked and the rest of the workers in the harbor did not want any goods to be transported to the two companies, at this stage some railway workers joined the strike. The outcome of this strike was that fired strikers where rehired, the wages of the strike days were paid and most important, unions were recognized. As compensation of the

[1] When employers intentionally abstain work from workers who are not on strike (during a strike), and also do not pay them their wages.

strike, the following bills were proposed: (1) strikes were made punishable by law for civil servants and workers in several sectors, including the railways, (2) a commission had to be formed to research the legal position of railway civil services and (3) a railway brigade had to be founded to keep order at the railways. These bills where called the “Worgwetten” (strangle laws). The “Commissie van Verweer” (commission of resistance) called a strike against the constraints of the Worgwetten. It became a general strike with employees from other businesses then harbor and railway, joining the strike. The strike ended the same day the government approved the Worgwetten. There was dissension within the union, which prevented the strike to be effective. Many workers lost their job because of the strike and the resulting approval of the Worgwetten.

The second strike we will describe in some more detail is strike in the United States which introduced the eight-hour work day. In Foner (Foner, 1986) the following phrase written by “McGuire of the Brotherhood of Carpenters and Joiners” in 1982 is cited: “The way to get [the eight-hour day] is by organization...We want an enactment by the workingmen themselves that on a given day, eight hours should constitute a day's work, and they ought to enforce it themselves." The Federation of Organized Trades and Labour Unions adopted this proposal, a eight-hour work day introduced at May 1st 1886. Companies did not agree with this proposition and as result over 300,000 workers went on strike on May 1st 1886 in the United States. In Chicago the strikes escalated, there were riots and fights between strikers and non-strikers, the police had to come in action and sadly, seven cops were killed. Leaders from the labor union in Chicago were accused of murder and were sentenced to dead. However the strike leaded to the introduction of the eight-hour work day. May Day also know as Labour Day, is now a holiday in most industrialized countries, exceptions are Canada, the Netherlands, South Africa and the United States.

Observing the important role of strikes in the previous two examples we are now ready to describe the different types of strikes. In the book “Stakingen in Nederland” (Strikes in the Netherlands) (Velden, 2000), four types of strikes are described; the classical strike, the selective strike, the relay strike and the work stoppage (protest strike). In a classical strike workers stop working for an unknown time period, until the demands are met. With selective strikes workers will lay down their work in certain parts of the business or industry. The aim is to get results for the entire company or industry. When workers strike at different places, it is called a relay strike. With work stoppages, workers lay down their work a short period of time to give a signal that action is on the way. Another way of grouping strikes, described in “Stakingen in Nederland” is by the demands, the demands can be classified in the following groups: (1) work condition strikes, which are about wage, working hours, company policy, (2) personal strikes, focus at specific persons and to support punished or fired coworkers, (3) union strikes, to get the right to be organized, (4) sympathy strikes, to support workers from other companies and (5) political strikes, which are aimed to terms of employment applied by the government and politics.

In other literature (mt.gov), (answers.com) other common categories of strikes are mentioned and the definition is sometimes different. For example, a union strike is denoted by a strike for which the strikers are members of a union; wildcat strikes, are strikes without formal union authorization; and sit-down strikes, is when workers occupy the workplace, but do not do their job and do not leave. Work-to-rule (Italian strike) is when the workers do their job as required but no better. Workers maximize their output in a Japanese strike, which can upset the planning. Green Ban strikes are for environmentalist or conservationist purposes. If in a particular community or region all workers, or large groups of workers strike, it is called a general strike. Other forms of protest are: a go slow, where workers do their job, but in a slow paste; and a work-in and a sit-in is where workers keep working and occupy work, so management cannot access the production process.

As seen in the previous sections, the categories can vary in different countries. Another example of this is the following: In The United States, The National Labor Relations Board (NLRB) provides legal protections for two kinds of strikes, economic strikes and unfair labor practices strikes. Note further that in some references (Ulster Business School), (infoshop) removal of overtime is considered as another form of protest while others say this is a part of the work-to-rule strike.

There is a lot of information available about strikes. Many different strikes through history are described in detail (wikipedia), (CBS). There is plenty of data available about how many workers participated in strikes and how many days where lost. Even a first categorization of strikes was done, as we saw in literature. However little quantitative research on strikes is done. Specific data on the costs of strikes is not known in literature as far as we could find. There are some models available calculating the strike activity, which we describe in the remainder of the paper, however no models are available for the strike costs. In this paper we are going to make a first attempt to model the costs of strikes.

1.3 Outline of the paper

In the second section of this paper we will discuss models on strike activity and a model on the influence of profit-sharing on the strike activity. In the third section the models on strike activity will be compared. In the fourth section we will propose a model for the costs of strikes in the transportation industry and we do a case study, applying the cost model to Connexxion, a Dutch bus company.

2. Models

In this section we discuss several papers on quantitative models of strikes (Velden, 2000), (Skeels & McGrath, 1991), (Leigh, 1984), (Buck, 1984), (Mauleon & Vannetelbosch, 1998). In the first four papers models are presented to calculate the strike activity and to show the influence of certain variables to the strike activity. To test the models regression analysis are used, a regression analyze can be used as statistical forecasting model and for the modeling and analysis of numerical data. A regression analysis is used to describe and evaluate the relationship between a given variable, usually called the dependant variable, and one or more other variables, which are usually called the independent variables. The last article, from Mauleon and Vannetelbosch, uses concepts from game theory to determine the influence of profit-sharing on strike activity.

2.1 Van der Velden Models

In this section models are discussed that analyze the effects of certain variables on the strike index, the strike index shows the development of strike activity, it shows if the strike activity has increased, decreased or has stayed the same through the years.

2.1.1 Strike activity

Van der Velden uses data from the CBS (Centraal Bureau voor Statistiek) which publishes every year information about the number of strikes, the number of workers involved in the strikes and the number of lost working days. They provide only data on strikes in the Netherlands. The number of strikes is denoted by N, the number of workers involved in the strike is called the intensity S and the number of lost working days is called the duration of the strikes D.

When talking about the number of strikes one can question which strikes to count, for example counting strikes with a minimal number of workers involved. However, then, should a strike involving 10.000 workers be compared with a strike involving two workers? The number of strikes is used to point out how the strike activity was spread through a year and to see differences between years. Two years are considered to be different if in one year there were five strikes involving 2000 workers and in the other year one strike involving 10000 workers. Thus strikes are also counted with only a few number of workers on strike.

In equation (1) the three variables (number of strikes, intensity and duration of strikes) are connected by calculating their unweighted averages:

$$A_x = \frac{100}{3} * \left(\frac{N_x}{\sum N} + \frac{S_x}{\sum S} + \frac{D_x}{\sum D}\right).$$

(1)

In the equation x denotes the profession group or region where the strike activity A is calculated. All three variables, N_x, S_x and D_x, have the same weight. One could choose to give different weights to these variables, but the weight would be a subjective number because there are no objective arguments to say which variable should get a higher weight. The equation gives a percentage for the strike activity for a specific profession, relative to all the strikes of that year. With this equation Van der Velden calculated that the strike activity for miners is not high but for dock laborers it is, relative to all the strikes of all professions.

2.1.2 Strike index

Galambos and Evans (Galambos & Evans, 1966) formulated an equation for the composite index for strike activity (equation 2). This index shows how the strike activity is developed through time. They used three indicators: the number of strikes, the number of workers involved in the strikes and the number of lost working days, the indicators are connected in the composite index.

$$I = 100/3 \cdot (N_t/N_b + (S_t/S_b + D_t/D_b)/\ W_t/W_b),$$

(2)

W is the dimension of the population, t the index year and b the basis year. In this equation the number of workers involved and the number of days is corrected with the dimension of the population but the number of strikes is not corrected. Van Kooten (Kooten, 1988) adjusted the equation, arguing that the number of strikes should also be corrected:

$$I = 100/3 \cdot \left((N_t/N_b + S_t/S_b + D_t/D_b)/\ W_t/W_b\right).$$

(3)

Van der Velden does not take over this correction on the number of strike days as Van Kooten proposed, since when the examination period is longer, there must be another measure bar for the number of strike days. Van der Velden introduced the following: the work volume, which is the number of workers times the number of hours they worked. So if the average number of hours worked is more in one year from another, the work volume changes a lot. An adjusted formula for the strike index is made. In this formula the net number of workers on strike is corrected, where net number of strikers means that strikers who were on strike more than ones in a year are only counted once, with the size of the active working population, not counting the self-employed, and with the number of strike days for the work volume. This results that days are being compared with days and people with people. The number of strikes is related to the number of companies involved. The number of strikers per company makes it possible to show the differences between businesses in different times. The formula is as follows:

$$I = 100 \cdot \frac{(N_t + C_t \cdot L_t) + Sn_t/Sn_b + D_t/D_b}{(N_b + C_b \cdot L_b) + V_t/V_b + B_t/B_b}, \tag{4}$$

C is the number of involved companies, L the number of strikers per company, S_n the net number of strikers, V the work volume in days and B the size of the active working population (not counting the self-employed).

Using this formula one can see that the total strike activity in the Netherlands has increased somewhat, with tops and downs, through 1850-1995. The number of strikes, has increased in the beginning of the 20th century and went down after this. The number of strikers increased, due to more workers and more willingness to strike, and the strike duration went down.

2.1.3 Literature

Research is done by van Dam van Isselt (Isselt, 1914) and Boomgaard (Boomgaard, 1973) about what influences strikes, and they came up with the following idea:

Van Dam van Isselt examined if there is a relation between the number of strikes and the development of retail prices and the unemployment. This leaded to the following statement: the higher the unemployment the lower the number of strikes. He also found that there is no correlation between retail prices and the numbers of strikes.

Boomgaard compared the development of the economic climate with the number of strikes, the duration and the intensity of the strikes. He expected a positive correlation, however he only found that the number of strikes depended partly on the expectation and not on the duration and intensity. Van Kooten, den Butter and Wals also did related research, they did not get any clear results on relations on the variables.

2.1.4 The model

Van der Velden built a model that shows the relation between different variables. He considered not only the explanatory variables used in equations 1 to 4, but also political influence and union influence. These expectations are used in the model. The combined model, illustrated in Figure 4, consists of three parts for which separate models are made; economic influence, political and institutional influence and union influence (Figure 1 to 3).

In the models plusses and minuses are presented next to the arrows to illustrate the correlation between the two variables that are connected by the arrows. The minus stands for negative correlation and the plus for positive correlation. The models work as follows: if there is a plus from variable A to B it means that when A goes up, B also goes up. If there is a minus from A to B, and A goes up then B goes down, if A goes down, B goes up. The variables in the models are based on literature (Card, 1988), (Franzosi, 1995).

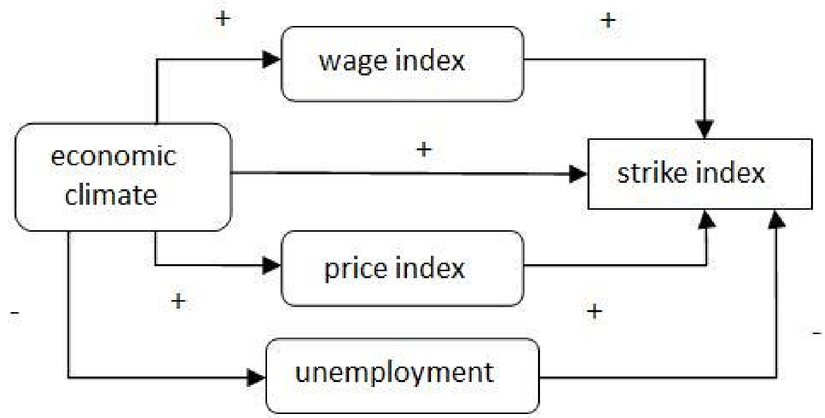

Figure 1: Economic Model

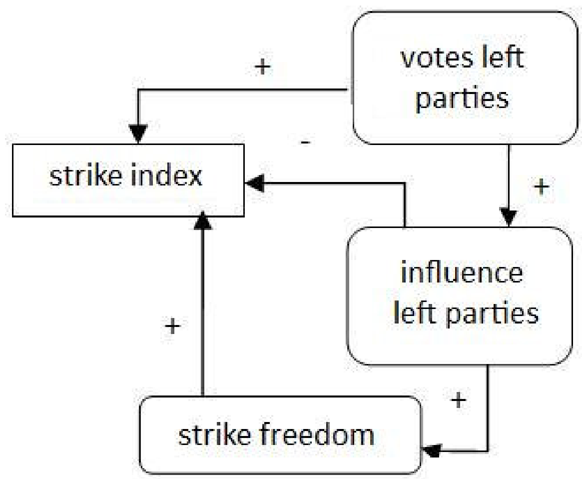

Figure 2: Political Model

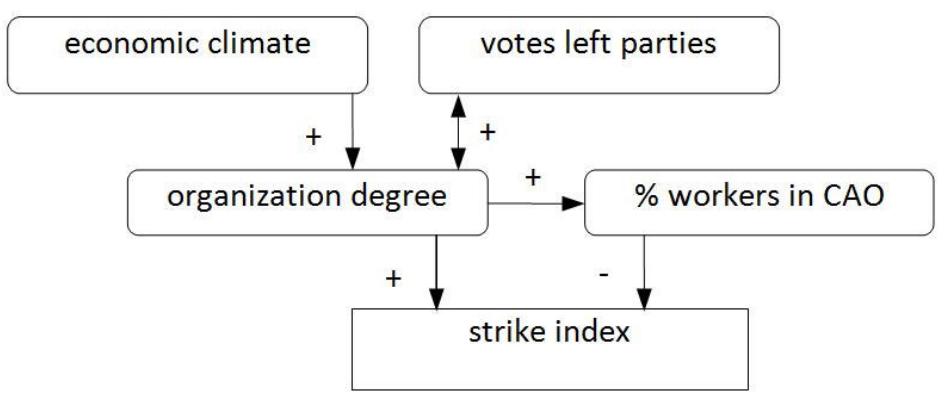

Figure 3: Union Model

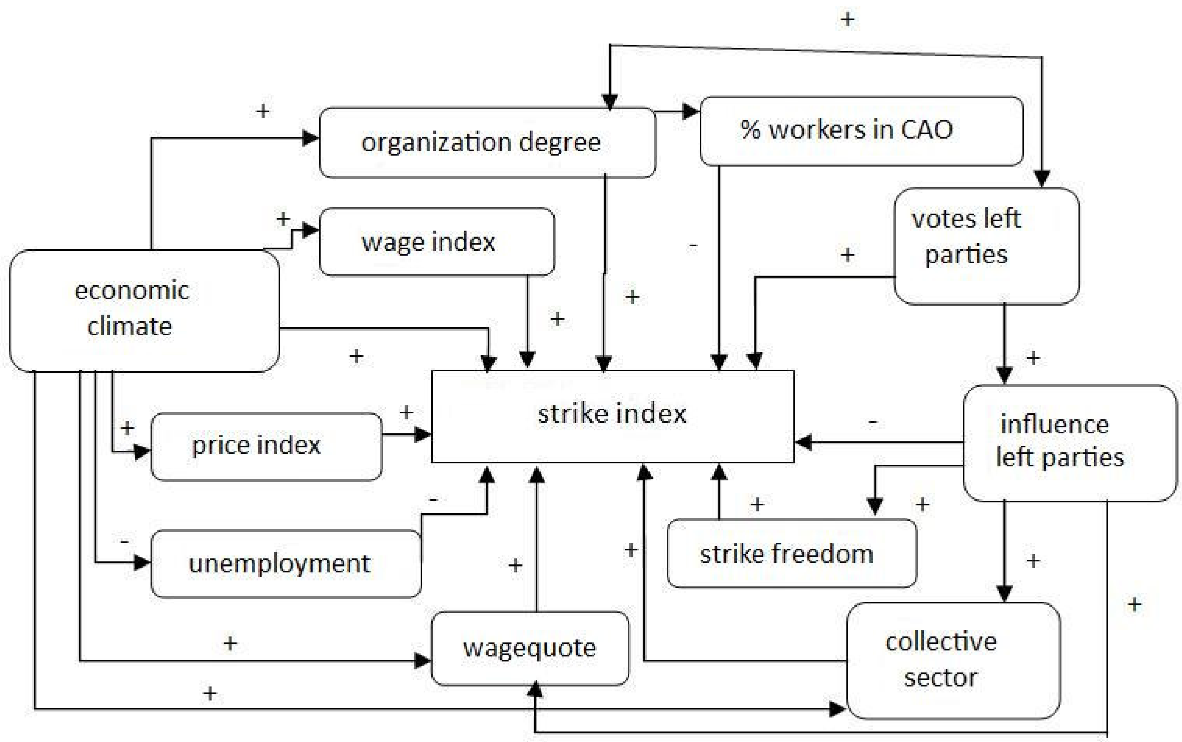

Figure 4: Combined Model

The model assumes that more influence of left parties, creates more freedom to strike and this leads to higher strike activity. Left votes are taken in the model as social dissatisfaction. The votes for the left parties are included in the model because it is assumed that the left parties are the parties who mostly speak out for the workers needs (which is not always the case).

We now explain some of the model variables. The organization degree (in the union part) is the number of workers who are members of unions and the wagequote (in the combined model) are the wages and salaries calculated as part of the national income. COA (in the union part) stands for "Collectieve Arbeidsovereenkomst" (collective employment contract), this is a contract in which the wage, work hours, free days and other contract issues are arranged for large groups of employees and employers. Binary values are used to describe the economic climate, variables that indicate economic prosperity get the value 1 and variables that indicate weak economic periods get a 0. By taking the 11-yearly average of the 0's and 1's, the series gives a Kondratieff-cycle[2] . This is what is called the economic climate mirror, which will be mentioned later on in this chapter.

In the Combined model eleven variables are used, however the data on strikes does not always contain all variables for some industries or time frames. This can be a problem because of the development of the variables. Another aspect that we should mention about the data is that not all the available data is as reliable, one unreliability for example is that the definition of unemployment is changed in 1988, this gives differences in the data for before and after this date.

Van der Velden verified the model as follows: The strike index is tested against thirteen independent variables: nominal wage, real wage, price index, unemployment, influence left parties, strike dis-freedom, organization degree, percentage of employees under CAO, wagequote, collective sector, national income, economic climate mirror and votes for left parties. For the different variables, data from different time periods, namely between 1880 and 1995 is used. The correlation coefficients are calculated and had an acceptable outcome. All the signs of the correlation coefficients were as expected and five of the variables were significant. Because of possible trend effects, the auto correlations were also tested. All independent variables and the strike index show trends. The series had to be transferred to get rid of the trend, which unfortunately resulted in very low correlations.

In spite of this outcome, the combined model is also tested with a multiple regression analysis, in which the dependent variable, which is the strike index in the model, is predicted by a linear combination of the possible explanatory variables:

$$Y = C + c_1X_1 + c_2X_2 + \cdots + c_nX_n, \tag{5}$$

where Y is the dependent variable which is the sum of the constant C and the independent variables X_i for $i = 1 \dots n$ (X_i is the i'th independent variable) multiplied by a regression coefficient C_i ($for\ i = 1 \dots n$).

The condition of this formula is that the independent variables are not allowed to have strong correlation with each other. Unfortunately a lot of the variables correlate with each other. In spite of this the regression analysis was done for the model, with the result that the model 18%

[2] The Kondratieff Cycle is a theory based on a study of nineteenth century price behavior which included wages, interest rates, raw material prices, foreign trade, bank deposits, and other data. He, like R.N. Elliott, Kondratieff was convinced that his studies of economic, social, and cultural life proved that a long term order of economic behavior existed and could be used for the purpose of anticipating future economic developments (angelfire).

of the variance of the independent variables explains. This means that 82% of the variance has to be explained by factors other than in the model. There is also just a reliability of 33% and there is some multicollinearity[3]. This in combination with the fact that some data was incomplete makes the model unreliable.

2.1.5 Adjusted model

Based on these observations a new model is created (figure 5), only the variables with the highest correlation to the strike index are used. The variables with multicollinearity are omitted. The new model is tested for the years 1911-1995, with almost no missing values. The following variables are in the model: real wage, price index, national income per head of the population and the wagequote. The correlations between the transformed strike index and the transformed independent variables are calculated which resulted in not significant variables. So the model is not tested with a multiple regression analysis.

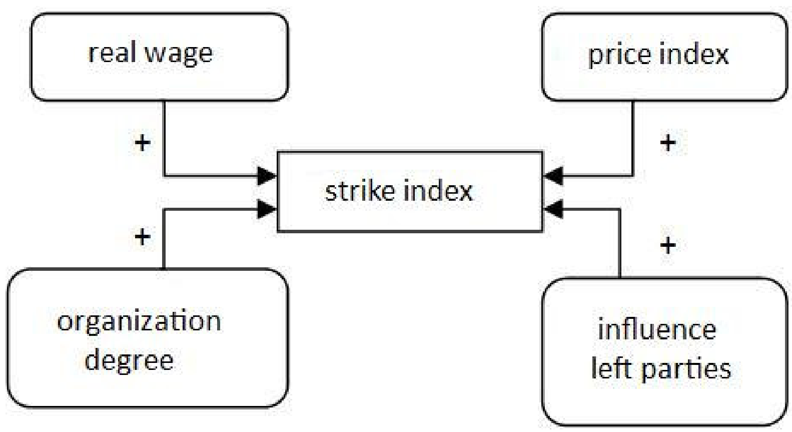

Figure 5: Adjusted Model

2.1.6 Single correlations

The single correlations are also calculated for the data, only considering periods of 20 years. From this calculation it is concluded that in 1901-1920 the unemployment and the strike dis-freedom were negatively correlated with the strike index, and that the organization degree also correlated negatively with the strike index. For some variables the correlation was positive and negative for different periods.

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[3] Multicollinearity is a statistical phenomenon in which two or more predictor variables in a multiple regression model are highly correlated (wikipedia).

Only the real wage has the expected effect during the whole time span, as expected it correlates positively with the strike index. The correlation of the unemployment with the strike index did not exactly result in what was expected, namely that the unemployment negatively correlates with the strike index. The result was that in between the first and second world war, the unemployment correlated positively with the strike index. The workers were probably not impressed by the crisis, after this period the unemployment correlated negatively with the strike index, maybe because of fear of losing of jobs. The correlation of the strike index with the economic climate mirror was what was expected, positive correlation, except in the 1930's, during an economic crisis.

In the literature no indication is given on how to consider incomplete data which makes it difficult to give another model. A more careful way of considering the data might help, since the presented models do not take changes in society in account, while doing this might help constructing a new, better model.

2.1.7 International strike index

An international strike index is constructed in (Velden, 2000), which is comparable with the Dutch strike index presented in this chapter. With the help of this index the Dutch strike behavior can be compared to the international strike behavior.

The international strike index is constructed based on the following variables: the number of work conflicts, the number of involved workers and the number of lost work days. These variables are added and held against the total working population for the following countries: United States, Canada, Australia, New Zealand, Belgium, Germany, Denmark, France, Great Brittan, Italy, Norway, Austria, Spain, Sweden, Switzerland and Japan. This international strike index is comparable with the index for the Netherlands in the 19th century. Totally comparable is the index not, because a lot of data is missing. For some countries there are no statistics on strikes for some years. In the international index there are also expulsions included (uitsluitingen in Dutch), expulsions are when one or more employers, hold work and pay to accomplish a certain aim. When this aim is accomplished the employees can get back to work and get paid again. The expulsions are not included in the Dutch index, but in the start of the 20th century there were lots of expulsions in the Netherlands, which was similar to the case in the United States (1881-1905). Also, in the international index almost no political strikes are considered, taking this into account different results are obtained.

From the international strike index can be concluded that there is a coherence between the development of the international class struggle and the general development of the economy. The Dutch strike behavior looks like it coincides with the global economic development.

The conclusion of this section is that workers react differently to changes in different social circumstances. Based on literature, some predictions can be made on what influences the strike activity, but it is hard to form a model for these expectations.

2.2 Skeels and McGrath Models

We now consider two other models that estimate strike activity, a version of the Asherfelter-Johnson estimation and the Hick's full information analysis. Both models are verified by Skeels and McGrath using regression analysis, using a significance level of 5 percent.

2.2.1 Introduction

In Hicks models the role of bargaining is contained. Employees and employers know their wage acceptance level before and during each time period of a possible strike and they also know each other's offer. Rationale parties with sufficient information will not strike which is known as "The Hicks Paradox" (Kennan, 1986). The union wage curve declines and the employer's curve increases and at some point the two lines intersect. In Gramm et al. (Gramm, 1986) the probability of a strike $P(K)$ is calculated by the employer and union estimation of inflation using:

$$P(K) = P(X_c - X_u) < \delta, \tag{6}$$

where K is a strike, X_c is the company's estimate of inflation, X_u is the union's estimate of inflation and δ is the minimum critical difference needed to generate a strike. The bigger the difference between inflation estimates in general, the more likely the union's and company's estimates will be significantly different. Gramm et al. tested this for data of the United States and came to the conclusion that the higher the price uncertainty the higher the probability that strikes will occur. The uncertainty variable is measured by the Livingston Survey price forecast's coefficient of variation. Cousineau and LaCroix (Cousineau & LaCroix, 1986) (using Canadian data) found three measures of uncertainty to be positively significant in explaining strike activity, namely: productive capacity utilization, job vacancy and selling price.

In the Gramm et al. analysis δ should remain constant, however in the Ashenfelter-Johnson tradition δ would vary cyclically and seasonally.

2.2.2 Ashenfelter-Johnson Model

In the Ashenfelter-Johnson model it is assumed that union leaders and employers are fully informed about each other's wage offer preference and are supposedly capable of a Hicks-type rational solution without a strike. However, union membership will lower its expectations when they experience a strike. When the final union wage demand is higher, strikes are more likely to occur. The profit-to-wage bill ratio, the discount rate and the minimum wage offer have influence on the strike activity. Strikes are less likely to occur when the firm's profit-to-wage-bill ratio, discount rate, and minimum wage offer are higher. Ashenfelter-Johnson developed empirical variables for these predictions, involving wage and price changes, unemployment and profit ratio, and several institutional variables such as time trends, seasonal factors and governmental actions.

Skeels and McGrath tested an updated version of the original Asherfelter-Johnson model. Skeels and McGrath made changes to the original model and tested the accuracy of this model against the original model. The Skeels and McGrath model uses unrestrained lags with prediction-error variables of wages and inflation and the original model uses the Almon lag of these variables. The original Asherfelter-Johnson model uses quarter dummies for the contract expirations and Skeels and McGrath the actual number of contract expirations. Skeels and McGrath also tested if future values are more significant than present values for the unemployment variable.

Before the results of tests to find out if the model of Skeels and McGrath is a good model compared to the original model are presented, the original Ashenfelter-Johnson model is presented. The original Asherfelter-Johnson estimation for strike activity is as follows:

$$S_t = a_0 + a_1 H_{2t} + a_2 H_{3t} + a_3 H_{4t} + a_4 \sum_{i=0}^{m} w_i \Delta R_{t-1} + a_5 U_t + a_6 \pi_{t-1} + a_7 T + e_t, \tag{7}$$

where S_t denotes the number of strikes in a given calendar quarter, H the calendar quarter, ΔR_{t-1} the lagged real wage change, U_t the unemployment rate, π the profit to compensation ratio, T the time trend and $\sum_{i=0}^{m} w_i \Delta R_{t-1}$ the weighted average of the real wage change used to model the difference between actual and expected wage change.

Skeels and McGrath changed the following in their version of the Asherfelter-Johnson model:

1. They introduced the actual number of contract expirations occurring during a calendar quarter as opposed to the quarterly variables (H) as proxies for the actual contract expirations in manufacturing in the original Asherfelter-Johnson model. As seen in equation 7, the original Asherfelter-Johnson model, multiplies the specific calendar quarter with some weight a, to get an estimation of the contract expirations.
2. To estimate $\sum_{i=0}^{m} w_i \Delta R_{t-1}$, the weighted average of the real wage change, the original Asherfelter-Johnson model uses an Almon polynomial lag structure (Schmidt & Sickles, 1975). To calculate this weighted average of the real wage change Skeels and McGrath used unrestrained lags with prediction-error variables. Skeels and McGrath do this, to be able to measure the difference between forecasted wages and actual wages more

directly. If the actual wage changes were larger than the expected wage changes the strike tendency should be less. In the Almon lag a fixed lag structure is required, what is not necessary in the method used by Skeels and McGrath.

Skeels and McGrath use the average contract length as the relevant time horizon. The normal wage is separated from inflation and the lagged 'error' measure is applied to price changes over the relevant period. Their study limits to strikes that occurred due to contract issues and strikes arising from economic issues.

The model Skeels and McGrath introduced raises three issues: Does the prediction-error variant of wages and inflation perform as well as the Almon lag form of these variables? Does using the number of contract expirations improve the performance of the estimation equation when replacing the quarter dummies? Are future values more significant than present ones for the unemployment variable?

The Asherfelter-Johnson model using the Almon lag and the model with the unrestrained lags with prediction-error variables were compared. They are tested and both have approximately the same level of explanation. The prediction-error variables of the Skeels and McGrath model are consistent with the expected error, e.g. the wage error is indeed significant and negative.

The contract expirations do not capture the seasonal differences in strike tendency as the quarterly variables do. So Skeels and McGrath decided to include both in the model in order to capture relative strike opportunity with seasonal variation.

It is not clear in the Asherfelter-Johnson model if the present or future values of unemployment, should be significant. To evaluate various discount profit streams the model requires future variables, such as prices and unemployment. The willingness to strike hinges on the current state of labor market (namely unemployment) and perhaps the future state if the strikes are unusually long. With testing the Asherfelter-Johnson model it seems that the future unemployment is not significant. This is tested by using in equation 7 the future values for unemployment instead of the actual unemployment (with some additional changes). The present unemployment explains the strike behavior better than the prediction of unemployment. Furthermore they found that for a given past wage-error and inflation-error the number of strikes reduces with a larger unemployment rate. This is tested by including two interaction variables in the model; the product of the present unemployment rate and past wage error and the product of the present unemployment rate and the past inflation-error. Including these variables also has caused the past-inflation error term to be statistical significant, the past-wage error to lose significance and the explanatory power of the model to increase. The significance level used by the regression analysis is 5 percent.

2.2.3 Hicks Model

The second model Skeels and McGrath tested is the Hick's full information model, for which the equation is as follows:

$$S_t = a_0 + a_1 H_{1t} + a_2 H_{2t} + a_3 H_{3t} + a_4 EXPIR_t + a_5 T + a_6 GDL_t + a_7 PGDL_t + a_8 PROCOM_t + a_9 FU_t + a_{10} FDW_t + a_{11} FINF_t + a_{12} ESCFINF_t + a_{13} UC_t + u_{t,} \quad (8)$$

in which $EXPIR$ is the expiration, GDL is the guideline and $PGDL$ is the past guideline, $PROCOM$ is the profit-to-compensation ratio and the following are the forecast values: FU is the unemployment, FDW is the wage change, $FINF$ is the inflation and $ESCFINF$ is the escalator clause adjusted inflation, the product of the forecasted inflation rate and the percentage of workers covered by the COLA clauses[4]. Uncertainty variables will be measured by the standard deviations (σ_e) or coefficients of variation (CV_e) of the expected values. CV_e should be a better measure of uncertainty if σ_e and X_e are related. Either σ_e or CV_e will be equally good measures of uncertainty if σ_e and X_e are not related, both are tested. The union and management will more likely select values for the expected inflation that diverge and are larger than δ (Gramm et al.) if the uncertainty about the future is greater. A widely used source of expectation variables in macroeconomic literature, namely The Livingston Survey, provides three relevant predictors for the model: inflation, wage change and unemployment rate. The standard deviations and the coefficients of variation of the predictions measure the uncertainty.

A regression analysis is done to analyze the model using a significance level of 5 percent. The regression results show that for the institutional variables like wage-price guidelines and time trend it is not clear if they are significant in the Hicks model. The sign of the time trend is not clear, given the small values as outcome of the regression analysis. However, the guideline is negative and the post guideline is positive, so the greater the guideline the lower the strike level and the greater the past guideline the higher the strike level. For the quarterly variables there is no clear prediction. Next we consider future variables, the future unemployment, the future wage change and the future inflation are not significant in all cases except the future unemployment in one case. The wage error and the inflation error are significant. The escalator clause is only significant in the model measured by the coefficients of variation. For the model measured by the coefficients of variation the inflation uncertainty is significant, with a negative

[4] A cost-of-living allowance (COLA) adjusts salaries based on changes in a cost-of-living index (wikipedia).

sign. This means that the greater the uncertainty, the lower the strike level. Hicks model, Gramm et al. and Cousineua and LaCroix reported that the inflation uncertainty would be significant and positive. However macroeconomics theorems say that uncertainty depresses economic activity, so uncertainty can have both a positive and a negative effect on economic activity. The expected sign on the uncertainty variable is positive, zero or negative depending on the strength of each effect.

With the use of the standard deviation to measure the fluctuations in uncertainty, the standard deviation of the future unemployment and the standard deviation of the future wage change are not significant, but the standard deviation of the future inflation is positive and almost significant. It seems that in some cases that σ_e and X_e are related, but the simple statistical evidence does not show that this is the case for inflation uncertainty.

2.2.4 Forecasting

To measure the error of the forecasting method, Skeels and McGrath used the Theil Inequality Coefficient (TIC), which gives the percentage deviation of the predicted value from the actual value. A perfect prediction gives a value zero and a value of one represents naïve forecasting (the model attains the same level of forecasting achieved by using the current value as the predictor for the next period). The Hicks and the Asherfelter-Johnson model do better than naïve forecasting for the period Skeels and McGrath took under consideration. The difference between the TIC values of the two models is not big. There are also small differences between the levels of explanation between the two models. Although, the Hicks model should have a lower level of explanation than the Asherfelter-Johnson model, because the expected coefficients of forecast variables of the Hicks model are zero. The error variables of the forecast variables are set to be zero, which results in changes is in the error variables of quarters, wage and price change. These changes increase the level of explanation, however, this increase is not correct. The Asherfelter-Johnson model does not give incorrect increases in the level of explanation so the Asherfelter-Johnson model is more consistent than the Hicks model.

Further, from the regression analysis of the Asherfelter-Johnson model, Skeels and McGrath conclude that non-manufacturing strikes are equally explained by the used variables as the manufacturing strikes. Skeels and McGrath also did an F-test, which showed that the coefficients for the Asherfelter-Johnson equations using manufacturing data and the Asherfelter-Johnson equations using non-manufacturing data do not differ much. From comparing economic and non-economic strikes, is concluded that the strike activity is explained 60 percent more for economic strikes than for non-economic strikes. By TIC it was also shown that the Asherfelter-Johnson equating using economic strikes performs better. The F-test shows that the level of explanation differs for strikes between contract periods and strikes during contract periods. The level of explanation is 17 percent higher for the strikes between contracts. The TIC values are also different.

To conclude, the updated Asherfelter-Johnson model is somewhat better than the Hicks model because it did not include not significant variables.

2.3 Leigh Model

The (Leigh, 1984) paper about the inter-industry propensity to strike is considered. They modified a statistical model of Farber and Katz (Farber & Katz, 1979). The model suggests that workers with the following characteristics are more likely to strike than workers without these characteristics: workers who expect more from a strike; workers who can more easily sustain a strike; workers who have less uncertainty surrounding the outcome of a strike and workers with less time preference and less risk aversion.

The model considers strikes as gambles and the agents who invoke them as gamblers. We distinguish two types of agents, namely the union agent and the management agent. The model uses proxies for the preferences and the perceptions of the agents that are derived for the union agent's parameters; it is assumed is that the agent union's characteristics are the same as the employees. The employer's preferences and perceptions do not seem to be the same as these of the management's agent. This can be explained by the fact that agent unions follow the needs of the employees, but the managements agent have to accept the guidelines given by the upper management and the stockholders.

The used data is from the University of Michigan's Quality of Employment Surveys (QES) for the years 1973 and 1977. There is only data available on the characteristics of workers, for which twenty-seven variables are used. The data is collected by interviewing around 1500 blue-collar workers[5] who work for an employer for a year.

In this paragraph Leigh's expectations on relations between variables will be described, since these relations are used in the model. Risk preference seems to be important for the model, because the workers risk aversion influences the likelihood of strikes. Many variables influence the risk, e.g. age, income, marital status, job characteristics, drinking, smoking and race. In (Leigh, 1984) they suspect that age has a negative association with the industry's propensity to strike, given that it is assumed that an increasing age serves as a proxy for increasing risk aversion. Next they expect family income will be positively related with workers willingness to strike. One would also expect workers with dangerous jobs to be more likely to strike than

[5] A blue-collar worker is a member of the working class who performs manual labor and earns an hourly wage (wikipedia).

workers with safe jobs. The willingness to gamble for better conditions, e.g. increase in their wages, increases with the workers wealth and income. A workers ability to weather a strike influences the expected winnings of a strike for the worker. As an example, finding part time work during a strike will be easier for whites and men than for blacks and women if race or sex discrimination happens in a community. There are also other factors that influences the sustainability to strike, e.g. health, place of work, education and the wealth of the family. In big cities there are more jobs available, which makes it easier to get a job, if one is well educated and if there is a lot of money in the family, one can afford be without a salary for a (short) time period. Perceived uncertainty during a strike, also varies for different groups of workers. It is likely that young workers have less information than older workers about the market conditions, about alternative job opportunities and about the companies strike history. Elderly workers have higher time preference, since they have less time to get higher wages after a long strike than the younger workers, and therefore elderly workers would prefer short strikes more that young workers. Also it is expected that smoking and drinking serve as proxies for high time preference, because smokers and drinkers do not greatly value longevity. Lower time preferences are also more likely for well educated workers. Also is assumed that unionization is related to the frequency of strikes in industries.

The model was tested using Ordinary Least Square Regression (OLS). This method gives values for the R^2's and the F-statistics[6]. The R^2's are low, but the F-statistics, which measure the overall significance of the regression, are greater than the critical value which is 0.05. For most of the variables the signs are as predicted. The model predicted that men should be more prone to strike than women, the regression supports that. Also supported by the model, if having employment in a hazardous job serves as a proxy for risk preference, weakly risk averse workers are more prone to strike than strongly risk averse workers. The predictions on family income, wage and western residence are also confirmed by the results of validating the model. The number of months a worker is with a firm correlates negatively significant, however it was expected that when the number of months with an employer increases the probability of a strike would increase. Schooling is significant and negatively related to strikes, but the prediction was that schooling should serve as a proxy for low time preference, low uncertainty surrounding strikes and high expected gain from a strike. OLS gives strong results for the percentage of an industry unionized, which should be associated with strike activity.

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[6] The R^2 describes what proportion of the variation in the dependent variable is associated with the regression of an independent variable. Obtaining a significant calculated F-value indicates that the results of regression and correlation are indeed true and not the consequence of chance (physicalgeography).

It may be that compensating wages occur in strike-prone industries and that the wages are high in strike-prone industries. A two-stage least square test is done to determine if strike activity and wage rates are simultaneously determined. The results support that there is simultaneous determination between strike activity and wage rates.

The conclusion in (Leigh, 1984) is that strike frequency seems to be greater in hazardous industries and in those employing a disproportional number of men and strike frequency seems to be small in industries employing blue-collar workers with better than average education.

2.4 Buck Model

This section is called Buck Model, after the author Buck who considers the strike frequency in a fixed interval to be a Poisson process. To validate this model he used data from 1959 till 1976 for coal mining, construction and metal manufacture and engineering industries from the United Kingdom. The model also calculates the strike frequency, the model parameters are estimated using the maximum likelihood technique.

In the model the negotiation process between the firm and union is included. The failure of a firm or an union to revise their concession rates quickly enough will result in failure to reach agreement before the strike deadline, and so there will be a strike. Success and failure of the negotiation process are recorded. The number of failures of the negotiation process in a given quarter is binomial, and if the number of negotiations goes to infinity, this limiting process is Poisson distributed. The rate of the Poisson distribution may then be modeled as a linear combination of the relevant economic variables, where the distribution function of the univariate Poisson is as follows:

$$P(X = k\ strikes) = \left[\exp\left(-\frac{T}{\tau}\right]\frac{\left(\left(T/\tau\right)^{k}\right)}{k!},\right. \tag{9}$$

in which T is the length of the interval, and the rate parameter τ is a linear combination of the relevant explanatory variables.

The number of strikes per quarter in the different industries are considered to be related through their error terms. Because the strike frequency in coal mining, manufacturing and construction are not independent, a multivariate Poisson model should be used. Elsewhere the multivariate Poisson process has been derived as the limiting form of the binominal or as a generalization of the bivariate Poisson. Because this does not have a closed form representation the strike frequencies are modeled as three bivariate Poisson models. The closed form of the bivariate Poisson process is used to estimate equation 9:

$$P(X,Y) = exp[-(a+b-d)] \quad \Sigma_{u=0}^{\min x,y} \quad \frac{(a-d)^{x-u}(b-d)^{y-u}(d)^u}{(x-u)!\,(y-u)!\,u!}, \tag{10}$$

where (X, Y) follows a bivariate Poisson distribution, if:

$$X = X^* + U, Y = Y^* + U. \tag{11}$$

The rate parameters a and b in a given industry depend on the wage bill relative to profits in the previous period, the elasticity of demand for labor, the union and other factors common to all industries. X^*, Y^*, U are independent Poisson variates and have means $a' = a - d, b' = b - d$ and d respectively, d is a linear function of the common variables. The treatment variables for each of the industries are the following: U_{jt} is the industry unemployment rate, $U_{\cdot t}$ the overall unemployment rate, $\pi_{\cdot t}$ the gross trading profits as a percentage of wages and salaries lagged on a quarter, R_{jt-1} the rate of change of the industry real wages lagged on a quarter and $R_{\cdot t}$ the rate of change of overall real wages.

The following equation is also used to estimate the strike frequency:

$$E(X|Y) - a = \frac{d}{b}(Y - b), \tag{12}$$

with the maximum likelihood estimates a and b as the sample means of X and Y. Parameter a is a linear function of unemployment and real wage changes in the Xth industry $(X * a)$ and b a linear combination of unemployment and real wage changes in the Yth industry $(Y * b)$. The coefficients in the linear specification were estimated using an iterative maximum likelihood technique and plugged in equation 12.

To determine

$$d = \delta_1 \pi_{\cdot t} + \delta_2 \pi_{\cdot t} + \delta_3 \pi_{\cdot t} = U\delta, \tag{13}$$

iterative least squares are used.

The coefficient estimates of the bivariate Poisson model are presented in the article (Buck, 1984). The estimates are given for the mean of coal mining given manufacturing, the mean of manufacturing given construction and the mean of construction given coal mining. The table with the results in (Buck, 1984) as well as the conclusion are not very clear to us and not well explained. However we can say that the overall unemployment rate has an inverse impact on the mean number of strikes, while overall real wage changes has the opposite effect. The conclusion in the article is that the expected number of strikes increases as the labor market gets tighter.

Construction and manufacturing strikes will decline if the profits increase relative to the wage bill and in coal mining it will increase. It is not clear on what these conclusions are based and in (Buck, 1984) there are also some conclusions about the industries separate, the expected number of strikes will decline in coal mining and increase in construction and manufacturing if the rate of change in real wages increases. Also the article concludes the following: the rate of change of industry real wages has a negative impact in construction, so if the wage change increases, the expected number of strikes decreases, and the rate of change of industry real wages has positive effect in mining and mixed in coal mining. This conclusion is not entirely clear to us, mining and coal mining are mentioned as separate industries, which has not been done earlier in the article, also manufacturing is not mentioned in this conclusion.

The only thing we conclude from (Buck, 1984) is that for various industries different factors play a role on strike activity. The overall unemployment rate has a negative impact on the mean number of strikes, while overall real wage changes has a positive effect. This means that when the unemployment rate increases the mean number of strikes decreases. And when the real wage change increases the mean number of strikes increases.

2.5 Mauleon and Vannetelbosch Models

In the article 'Profit Sharing and Strike Activity in Cournot Oligopoly' the effects of adopting profit-sharing on the wage outcome and the strike activity are investigated. In this investigation many concepts of "game theory" are used, there are many books and articles about this subject, see e.g. (Dutta, 2001).

2.5.1 Introduction

In a profit–sharing scheme, firms promise to pay each employee a base wage and additionally a share of the real profit. Profit-sharing may increase the employee productivity and firm profitability. A positive correlation between profit-sharing systems and firms economic results in productivity and growth was observed for the French manufacturing industry. A huge increase in profit-sharing agreements improve the productivity of the French manufacturing industry and seem to improve the productivity for the manufacturing, construction and retailing sectors in the UK, see (Cahuc & Dormont, 1992) and (Bhargava & Jenkinson, 1995). Profit-sharing also reduces activities like strikes and lockouts. A model for wage determination taking into account profit-sharing in a unionized Cournot oligopoly[7] is developed.

2.5.2 Oligopolistic market

First we introduce the following equation which describes the Oligopolistic market:

[7] An oligopoly is an intermediate market structure between the extremes of perfect competition and monopoly (enotes).

$$P(Q) = \begin{cases} a - Q \;\; if \;\; Q < a, \\ 0 \qquad if \;\; Q \geq a, \end{cases} \qquad \text{when} \quad Q \equiv \sum_{n=1}^{N} q_n, \tag{14}$$

where $P(Q)$ is the market-clearing price[8] and a is a threshold greater than 0. Each firm n supplies a quantity q_n of identical products to the market with Q the total market supply. The Oligopolistic market only exists if $N \geq 2$, since then there can only be profit maximizing firms $(n = 1, \dots, N)$ with respect to other firms. The labor input l_n equals q_n and $q_n w_n$ are the total costs to firm n producing quantity q_n where w_n is the real base wage, $\overline{w}$ is the expected real income of an employee who loses his job, π_n is the total real profit in firm n, given by:

$$\pi_n\big(w_n, l_n, (q_1, \dots, q_N)\big) = \begin{cases} \left(a - \sum_{n=1}^{N} q_n\right) q_n - l_n w_n \;\; if \;\; \sum_{n=1}^{N} q_n < a\,, \\ 0 \qquad\qquad\qquad\qquad\qquad if \;\; \sum_{n=1}^{N} q_n \geq a. \end{cases} \tag{15}$$

Profit-sharing is assumed to be enforceable by law. In the profit-sharing system under consideration, the profit-sharing parameter λ (the share going to the workers) is fixed by the government or social planner at some predetermined value and the firms and unions can negotiate over the base level. The utility level of firm n is presented in equation 16 and the local union's utility[9] is presented in equation 17 :

$$\Lambda_n\big(w_n, l_n, (q_1, \dots, q_N)\big) = (1 - \lambda) \cdot \pi_n\big(w_n, l_n, (q_1, \dots, q_n)\big), \tag{16}$$

$$u_n\big(w_n, \overline{w}, l_n, (q_1, \dots, q_N)\big) = l_n w_n + (1 - l_n)\overline{w} + \lambda \cdot \pi_n\big(w_n, l_n, (q_1, \dots, q_n)\big) \tag{17}$$

The following game structure is used: Wages are bargained at firm or industry level and then the Cournot competition occurs, in this competition the firms choose their quantities to produce and so the level of employment, the industry output and the market clearing price. To calculate the quantities to be produced the Nash equilibrium[10] for the Cournot competition is used, which is as follows:

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[8] A Market Clearing Price is the price of a good or service at which quantity supplied is equal to quantity demanded. Also called the equilibrium price (wikipedia).

[9] Utility is a measure of the happiness or satisfaction gained from a good or service in economics and game theory (NationMaster).

[10] In game theory, the Nash equilibrium (named after John Forbes Nash, who proposed it) is a solution concept of a game involving two or more players, in which each player is assumed to know the equilibrium strategies of the other players, and no player has anything to gain by changing only his or her own strategy (i.e., by changing unilaterally) (wikipedia).

$$Q^*(w_1, \dots, w_N) = \frac{N_a - \sum_{n=1}^{N} w_n}{N+1},$$

(18)

$$q_n^*(w_1, \dots, w_N) = \frac{a - (N+1)w_n + \sum_{k=1}^{N} w_k}{N+1}, \qquad n = 1, \dots, N.$$

(19)

The output of the Nash equilibrium for a firm decreases with its own wage and the number of firms in the industry and the output increases with other firms wages and with total industry demand.

Two bargaining structures are considered, bargaining at industry level and bargaining at firm level. We will first describe the bargaining process at industry level.

2.5.3 Industry level wage bargaining

In the industry level bargaining structure a single union's representative, the central union, is representing the employees and the central firm is representing the employers. The central union wants to maximize the local unions utilities and the central firm want to maximize the sum of the local firms profit. The central union and central firm negotiate the industry base-wage level; in this case the negotiation of all firms is centralized which means that a uniform base wage is set for all firms. The feasible agreements for this base-wage are in set X, with w the base wage and E is the disagreement event.

$$X = \{w \in \mathbb{R} | 0 \leq w \leq a\}.$$

(20)

The utility of a local firm n (von Neumann-Morgenstern) is given by:

$$\Lambda(w, l^*(w)) = (1-\lambda)\left[l^*(w) \cdot \left(a - w - Nl^*(w)\right)\right].$$

(21)

The utility of a local union n is equal to the total amount of money received by the members:

$$u(w, \overline{w}, l^*(w)) = l^*(w) \cdot w + \left(1 - l^*(w)\right) \cdot \overline{w} + \lambda \cdot \left[l^*(w) \cdot \left(a - w - Nl^*(w)\right)\right].$$

(22)

For sake of presentation:

$$u\left(w, \overline{w}, l^*(w)\right) = l^*(w) \cdot [w - \overline{w}] + \lambda \cdot \left[l^*(w) \cdot \left(a - w - Nl^*(w)\right)\right].$$

(23)

The local firms profit is zero and the local union receives $\overline{w}$ when the central firm and central union disagree. The disagreement point for the central firm is zero and for the central union $N\overline{w}$. The utility of the local union is rewritten so that the disagreement point shifts to zero.

So the von Neumann-Morgenstern utility is:

$$u(w,\overline{w}) = \frac{a-w}{N+1}(w-\overline{w}) + \lambda\left(\frac{a-w}{N+1}\right)^2. \tag{24}$$

The local firms utility:

$$\Lambda(w) = (1-\lambda)\left(\frac{a-w}{N+1}\right)^2. \tag{25}$$

The utility pairs that are possible when there is an agreement:

$$Y \equiv \left\{\left(\left[0, N\frac{a-w}{N+1}\left((w-\overline{w}) + \lambda\left(\frac{a-w}{N+1}\right)\right)\right], \left[[0, N(1-\lambda)]\left(\frac{a-w}{N+1}\right)^2\right]\right) | w \in X\right\}. \tag{26}$$

This is a compact convex set, with disagreement point $d = (0,0)$ in its interior, so $\langle Y, d\rangle$ is a bargaining problem. The central firm and central union take action at periods in set $T \equiv \{1,2,\dots\}$ which is infinite. The central firm makes the first offer in period one, this offer can be accepted by the central union in period two, or the central union can give a counter offer. Like this the central firm and the central union take turns until one of the parties accepts an offer of the other party. The agreement w at time t is denoted by (w,t). This process is Rubinstein's alternating-offer bargaining model (this model will also be used with the wage bargaining game at firm level). Assumingly, the central union is on strike during all the periods till agreement. The payoffs in the wage bargaining are given by:

$$U(w,t) \equiv N \cdot \delta_u^{t-2} \cdot u\big(w, \overline{w}, l^*(w)\big), \tag{27}$$

$$\Pi(w,t) \equiv N \cdot \delta_f^{t-2} \cdot \Lambda\big(w, l^*(w)\big) \qquad \forall (w,t) \in X \times T, \tag{28}$$

where U is the central unions von Neumann-Morgenstren utility function, with subscript u identifying the central union and Π is the central firm's von Neumann-Morgenstren utility function, with subscript f identifying the central firm and $\delta_i \in (0,1)$ is the discount factor for player i, for $i = f, u$ (the discount factors are assumed to be the same for all firms and for all unions). Δ is the length of the bargaining period, the focus is for the period length to shrink to zero. The discount factors $\delta_i = \exp(-r_i\Delta)\,, for\ i = u, f$ with r_u and r_f the discount rates and $r_u \geq r_f \Leftrightarrow \delta_u \leq \delta_f$ (a lower discount rate and a higher discount factor comes with greater patience, both parties are assumed to be inpatient).

Information about the discount rates is not always complete, but if this information is complete and the period length shrinks to zero, then $G(r_u, r_f)$ denotes the base-wage-bargaining game. When the length shrinks to zero, a unique SPE (subgame-perfect equilibrium) payoff vector can be obtained. The unique limiting SPE of $G(r_u, r_f)$ approximates the asymmetric Nash bargaining solution to the problem $\langle Y, d \rangle$. The central union's bargaining power is denoted by:

$$\alpha = r_f/(r_u + r_f). \tag{29}$$

The predicted wage:

$$w_c^{SPE} = \arg\max_{w \in X} [N \cdot u(w, \overline{w})]^{\alpha} \, [N \cdot \Lambda(w)]^{1-\alpha}, \tag{30}$$

which is:

$$w_c^{SPE} = \overline{w} + (a - \overline{w}) \frac{(N+1)\alpha - 2\lambda}{(N+1)2 - 2\lambda}. \tag{31}$$

So under complete information the central base wage is a decreasing function of the profit-sharing parameter. The payoff vector of $G(r_u, r_f)$ is:

$$\left(U^*(r_u, r_f), \Pi^*(r_u, r_f)\right) = \left(\frac{N(2-\alpha)\alpha}{4(N+1-\lambda)}(a-\overline{w})^2, \frac{N(1-\lambda)(2-\alpha)^2}{4(N+1-\lambda)^2}(a-\overline{w})^2\right). \tag{32}$$

Efficient outcomes of the bargaining process are predicted by the model under complete information, if the bargaining game is done under incomplete information this is not the case.

In the base wage bargaining game takes place under incomplete information the players are uncertain about each other's discount rates. The discount rates are drawn from a probability distribution p known by both parties. In this case the wage-bargaining game is denoted by $G(p)$. The following counts for the PBE[11] (Perfect Bayesian equilibrium) of the wage-bargaining game:

The payoff of the central union belongs to $\left[U^*(r_u^I, r_f^P), U^*(r_u^P, r_f^I)\right]$, and the payoff of the central firm belongs to $\left[\Pi^*(r_u^I, r_f^P), \Pi^*(r_u^P, r_f^I)\right]$.

[11] To refine the equilibria generated by the Bayesian Nash solution concept or subgame perfection, one can apply the Perfect Bayesian equilibrium solution concept. PBE is in the spirit of subgame perfection in that it demands that subsequent play be optimal. However, it places player beliefs on decision nodes that enables moves in non-singleton information sets to be dealt with more satisfactorily (wikipedia).

For the discount rates $r_i \in [r_i^P, r_i^I], i = u, f \ where \ 0 < r_i^P \leq r_i^I < 1$, the I denotes the most inpatient types and P the most patient types.

The centralized base-wage outcome w_c^* is bounded as follows:

$$\bar{w} + \frac{(N+1-2\lambda)r_f^P - 2\lambda r_u^I}{2(N+1-\lambda)(r_f^P + r_u^I)}(a - \bar{w}) \leq w_c^* \leq \bar{w} + \frac{(N+1-2\lambda)r_f^I - 2\lambda r_u^P}{2(N+1-\lambda)(r_u^P + r_f^I)}(a - \bar{w}). \tag{33}$$

By choosing the distribution p each base wage satisfying these bounds can be the centralized outcome.

When the players of the bargaining game have private information the introduction of a profit-sharing scheme does not necessarily mean that the wage level always decreases and the production output and the customer surplus increases, like what happens under complete information. To recover the complete information results the following condition is needed:

The wage outcome with profit-sharing is always smaller than the wage outcome without profit-sharing if and only if there exists a profit share $\lambda \in (\lambda^*, 1]$ where:

$$\lambda^* = \frac{(N+1)[r_f^I r_u^I - r_f^P r_u^P]}{(r_f^I + r_u^P)(r_f^P + 2r_u^I)}. \tag{34}$$

Using the equations described above an equation for the strike activity is constructed. The strike activity is the maximum delay in reaching a wage agreement (difference between the upper and lower bound of the of the bargaining outcome) which is given by:

$$\psi_c(\lambda) = \frac{(N+1)[r_f^I r_u^I - r_f^P r_u^P]}{[r_f^P + r_u^I][r_f^I + r_u^P]2(N+1-\lambda)}(a - \bar{w}). \tag{35}$$

From this equation the following can be stated: the introduction of a profit-sharing scheme increases the strike activity if the base wage bargaining takes place at industry level, because $\psi_c(\lambda \neq 0) > \psi_c(\lambda = 0)$.

2.5.4 Firm level wage bargaining

The local-union's representative is representing the employees and the local firm representative is representing the firm. The goal of the representatives is to maximize the local union's utility versus the local firms utility. Inside each firm the local-union's representative negotiates the base wage level with the local-firm's representative. All negotiations are simultaneous and independent. In this case the bargaining for the base-wage is done per firm, and is not necessarily the same for all firms. Like the wage bargaining game at industry level, the bargaining process at firm level is described by the Rubinstein's alternating-offer bargaining model (described above). In this case the von Neumann-Morgenstern utility functions that give the payoffs are given by:

$$U_n(w_n,t) \equiv \delta_u^{t-2} \cdot u_n\big(w_n, \overline{w}, l_n^*(w_1^*,.,w_n,.)\big), \tag{36}$$

$$\Pi_n(w_n,t) \equiv \delta_f^{t-2} \cdot \Lambda_n\big(w_n, l_n^*(w_1^*,.,w_n,.)\big) \qquad \forall (w_n,t) \in X \times T, \tag{37}$$

in which Π_n gives the function for the local firm n and U_n for the local union n and $\delta_i \in (0,1)$ is the discount factor for player i, for $i = f, u$ where the f stands for the local firm and the u for the local union, the discount factor is the same for all firms and for all unions.

Under complete information the SPE payoff vector at firm n of the decentralized-wage-bargaining game when the length of a single bargaining game approaches zero is:

$$(U_n^*(r_u,r_f), \Pi_n^*(r_u,r_f)) = \frac{N(2-\alpha)(a-\overline{w})^2 \cdot [\alpha[N+1-\lambda N], (1-\lambda)N(2-\alpha)]}{[2N\,(N+1+\lambda) - \alpha(N+1)(N-1)]^2}. \tag{38}$$

The decentralized wages are given by:

$$w_d^{SPE} = \overline{w} + \frac{(2\lambda N - N - 1)r_f + 2\lambda N r_u}{2(\lambda N - N^2 - N)r_u + (2\lambda N - N^2 - 2N - 1)r_f}(a-\overline{w}), \tag{39}$$

where α is given by equation 29.

In the decentralized-wage-bargaining game under incomplete information the players are uncertain about each other's discount rates. Just like in the central case described above, the discount rates are drawn from a probability distribution p over types. The following counts for the PBE (Perfect Bayesian equilibrium) of the wage-bargaining game:

The payoff of the local union belongs to $\left[U_n^*(r_u^I, r_f^P), U_n^*(r_u^P, r_f^I)\right]$, and the payoff of the local firm belongs to $\left[\Pi_n^*(r_u^I, r_f^P), \Pi_n^*(r_u^P, r_f^I)\right]$, for $r_i \in \left[r_i^P, r_i^I\right], i = u, f$. The bargaining outcome satisfies the following:

$$w_d^* \geq \overline{w} + \frac{[(2\lambda N - N - 1)r_f^P + 2\lambda N r_u^I](a-\overline{w})}{2(\lambda N - N^2 - N)r_u^I + (2\lambda N - N^2 - 2N - 1)r_f^P}, \tag{40}$$

$$w_d^* \leq \overline{w} + \frac{[(2\lambda N - N - 1)r_f^I + 2\lambda N r_u^P](a-\overline{w})}{2(\lambda N - N^2 - N)r_u^P + (2\lambda N - N^2 - 2N - 1)r_f^I}. \tag{41}$$

The upper and lower bound give the base-wage outcome of the complete information game. By choosing the distribution p each base wage satisfying these bounds can be the decentralized outcome.

Like at industry level, the profit-sharing scheme does not always decrease the wage level and does not always increase the production level and employment level when the players possess private information. With the wage bargaining game with complete information, a profit-sharing scheme does always decrease the wage level and does always increase the production level and employment level, to recover these results for the bargaining game with incomplete information the following should hold (the same as at industry level):

The wage outcome with profit-sharing is always smaller than the wage outcome without profit-sharing if and only if there exists a profit share $\lambda \in (\lambda', 1]$ where:

$$\lambda' = \frac{(N+1)[r_f^I r_u^I - r_f^P r_u^P]}{\left(r_f^I + r_u^P\right)\left(r_f^P + 2r_u^I\right)}. \tag{42}$$

The following is sufficient: $\lambda > (N+1)\lambda[2N]^{-1}$, which converges to a halve if the number of firms in the industry becomes large and it decreases with the number of firms.

The equation for the strike activity at firm level can now be stated:

$$\psi_d(\lambda) = \left[\frac{[2N(N+1)(1+N-\lambda N)]\left[r_f^I r_u^I - r_f^P r_u^P\right](a-\overline{w})}{(2\lambda N - N^2 - 2N - 1)r_f^P + (\lambda N - N^2 - N)2r_u^I}\right] \cdot \left[\frac{1}{(2\lambda N - N^2 - 2N - 1)r_f^I + (\lambda N - N^2 - N)2r_u^P}\right]. \tag{43}$$

This means that $\psi_d(\lambda \neq 0) < \psi_d(\lambda = 0)$ if $N > 2$, so the introduction of a profit-sharing scheme reduces the strike activity if the base-wage bargaining takes place at firm level and the number of firms in the industry is greater than two.

The conclusion of the article is as follows: If the base-wage bargaining takes place at industry level than the introduction of a profit-sharing scheme increases the strike activity but if the base-wage bargaining takes place at firm level (and the number of firms in the industry is greater than two) than the introduction of a profit-sharing scheme reduces the strike activity.

3. Comparison of the models

In sections 2.1 to 2.4 models on strike activity are discussed. Section 2.5 also gives a quantitative model but on the influence of profit-sharing on the strike activity. In this section we therefore compare the models from section 2.1 to 2.4.

The following table illustrates the different variables used in the models described in chapter 2:

2.1 Van der Velden Combined	**2.1 Van der Velden Adjusted**	**2.2 Ashenfelter-Johnson**	**2.2 Hicks**	**2.3 Leigh**	**2.4 Buck**
strike index	strike index	number of strikes	number of strikes	strikes	industry unemployment rate
organization degree	organization degree	calendar quarter	calendar quarter	smoke	overall unemployment rate
price index	price index	Profit to compensation ratio	profit to compensation ratio	exercise	gross trading profits
influence left parties	influence left parties	time trend	time trend	schooling	rate of change of the industry real wages
wagequote	real wage	lagged real wage change	expiration	wage	rate of change of overall real wages
wage index		weighted average of the real wage change	future wage change	other family income	
unemployment		unemployment rate	future unemployment	age	
economic climate			future inflation	earnings	
strike freedom			escalator clause adjusted inflation	married	
collective sector			guideline	union	
% of workers in CAO			past guideline	organization size	
votes left parties				health	
				city	
				%unionized	
				western residence	
				southern residence	
				months with employer	
				job satisfaction	
				physical effort	
				drinking	
				bad hours	

repetitious job
male
white
lost working days
number of production workers

Table 1: The variables used in the models in Section 2.1 to Section 2.5.

As we already see in table 1 the models use many different variables. The two models from section 2.2, the Asherfelter-Johnson model and the Hicks model, both use the profit to compensation ratio, quarterlies and the time trend. They also both use some form of unemployment and wage. Data for manufacturing, non-manufacturing, economic and non-economic, intercontractual and intracontractual strikes are used in the models. In the Buck model the strike frequency in three industries is compared; coal mining, construction and manufacturing. This model does not use many variables, the model does use some form of unemployment and wage. The Leigh model does use many variables, many personal factors are taken into account, which is not done in the other models. This model does use the wage but not the unemployment. Leigh investigates the strike activity for different industries and investigates what influences the strike activity. Van der Velden calculated the strike activity for the Netherlands, and included political factors. Van der Velden takes political variables in account in the model because votes for the left parties is a sign of dissatisfaction he says, and dissatisfaction increases the willingness to strike. The other models do not mention anything like this. This can be because van der Velden did his research for data for the Netherlands. Van der Velden does not make differences between industries, he also uses the wage and unemployment in the combined model but drops the unemployment in the adjusted model, because of multicollinearity.

The only variable that all models have in common is the wage and most models use the unemployment. These two factors seem to be the most important factors in calculating the strike activity. Wage is probably important because most strikes originate because workers want to earn more.

The van der Velden models did not give significant outcomes. In the Asherfelter-Johnson model and the Hicks model the unemployment also does not seem to be significant but the Buck model does have as outcome that the unemployment does influence the strike activity. Literature points out that the unemployment does influence the strike activity, but most models do not support this.

Table 2 denotes if some form of the wage and unemployment were significant in the different models. For the van der Velden models we give the significance for the single correlations of the variables with the strike index and for the buck model we use the overall unemployment and wage rates.

A "+" is illustrated in the table if there was a positive correlation, if a "–" is illustrated there was negative correlation, if there is "not" stated, there was no significant correlation and n/a means the variable was not in the model.

Model **Variable**	**2.1 Combined**	**2.1 Adjusted**	**2.2 Ashenfelter-Johnson**	**2.2 Hicks**	**2.3 Leight**	**2.4 Buck**
Wage	+	not	+	not	+	+
Unemployment	not	not	+	not	n/a	-

Table 2: Significance of the wage and the unemployment in the different models.

The different models have different outcomes concerning wage and unemployment. This can be because the data that is used in the models is from different countries and from different times. Van der Velden uses data from the Netherlands, in the Ashenfelter-Johnson, Hicks and Leigh models data from the United States is used and in the Buck model data from the United Kingdom is used. Although van der Velden did calculate an international strike index and the Dutch strike behavior looks like it coincides with the global economic development, the strikes from the different countries cannot be fully compared. Definitions of variables can be different, the variables can be calculated differently, the countries are not developed the same way, the politics are different etc.

It can also be that flaws in the data cause results to be bad, definitions of variables have changed in time, for certain time periods data is missing, data can be incorrectly recorded etc. Data can contain trends, which can upset models, like multi-correlation does. Maybe this is not tested in all the models, only van der Velden mentioned it.

Some models looked at strike activity in different industries, some used more general data, this can also give differences. Maybe it is not possible to generalize strikes, and make a model that includes all strikes. Some of the models did give differences in the results for different industries, maybe if there are really big differences between industries a general model will not give clear results.

The buck model suggests that the strike activity is different in different industries and the Leigh model suggests that certain types of workers are more likely to strike than others. So the difference in strike activity in different industries can be connected to the types of workers in that industry. It can be for example that most workers in manufacturing are low-schooled and are mostly men. This is as Leigh also concluded; the strike frequency seems to be greater in hazardous industries and in those employing a disproportional number of men and strike frequency seems to be small in industries employing blue-collar workers with better than average education. It can be that the variables used in the Leigh model influence the variables used in the Buck model.

4. Cost Model

The question about the quantitative costs of strikes remains unanswered after studying literature, as seen in chapter 2, therefore we make a first attempt to do so. We will present a model to calculate the costs of a strike for a company in the passenger transportation industry. Next we do a case study, we apply the model to Connexxion, a Dutch bus company.

4.1 The Model

The developed cost model consists of three parts. The first part will give the difference between the revenue normally made, and the revenue during a strike. During a strike the revenue will be less than normal, so this will be an amount of money the company "loses". The second part will contain the difference between the normal wage costs and the wage costs during a strike. This difference is an amount of money the company saved. The third part will contain the difference between the normal maintenance costs and the maintenance costs during a strike. The maintenance costs include the maintenance of a machine independent of its use and the costs of being in use. The maintenance costs will be less during a strike, so this part will also be an amount of money the company saved.

The total costs of a strike can be calculated as follows:

$$\mathbb{C} = V_R - V_W - V_M, \tag{1}$$

where V_R is the difference between the normal revenue and the revenue during a strike, V_W is the difference between the wage costs normally and during the strike and V_M the difference for the maintenance costs.

4.1.1 Revenue loss

The revenue of companies in the passenger transportation industry consists of the money passengers pay to be transported and (sometimes) money from the government. Depending on the company, the passengers can travel with different kind of tickets. We distinguish annual tickets, daily tickets and one-ride tickets. This results in the following equation:

$$R_i = \text{Ŧ}\alpha_i + O\sigma_i + G_i, \qquad i = n, s, \tag{2}$$

where Ŧ is the profit for a company of an annual ticket and α is the number of annual tickets sold, O is the profit of an one-ride ticket and σ is the number of passengers using this ticket, G is the money received from the government. The money received from the government does not necessarily have to be a fixed amount, but it can be, for example, that the company gets an amount of money per passenger, if this is the case, the amount of money per passenger G, needs to be multiplied with the number of passengers. To calculate the revenue under normal conditions take $i = n$, and to calculate the revenue during a strike let $i = s$. The loss of revenue will be:

$$V_R = R_n - R_s. \tag{3}$$

4.1.2 Wage costs

When there is a strike in a transportation company there are different scenarios possible, namely it can be that there is not driven at all, or that during some periods of time there will be driven and during some periods of time there will not be driven. If there is driven the company can decide to pay the strikers for those driven hours. It also happens that strikers will drive, but do not let the passengers pay, in this case the company can decide to deduct some money from the strikers wage. Taking these scenarios into account, equation 4 can be used to calculate the wage costs.

$$W_i = [\tau - (1 + d_i h_i - d_i)\varepsilon p_i]w, \qquad i = n, s, \tag{4}$$

where d_i is the percentage of the day the workers drive, h_i the percentage of the wage held when there is free transportation, ε the number of drivers needed for all shifts, p_i the percentage of drivers on strike, τ the total number of drivers and w the wage for one driver.

Equation 4 can be used to calculate both the normal wage costs and the wage costs during a strike. The savings on wage costs can be calculated using equation 5.

$$V_W = W_n - W_s, \tag{5}$$

4.2.3 Maintenance savings

The last part of equation 1 is the difference between the maintenance cost given a normal and a strike situation:

$$V_M = M_n - M_s, \tag{6}$$

where M_n are the maintenance costs on normal days and M_s are the maintenance costs on strike days, with M_i the equation (7) for both.

$$M_i = F\rho_i + Z\mu_i, \qquad i = n, s, \tag{7}$$

where ρ_i denotes the total number of rides, F denotes the fuel costs for one ride, μ_i denotes the number of machines and Z denotes the costs made for the machine (maintenance etc.). It is possible that the fuel costs will be calculated per kilometer, in this case ρ_i will be the number of driven kilometers and F_i the price of the fuel per kilometer.

The three parts of which the costs model exists are described above, and thus we can now calculate the strike costs for a company with the help of this model.

4.2 Connexxion

We will apply the equations from section 4.1 to Connexxion Almere. Connexxion is a Dutch bus company where the drivers were on strike from April 30th to June 11th 2008, however not continuously. We obtained some information about this strike for the inner city lines of Almere from Bos (Bos, 2008).

4.2.1 Introduction

On average Connexxion Almere has 108 shifts that have to be driven every day, in about 82% of these shifts the drivers were on strike every day. In total there are 173 drivers, fulltime and part time (including temporary employees). The workers who were not on strike were not able to drive their busses either because of the cyclic structure of the employee schedule. During the strike the company had 75% of the normal wage costs and the average gross income of a driver is €2700,- a month for full-time drivers.

The company saved about 20.000 euro on fuel costs in the strike period. Normally the fuel costs are about 10.000 euro a day. The company did not save any money on maintenance, because the company has a contract wherein the costs are set independent of their use.

Now we consider the profit of the company. It has less income than usual because the government deducted some money and less tickets were sold. We could not get specific figures of these costs and therefore we approximate these. Connexxion Almere transports 25,000,000 passengers a year, this is approximately 68,493 a day. We assume that every day the same amount of passengers are transported, which will not be the case in reality. During week days probably more passengers will be transported than during weekends and also on holidays less passengers will be transported than normally. We do not have data on the amount of passengers that travels with an annual ticket and with a daily ticket. Therefore we do not take into account these differences, and assume every ride costs €2-. This guess is made based on the value of one ticket in Almere.

This means that on a normal day the income of tickets is 68,493 · €2 = €136,986.-

Since we do not know the amount of money the company gets from the government, we decided to take this equal to zero.

Now we consider the revenue and wage costs, which depend on the strike activity. There were four different ways of striking during the strike period, namely:

1. free transportation, for 6 days,
2. free transportation in peak hours (4.30am-9.00am / 4.00pm-7.00pm) and strikes all other hours of the day, for 6 days,
3. 100% strike, for 13 days,
4. transportation in peak hours (7.00am-9.00am / 4.00pm-7.00pm) and strikes all other hours of the day, for 6 days.

The wage cost were different for these different periods. Connexxion deducted 50% of the wages when the strikers drove the whole shifts without having passengers pay. When the busses only drove in peak hours without the passengers paying, 80% of the strikers wages was deducted for the hours they drove, however the rest of the day they were not paid at all. When the drivers were fully on strike, the strikers were not paid and when the drivers drove in peak hours, and let the passengers pay, the drivers only got paid for these hours.

4.2.2 Revenue loss

Overall, for a period of 25 days, the company did not get any income from ticket sale. We do not know the amount of passengers traveling in peak hours and therefore we assume this is halve of all the passengers a day. This means that the only income the company had during the strike was the ticket sale for 6 days in the peak hours, which is:

68,493 · €2 · 0.5 · 6 = €410,958.9

So the average daily income during the strike was

€410,958.9 / 31 = €13,256.74

So the average daily revenue loss during the strike, calculated by using equation 3, is:

€136,986 - €13,256.74 = €123,729.6

In this calculation it is assumed that Connexxion did not get any money from ticket sale when the busses did not drive. This assumption may not be completely correct because the company probably got a fixed amount of money for the annual tickets and got a daily fixed amount of money from ticket sale points. Another problem is that some tickets are not only valid for Connexxion, but also for the other bus companies in the Netherlands. These tickets are called 'strippenkaarten'. With these tickets a passenger can travel several times. All bus companies get an amount of money for the sale of these tickets. The tickets of €2,- are tickets that can be used 1 time only, and are for Connexxion only. Travelling with a strippenkaart is cheaper than travelling with a single ticket. So the missed income during the strike will be somewhat less than calculated.

4.2.3 Wage savings

Now we will calculate the difference between the normal wage costs and the wage costs during the strike.

The average cross income of a driver is €2700,- a month, which is €2700 · 12 / 365 = €88.77 a day, so the wage costs for all 173 workers equals €88.77 · 173 = €15,356.71 a day (using equation 4 with $d = 1$, $h = 0$, $p = 0$, $\varepsilon = 108$, $\tau = 173$ and $w = 88.77$).

We distinguish four scenarios:

1. When the drivers were fully on strike, no busses drove and the strikers did not get paid by the company at all, this means that $d = 0$ and $h = 1$. For this part of the strike we have the following costs per day, using equation 4:

   ((0 - 0 · 1 - 1) · 108 · 0.82 + 173) · €88.77 = €7495.5

2. In the case that the busses drove all day without letting the passengers pay, only the following variables change in equation 4: $d = 1$ and $h = 0.5$, so in this case the wage costs are:

   ((0.25 – 0.25 · 0 – 1) · 108 · 0.82 + 173) · €88.77 = €9460,8

3. When the busses drove in peak hours, with passengers paying, the strikers got paid for those hours only. In this case the busses drove a quarter part of the day, so $d = 0.25$ and $h = 0$ which results in the following wage costs:

   ((1 – 1 · 0.5 – 1) · 108 · 0.82 + 173) · €88.77 = €11426.1

4. When the busses drove in peak hours without the passengers paying, 80% of strikers wages were held for those hours, so $h = 0.8$ and the busses drove three-eight part of the day so $d = 0.375$.

   ((0.375 – 0.375 · 0.8 – 1) · 108 · 0.82 + 173) · €88.77 = €8085,087

This leads to the following daily average wage costs during the strike:

(13 · €7495.5 + 6 · €11426.1 + 6 · €9460,8 + 6 · €8085,087)/31 = €8750.76

Using equation 5 gives the following savings on wage costs:

€15,356.71 - €8750.76 = €6605.96

This means the company saved approximately €6606 per day and in total €204,784.7. This is approximately 43% of the wages paid under normal conditions.

4.2.4 Maintenance savings

The last part of equation 1 gives the difference for the maintenance costs. In the Connexxion case, the machines are the busses. Connexxion has a fixed contract for the maintenance of the busses, so there were no savings for this during the strike. Normally the fuel costs are about €20,000.- a day. Connexxion says that in total, during the strike they saved €10,000.- in fuel costs. Busses still drove to be cleaned and checked out during the strike, which has cost some fuel, but a saving of €10,000.- seems to be a too rough approximation. It could be that the company did not save a lot of money because of less fuel use because they also have a fixed contract for the fuel. We do not know if this is the case, so we tried to calculate the fuel costs our selves. We assume half of the fuel costs are made when the busses drove in the peak hours.

For a period of 12 days there was transportation in peak hours, 6 days there was transportation the whole day and 13 days there was no transportation at al. Normally the fuel costs are €20,000.- a day, so for the strike days the fuel average daily costs were:

(12 · 10,000 + 6 · 20,000) / 31 = 240,000 / 31 = €7,741.94

Normally the fuel costs are €20,000 a day, which is €620,000 for the whole strike period.

So the daily savings during the strike were:

20,000 – 7,741.94 = €12,258.06

Which is €380,000 during the whole strike period.

4.2.5 Result

We have calculated all the costs needed to fill in equation 1, namely:

1. Lost income a day: €123,729.6
2. Savings on wage a day: €6605.96
3. Savings on fuel a day: €12,258.06

So equation 1 gives the following for the average daily costs during the strike:

€123,729.6 - €6605.96 - €12,258.06 = €104,865.6

For the whole period of 31 days it is €3,250,823 (€3,835,608 - €204,784.7 - €380,000 = €3,250,823)

This result shows that the savings on wage and fuel do not nearly compensate the loss in ticket sale. The real loss will probably be less, because the company probably will not lose all the money they get from the government, and will get some income from ticket sale, due to the fixed contracts. Even if the loss in ticket sale was half as much as calculated above, it is still much more than the savings of the wage and fuel together. In Figure 1 the total costs are plotted against the percentage of workers on strike. The dotted line gives the value for when a ticket is 1 euro and the straight line for when a ticket is 2 euro. You can see that the costs stay pretty high even if a ticket costs only 1 euro.

The costs of the company would increase somewhat if less drivers would have been on strike, because the company would have more wage costs. The savings on wage grow with the percentage of workers on strike. Figure 1 shows that the total costs decrease somewhat with an increasing percentage of strikers. If for example 50% of the drivers would have been on strike, still none of the busses would have been able to drive, so the strike would still work. You could imagine that unions can come up with some strike strategies, to make it more costly for a company to sustain a strike, like letting less employees strike. Companies would also benefit a lot, if they know how much a strike costs, it gives more insights and gives a better position in the bargaining process.

Figure 1: The total costs for the company are huge, even if the ticket price is only 1 Euro.

5. Conclusion

In this paper we first introduced the concepts of strikes. From this, we immediately see the many variations of strikes, the different ways of categorizing them and the impact of countries and their government.

Our focus is mainly on quantitative models capturing strike issues. The complexity of strikes might have been a reason for the small amount of models that we found in literature. However there are a few number of models to calculate the strike activity and there are models that show the influence of certain variables to the strike activity. These models are extensively discussed in section two. In section three these models are compared.

The models use many different variables and the significance of the variables is not the same in all models. It seems that present variables perform better than the future variables. Furthermore it seems that wage and unemployment are important variables in calculating the strike activity. As concluded from some of the models, the strike activity is different in several industries, this means that constructing a model for the strike activity including the strikes of all industries may not be possible.

Better knowledge of the available data, and better storage of the data can help to form a better model. The influence of certain variables on the strike activity can also change in time, which means that a model can change in time and could be different for e.g. 50 years ago and now. The strike activity and the influence of variables on the strike activity can also differ for different countries, e.g. because the political situation in the countries is different.

There is still a lot open in the quantitative part of strikes. There are a lot of flaws in existing strike activity models. It is probably hard to get a good model because of lacking data. There is data available about strike activity, but about strike cost is little to be found. This makes it hard to come up with a good model. One of our main interests, cost models for strikes, are not known to us, so in section four we made a first attempt for a costs model.

We think that finding good models on the strike activity and strike costs is an interesting and wide open field and should be researched some more. With more knowledge about the influence of certain variables to the strike activity, better decisions to prevent strikes and/or reduce costs can be made.

Abbreviations

α number of annual tickets sold

A strike activity

b basis year

B size of the active working population

C number of involved companies

$\mathbb{C}$ total costs of a strike

d_i percentage of the day the workers drive

ΔR_{t-1} lagged real wage change

D duration of the strikes

δ minimum critical difference needed to generate a strike

$ESCFINF$ escalator clause adjusted inflation

$EXPIR$ expiration

ε number of drivers needed for all shifts

F fuel costs

FDW future wage change

$FINF$ future inflation

FU future unemployment

G money received from the government

GDL guideline

h_i percentage of the wage held when there is free transportation

H calendar quarter

I Strike index

K strike

l_n labor input

L number of strikers per company

λ share going to the workers

M_i maintenance costs

N Number of strikes

O income from one ticket

p_i percentage of drivers on strike

$PGDL$ past guideline

$PROCOM$ profit-to-compensation ratio

$P(Q)$ market-clearing price

π profit-to-compensation ratio

$\pi_{.t}$ gross trading profits as a percentage of wages and salaries lagged on a quarter

π_n total real profit in firm n

q_n quantities of the commodity produced by firm n

Q total market supply

R revenue

R_{jt-1} rate of change of the industry real wages lagged on a quarter

$R_{.t}$ rate of change of overall real wages

ρ_i total number of rides

S strike intensity

S_n net number of strikers

S_t number of strikes in a given calendar quarter

σ number of travelers with a single ticket

t index year

T time trend

Ŧ income for the company from an annual ticket

τ total number of drivers

U_t unemployment rate

U_{jt} is the industry unemployment rate

$U_{.t}$ the overall unemployment rate

μ_i number of machines

V work volume in days

V_m difference between the material costs normally and during the strike

V_r difference between the normal revenue and the revenue during a strike

V_w difference between the wage costs normally and during the strike

w wage

$\bar{w}$ expected real income of a worker who loses his job

w_n real base wage

W dimension of the population

W_i wage costs

x profession group or region

X_c company's estimate of inflation

X_u union's estimate of inflation

Z costs made to a machine

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