Agent-based Modelling of Monopsony and the Minimum Wage[1]

Peter Green

July 2007

[1]A dissertation submitted in partial fulfillment of the requirements for the degree of Master of Business at the University of Otago, Dunedin, New Zealand

Acknowledgements

Robert for incredible patience.

Pisey for company at the library and during coffee breaks.

Jenny for proof-reading (any remaining errors, of course, are mine).

CONTENTS

LIST OF FIGURES

Introduction

A simple supply and demand argument apparently[1] shows that minimum wage policy, ironically, hurts the workers it is ostensibly aimed at helping, by increasing their chances of unemployment. Stigler (1946) claims that economists should be "outspoken, and singularly agreed" on the issue. While the profession happily achieves the former, they are a long way from the latter (Klein & Dompe 2007).

Early last century, Sidney Webb (1912) claimed that minimum wage laws had increased productivity growth, both by drawing employers attention away from cost-cutting and towards productivity improvements, and by providing a relative advantage to high-wage firms. Today, this is backed up by mathematical models (e.g. Cahuc & Michel 1996, Acemoglu 2001)

Recent studies — the "new economics" of the minimum wage — have provided more ambiguous evidence about employment effects.

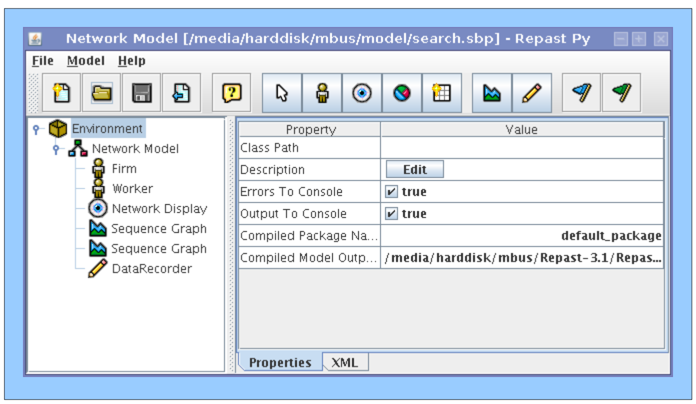
Monopsony models have become fashionable since they were used to account for increases in employment in Card & Krueger's (1995*a*) *Myth and Measurement*. Although the word "monopsony" initially referred to markets with a single buyer, the modern usage refers to models where individual buyers face upward sloping supply curves. Despite the shift in meaning, the term still carries some stigma, especially if it is used in contexts where the assumption of one buyer would not be credible (Boal & Ransom 1997).

[1] If taken seriously, the usual Econ101 argument (along with reported elasticities of labour demand less than one) actually shows that representative minimum wage workers get more pay for less work.

This project investigates whether a simple agent-based model is better described by a competitive model or by a monopsony model, and what implications this has for minimum wage policy. Two models were built. The first is a toy model which simply reproduces a competitive model in simulation form. The second, based on search models of labour markets, exhibits behaviour similar to a monopsony model.

The simulated models were built in *Repast*[2], the "Recursive Porous Agent Simulation Toolkit". After consulting a comparison of agent-based modelling software in Tobias & Hofmann (2004), *Swarm*[3] and *Repast* were chosen for further evaluation. *Repast* was chosen for its faster initial learning curve, and for its inclusion of the rapid-development tool *RepastPy*[4].

Figure 0.1: *RepastPy*



The first three chapters of this report review some of the literature on the minimum wage. Chapter 1 presents some of the theoretical arguments for and against the minimum wage. The standard textbook model predicts an increase in unemployment following a minimum wage increase, but models with imperfect labour markets, such as monopsony and search have more ambiguous predictions.

[2]http://repast.sourceforge.net/

[3]http://www.swarm.org/wiki/Main_Page

[4]Although *RepastPy* is very easy to use, it is unfinished (occasionally requiring hand-editing of its XML output), and will likely stay that way since it will be superceded by *Repast Simphony* (North et al. 2005), which is currently in development.

Chapter 2 discusses some of the empirical work done on the minimum wage, starting with Card & Krueger's (1994) landmark study of fast-food restaurants in New Jersey and Pennsylvania, and the responses to their results. Evidence for monopsony in labour markets is also presented.

Chapter 3 introduces an agent-based approach to the labour market. Agent-based modelling allows a model to incorporate heterogeneity, market frictions and power relations while side-stepping the mathematical difficulties these topics pose in a purely analytical framework.

The final two chapters describe the two simulated labour market models built for this project. Chapter 4 builds a simple analytical model of an idealised "textbook" labour market, and then attempts to reproduce that model as a computer simulation. The simulated model is used to demonstrate some of the properties of agent-based models. Agent-based models can be used as "computational laboratories" (Tesfatsion 2002), performing experiments that are not possible with real economies. The model can be modified in ways that would be intractable analytically, such as replacement of representative agents with heterogeneous agents.

In Chapter 5 an agent-based simulation, based on a search model, is presented. While the model itself is very simple, its behaviour is complex. Experiments performed on this model show the existence of monopsony power for firms when the ratio of workers to firms is large, but show no evidence of any positive effect of a minimum wage on employment.

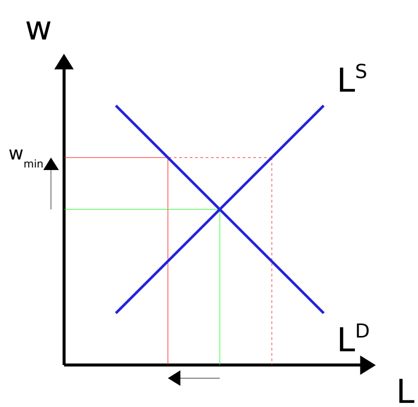
CHAPTER

ONE

Theory

1.1 The Textbook Model

Figure 1.1: The textbook model.



In the standard "textbook" model, the labour market is characterised by an upward sloping labour supply curve and a downward sloping labour demand curve. The market wage and employment are determined by the intersection of these two curves.

A minimum wage acts as a price floor, forcing the wage above its equilibrium value. This increases the amount of labour workers are prepared to supply, but at the same time decreases firms' demand for labour. This results in an excess of labour supply over demand. The economy moves up and back along the labour demand curve, with wages increasing and employment decreasing.

Total wages will increase if the elasticity of labour demand is less than one. If L represents hours worked, then workers are receiving more wages for less work; if it represents the number of workers employed then some workers get a wage increase at the expense of other workers losing their jobs.

1.2 Monopsony

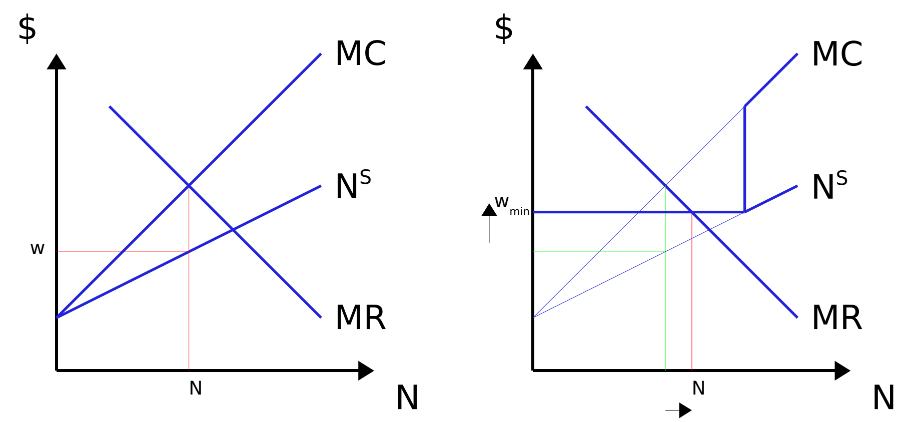
Card & Krueger (1995a) recommend using monopsony models to explain possible increases in employment following a minimum wage increase. These models are usually credited to Robinson (1933). Despite the name, monopsony models do not require the assumption of a single employer; all that is required is that employers have some market power (Stigler 1946). Suppose that an employer's costs are based on the wage paid (w) to the number of workers employed (N). Then cost $C = Nw$ and, differentiating, we get the marginal cost

$$MC = w + N\frac{\mathrm{d}w}{\mathrm{d}N}.$$

In a model with perfectly competitive labour markets, firms are assumed to be price takers, that is $\mathrm{d}w/\mathrm{d}N = 0$, and this reduces to the familiar $MC = w$. If the firm has some market power in the labour market, it will face an upward sloping labour supply curve. In this case $MC > w$. This is because, in order to pay enough to attract the next worker, the firm must raise the wages of its current employees. The firm will choose the wage and employment level shown in the left-hand diagram in Figure 1.2, where the marginal cost equals the marginal revenue (MR).

The right-hand side of Figure 1.2 shows the effect of a minimum wage w_{min}. The firm's current employees are now all paid w_{min}, and so the marginal cost of the next worker is reduced $MC = w_{min}$. The firm will move down the marginal revenue curve to equalise marginal cost and revenue. Note that a smaller increase could have increased employment more, up to the intersection of the MR and L^S curves. A minimum wage above the intersection

Figure 1.2: The monopsony model.



of the *MR* curve and original *MC* curve would reduce employment from its original level.

Stigler (1946) argues that finding the optimal minimum wage under this model will be difficult in practice, and might be impossible in principle due to heterogeneity in workers, firms and industries.

1.3 Total Compensation

Workers can be compensated with more than just wages. On-the-job training may be more important to young and low-wage workers as it increases their future earnings (Rosen 1972). McKenzie (1980) models worker compensation as both *wages* which are subject to minimum wage laws, and *benefits* which are not. Because an increase in wages can be offset by a decrease in benefits, there will only be small employment effects of a minimum wage. Since the previous mix of wages and benefits was presumably optimal for workers, the wage increase will not balance the loss of benefits, and workers will be worse off.

1.4 Good and Bad Jobs

It is sometimes claimed that a worker's wage is based on their productivity. But productivity is not some innate quality possessed by workers. Instead, it depends on the combination of a worker and a job. Two otherwise identical workers will produce a different amount depending on how much capital they have access to. Burdett & Mortensen (1998) present a model where homogeneous workers receive different wages in equilibrium.

Workers will prefer a high-wage capital intensive job over a low-wage job. But employers' preferences could go in either direction. While the high-wage worker might be more productive, their productivity depends on the relative total costs of low-wage and high-wage workers. Offering a *good* job means paying a higher wage and supplying the employee with more capital than offering a *bad* job.

With cooperative industrial relations, workers are paid more and are more productive. But managers are paid less than they would be in an uncooperative firm (Altman 1998). Additionally, managers might prefer working in an uncooperative environment to working in a cooperative one. X-inefficient (Leibenstein 1979) high-wage and low-wage firms can coexist if there is insufficient competitive pressure to force high-wage firms to cut wages or to force low-wage firms to increase productivity (Altman 2000).

High-wage jobs may result in positive externalities. More human capital is required to perform high-wage jobs, and the accumulation of human capital becomes easier if your peers are also trained or educated. If firms cannot internalise these externalities, then there will be more bad jobs in equilibrium than is efficient (Cahuc & Michel 1996).

Acemoglu (2001) describes a search model with good and bad jobs. Moving from a competitive labour market to a market with search adds an additional cost of labour — the risk that a job will be unfilled. This cost is higher for high-wage jobs, since they have greater sunk capital costs. Therefore, a search model will have fewer good jobs in equilibrium than the optimum arrived at by a competitive labour market.

If the number of good jobs is less than optimal in the unregulated equilibrium, then a moderate increase in the cost of bad jobs will shift the equilibrium towards a more efficient state. Ways of doing this include increasing unemployment benefits, public sector wages, or of course the minimum wage.

The main focus of these models is the composition of jobs. An increase in the minimum wage improves the composition of jobs, by creating a mix that has more good jobs and is more efficient. The increase may have other effects; in Acemoglu (2001) unemployment is increased, and in Cahuc & Michel (1996) economic growth is increased.

1.5 Other Models

Acemoglu & Newman (2002) present a model similar to Shapiro & Stiglitz's (1984) shirking model, but with an endogenous level of monitoring. Monitoring transfers some of the workers' efficiency wage premium back to the firm, in an inefficient manner. A minimum wage increases worker effort reducing the need for costly monitoring, and so increasing net output.

Cubitt (1999) present a two-period general equilibrium model where firms and workers invest in capital and education. Investment is costly for the agent making the investment, but the gains are shared between employee and employer. Imposing a minimum wage increases investment in both capital and education, and can either increase or decrease employment. This model is particularly interesting because it uses representative agents with rational expectations.

CHAPTER

TWO

Evidence

2.1 Employment

2.1.1 New Economics

Minimum wage research in the 1990s, based on new data and using new methods, is known as the "new economics" of the minimum wage (Card & Krueger 1995*a*).

The most well-known example of the new economics is Card & Krueger's (1994) study of fast-food restaurants in New Jersey and Pennsylvania. An increase in New Jersey's minimum wage from US$4.25 to US$5.05 in April 2002 provided a natural experiment in the effects of minimum wages on employment. Neighbouring Pennsylvania did not increase their minimum wage, providing a control group. There was a two-year lag between the legislation's passage and its effect, with the increase happening during a recession[1], which should have mitigated the endogeneity of the decision.

Data was collected on employment in fast-food restaurants from New Jersey and Pennsylvania both before (January/February) and after (Novem-

[1] There were attempts to reduce the increase, which were vetoed by the state's governor.

ber/December) the increase. The data was collected via a telephone survey.

The study compared the *difference-in-differences* between the two groups, that is, the change in employment in New Jersey relative to the change in employment in Pennsylvania. Employment in New Jersey increased relative to employment in Pennsylvania, although the increase was not statistically significant. The minimum wage did not have a negative employment effect. This result was surprising, but not unprecedented. Kennan (1995) surveys some earlier studies which showed no employment effect of a minimum wage.

The use of telephone surveys has been criticised (e.g. by Neumark & Wascher 2000) as susceptible to measurement error. However, there is no reason to believe measurement errors would be systematically different in the two states, and so the results should be unbiased (Card & Krueger 2000). Despite the survey being carried out by a single professional interviewer, telephone surveys seem to provoke a visceral dislike from economists. Neumark & Wascher (1995) repeated the study using payroll records, and found a decrease in employment due to the minimum wage. Card & Krueger (2000) in turn criticised the use of data supplied by lobby-groups, and confirmed their earlier result using payroll data from the Bureau of Labor Statistics.

The employment increase in the fast-food sector might have been offset by decreases elsewhere. Kennan (1995) suggests the "hungry teenager" effect: if you pay teenagers more, they spend the money on burgers. This increase in demand (coming from teenagers in all sectors) more than offsets any direct effect of the minimum wage. This offset will not occur in sectors that do not capture the discretionary income of minimum wage workers. Neumark (2006) proposes substitution from relatively labour-intensive food (such as pizza) to relatively capital intensive food (such as burgers and fried chicken).

2.1.2 Surveys

In a comprehensive review for the Minimum Wage Study Commission, Brown et al. (1982) found that a 10% increase in the minimum wage resulted in a 1–3% decrease in teenage employment, with the more credible studies indicating smaller decreases. The effect on adult employment was less clear but probably smaller. The effect on teenage employment is less important than the effect on adult workers, since it could mean more adults working and teenagers getting more education (Webb 1912). However, the majority of studies focussed on teenage and youth employment, because data for these demographics were traditionally easier to obtain (Neumark 2006).

In a more recent review, Neumark & Wascher (2006) find a wider range of estimates, though still supporting a negative employment effect. In particular, studies with longer panel data and with regional and yearly variation tend to estimate negative effects, while positive estimates tend to come from studies with shorter panel data and specific regions or industries. This suggests that there is a significant lag between minimum wage increases and any employment effects, and that substitution between industries and between regions makes economy-wide effects impossible to measure from restricted datasets.

2.1.3 Meta-analysis

Given a true null hypothesis, five percent of studies should reject the null at a five percent significance level. By combining the results of all studies, the size of the sample can be increased, reducing the chance of an error (Stanley 2001). Meta-analysis is difficult, because it involves collecting as many studies as possible, and summarising the conclusions of those papers so that they are comparable. The collection of studies is hindered by the *file-drawer problem* and by *publication bias*. Studies with no interesting result may be filed away and remain unpublished. Publication might favour significant results, which may encourage specification searches.

As sample size increases, the estimated errors should become smaller relative to the effect being studied. Therefore larger studies should find more significant results. (Card & Krueger 1995*b*) found that significance was fairly constant across studies of all sizes. They concluded that empirical evidence of a negative effect on employment of minimum wages is a result of publication bias. Neumark & Wascher (1996) suggest that the evidence can be interpreted as the result of changes in the size of the effect over time.

2.2 Monopsony

2.2.1 Coal Mining

Large mining companies, company towns, and low labour mobility should make early twentieth century coal mining a likely case for monopsony power. When Boal (1995) investigated this (for West Virginia coal mining, 1897–1932), he found low short-run inverse elasticities of labour supply, and zero long-run elasticities, suggesting that mining companies had very little monopsony power. This can be explained by looking more closely at the history: there were actually many firms, workers could use the coal railways to relocate, and company accommodation made moving easier.

2.2.2 Nurses

Hospitals consistently report shortages of nurses (Hirsch & Schumacher 1995). Since a competitive market should clear, an alternative model is needed. In the monopsonistic equilibrium, the employer would like to hire more workers, but is not prepared to raise current wages enough to attract additional workers. So labour shortages are evidence for monopsony in a labour market.

Staiger et al. (1999) use the Nurse Pay Act of 1990 for a natural experiment to determine the labour supply curves faced by individual Veterans' Affairs hospitals. Wages for registered nurses at VA hospitals were changed by legislation; this was assumed to be exogenous. The change in employment at these hospitals could be used to estimate the elasticity of labour supply. The elasticity was estimated at 0.1, i.e the labour supply curve has a steep upward slope. This is strong evidence in favour of monopsony power at VA hospitals. This elasticity is unusually low, compared to earlier studies such as Sullivan (1989), where short and long run elasticities of 1.3 and 3.8 were reported. This could be because of the quality of the Nurse Pay Act as an instrument.

CHAPTER

THREE

Agent-based Models

3.1 Agent-based Modelling

Labour markets are complicated by heterogeneity, power relationships, asymmetrical information, bounded rationality, and path-dependence. Traditional models quickly become intractable when these complexities are introduced. Agent-based modelling uses computer simulation to get around these problems. For a brief introduction to this methodology see Green (2007).

3.2 Practical Applications

Agent-based modelling is distinguished from other forms of simulation by its focus on theoretical explanation (Macy & Willer 2002). Models should be as simple as possible while explaining the phenomena being studied. Forecasting simulations are more complicated, because their ability to predict is more important than being able to understand their results.

However, agent-based models can form the basis for larger practical simulations. Leombruni & Richiardi (2006) use an agent-based model to forecast demographic trends in the Italian labour market. Chaturvedi et al. (2005)

use an agent-based simulation to train military recruiters. Gates & Nissen (2001) use an automated agent-based labour market to increase the efficiency of internal assignments in the US Navy.

3.3 Aggregate Regularities

The Beveridge curve[1], wage curve[2] and Okun curve[3] are empirical regularities that occur in labour markets. While theoretical models can reproduce these regularities individually, they cannot generate them all in the same model (Fagiolo et al. 2005).

Fagiolo et al. (2004) build an agent-based simulation with interacting labour and goods markets. The model generates all three curves under most combinations of parameters. Richiardi (2006) build a matching model that generates all three curves, as well as income and firm size distributions, and a constant returns to scale matching functions. The wage curve and CRS matching function only appear when the simulation is not in equilibrium. This suggests that analytical models that assume equilibrium will not be able to model these regularities.

3.4 Endogenous Matching Functions

Agent-based models have been used to create endogenous matching functions from urn-ball search models. Neugart (2004) takes a pure agent-based approach, building a simulated economy which produces a matching function with decreasing returns to scale. Richiardi (2004) takes a mixed approach, creating an analytically solvable model, and using an agent-based simulation to test its robustness to heterogeneity, behavioural rather than rational agents, and its out-of-equilibrium behaviour. He found similar behaviour in the analytical and simulated matching functions. However, the simulated model was able to generate both Beveridge curves and Okun curves.

[1] A negative relationship between vacancies and unemployment.
[2] A negative relationship between unemployment and real wages.
[3] A 1% decrease in the unemployment rate leads to a GDP increase of over 1%.

3.5 Trade Network Games

In the Trade Network Game (Tesfatsion 1997), each agent can remember the outcomes of its interactions with other particular agents. When outcomes are uncertain, agents prefer to interact with other agents where there was a good previous outcome. The agents form trade networks, with agents as vertices, and with pairs of preferred agents as edges.

Tesfatsion (2001*b*) uses this framework to investigate market power in employment relationships, finding that the number of jobs available, relative to the number of workers, contributes more to market power than employer size. Tesfatsion (2001*a*) modifies this model to investigate the effects of path dependency. Identical workers might behave differently when employed by different firms, or when they end up in a different location in the network. This can explain the excess wage heterogeneity seen in observationally identical workers.

CHAPTER

FOUR

Market Model

4.1 The Model

4.1.1 Representative Firm

The representative firm has a production function $q = q(k, \ell)$ with $\frac{\partial q}{\partial k}, \frac{\partial q}{\partial \ell} > 0$ and $\frac{\partial^2 q}{\partial k^2}, \frac{\partial^2 q}{\partial \ell^2} < 0$. Simulation requires a concrete function, so, normalising capital to 1, and including a productivity parameter A, let $q(\ell) = A\sqrt{\ell}$.

Given a market wage w, the firm maximises its profit function $\pi = q(\ell) - w\ell$ by choosing labour demand

$$\ell^d(w) = \frac{A^2}{4w^2}.$$

If there are F firms, then market demand for labour is

$$L^d(w) = \frac{FA^2}{4w^2}.$$

4.1.2 Representative Worker

The representative worker has utility $U = U(\underset{+}{c}, \underset{-}{\ell})$ where ℓ is labour supplied, and at wage w, $c = w\ell$ is consumption. Let $\bar{c}$ and $\bar{\ell}$ be the worker's endowments of consumption and labour. Then the utility function $U(c, \ell) = (\bar{c} + c)(\bar{\ell} - \ell)$ gives the individual labour supply function at wage w

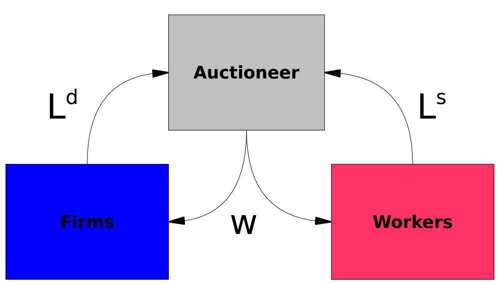
$$\ell^s(w) = \frac{1}{2}\left(\bar{\ell} - \frac{\bar{c}}{w}\right).$$

If $\bar{\ell}$ is normalised to 1, then the worker's reservation wage $w^r = \bar{c}$. Then with N workers, the market supply function is

$$L^s(w) = \frac{N}{2}\left(1 - \frac{w^r}{w}\right).$$

4.1.3 Labour Market

Figure 4.1: Walrasian labour market.



The market wage w is set by an auctioneer; firms and workers respond by demanding and supplying labour $L^d(w)$ and $L^s(w)$. The auctioneer adjusts the wage w until the equilibrium wage w^* is found that satisfies $L^d(w^*) = L^s(w^*)$.

For the labour supply and demand given above, the equilibrium wage is

$$w^* = \frac{1}{2}\left(w^r + \sqrt{w^{r2} + 2A^2\frac{F}{N}}\right),$$

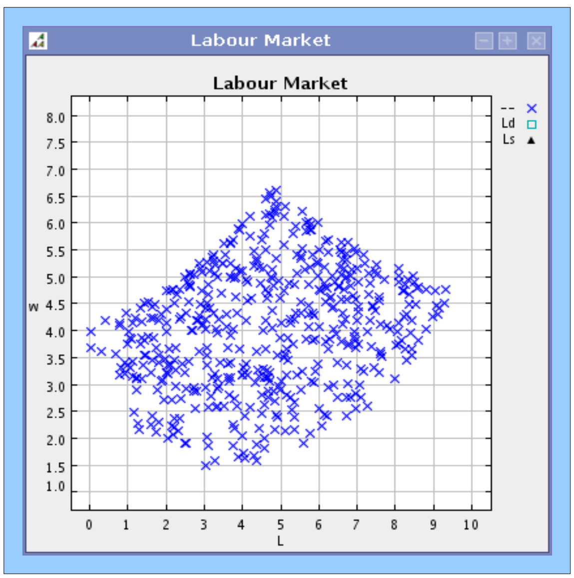
which gives us equilibrium employment $L^* = \frac{FA^2}{4w^{*2}}$

4.2 Simulation

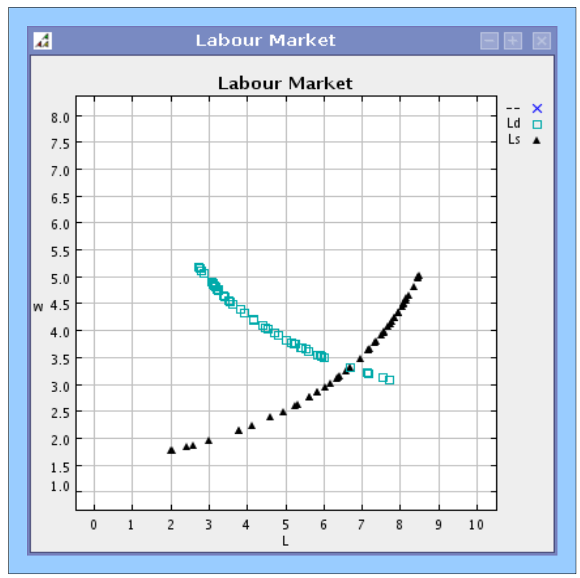
4.2.1 Experiments

Figure 4.2(a) shows the results of 500 runs of the simulation. A is taken from a uniform distribution over [2, 12], and w^r over [1, 4]. Notice the shape formed by the points — this is the rectangle $[A_{min}, A_{max}] \times [w^r{}_{min}, w^r{}_{max}]$ transformed into (w, l) coordinates. The well defined edges make it possible to infer the underlying supply and demand curves; a more realistic distribution would result in an amorphous collection of points.

Figure 4.2: Simulation allows variables to be held constant so that other variables can be changed *ceteris paribus*



(a)



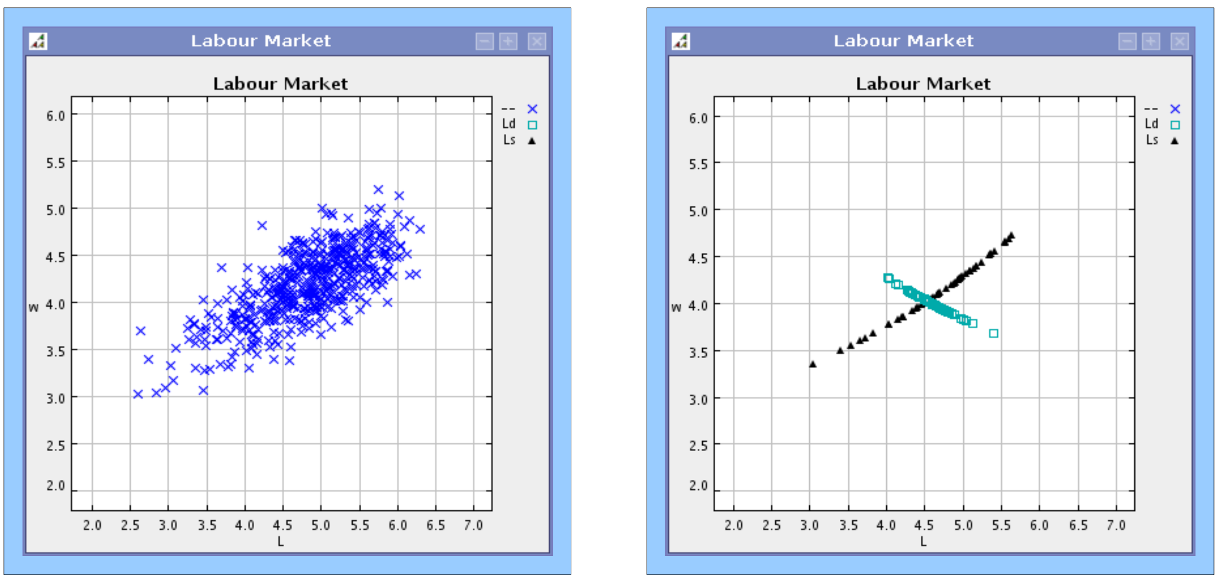
(b)

Extracting the supply and demand curves from real data would require controlling for A and w^r. Simulation makes this easier, because proper experiments can be run. Figure 4.2(b) shows supply and demand curves generated by holding A and then w^r constant.

4.2.2 Heterogeneity

Figure 4.3 shows another 500 runs of the simulation. This time, the agents' productivities and reservation wages are heterogeneous. Although the individual productivities A_i and reservation wages ${w^r}_i$ are drawn from the same distributions as before, their averages will now be approximately normal.

Figure 4.3: Simulation with heterogeneous agents.



(a) (b)

Figure 4.3(b) is analogous to Figure 4.2(b), but with heterogeneous agents. Holding the distribution of productivities and then the distribution of reservation wages constant causes the simulation to trace out nice supply and demand curves, showing that the move away from representative agents has had little effect in this case.

4.2.3 Minimum Wage

Figure 4.4: 500 runs with $w_{min} = 3.0$.

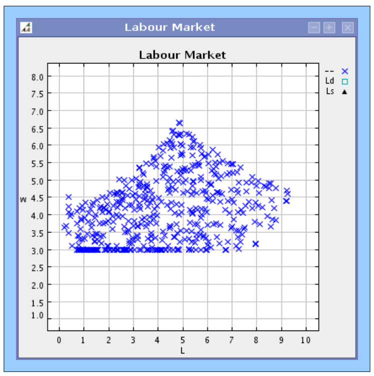
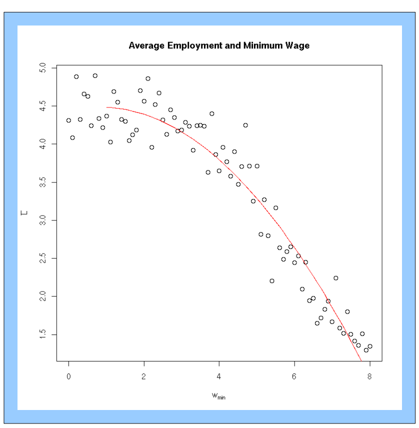


Figure 4.4 shows 500 runs of the simulation where the auctioneer is limited by a minimum wage constraint. In this particular set of runs the minimum wage is set to $w_{min} = 3.0$. Where the market wage would be above the minimum the simulation is unaffected. Points that would be below $w = w_{min}$ are now on that line. Where the minimum wage "bites", $L^* = \min\left(L^s(w^*), L^d(w^*)\right) = L^d(w^*)$, so these points cluster near to the w axis.

Figure 4.5 is a plot of data generated by a "batch" run of the simulation. There are 81 sets of 50 simulations, with the minimum wage parameter varied from 0.0 to 8.0 in steps of 0.1. The average of L^* from each set is plotted against w_{min} for that set. The red line is a quadratic fitted to the data. As expected it slopes downwards[1].

Figure 4.5: w_{min} and $\bar{L}$ for 81×50 runs.



A simple simulation of the textbook model does not produce any surprising results, nor should we expect it to. The next chapter introduces a more interesting simulation model.

[1] At least for $w_{min} > 1.0$. Since $w^r \in [1.0, 4.0]$, w_{min} must be above 1.0 to have any effect.

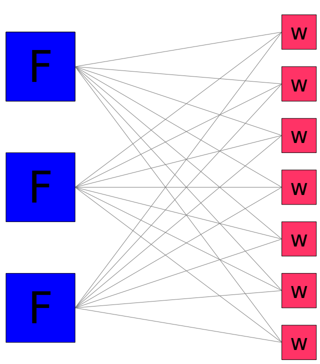
CHAPTER

FIVE

Search Model

5.1 The Model

Figure 5.1: Firms and workers meet at random.



There are F firms and N workers. Each firm is characterised by a productivity A, and has production function $q(\ell) = A\sqrt{\ell}$, where ℓ is the labour used by the firm. Prices are exogenous and normalised to one; the firm's profit function is $\pi(\ell) = A\sqrt{\ell} - w\ell$. Workers are characterised by a reservation wage w^r, and will supply one indivisible unit of labour if paid at least w^r.

At regular intervals, each firm "meets" one randomly drawn worker (cf. figures 5.1 and 4.1). If that worker is not employed by the firm, the firm offers that worker a wage $w_{offer} = mp^+(\ell) := q(\ell + 1) - q(\ell)$.

That is, the worker is offered their marginal product. The worker accepts the offer if w_{offer} is greater than both the worker's current wage and their reservation wage.

If the worker is currently employed by the firm, the firm compares their current wage with their marginal product $mp^{-}(\ell) := q(\ell) - q(\ell - 1)$. If $w > mp^{-}(\ell)$ then the worker is fired, that is, the worker is fired if the saving in wages exceeds the loss in production.

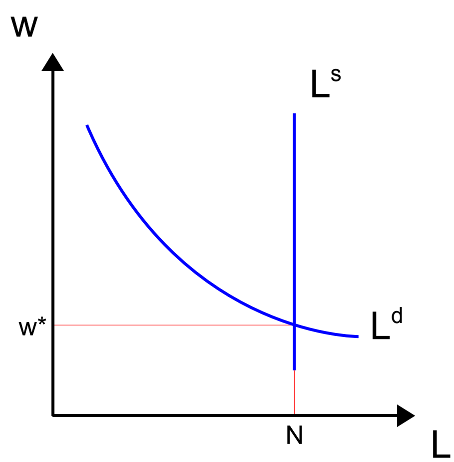
5.1.1 Analytical Approximation

Labour demand, assuming homogeneous firms, is given by $L^d(w) = \frac{FA^2}{4w^2}$ from Chapter 4. For wages above the workers' reservation wages, labour supply is $L^s(w) = N$.

The equilibrium is therefore (see Figure 5.2):

$$w^* = \frac{1}{2}A\sqrt{\frac{F}{N}} \qquad L^* = N$$

Figure 5.2: Approximate solution.



5.2 Simulation

5.2.1 Example Run

This section describes a typical run of the model. There are 6 firms and 24 workers. Firms' productivities are drawn from a uniform distribution over the interval [5,50], and workers reservation wages are drawn from a uniform distribution over [1,4]. The simulation is run for 500 steps, that is, each firm has 500 "meetings" with randomly drawn workers.

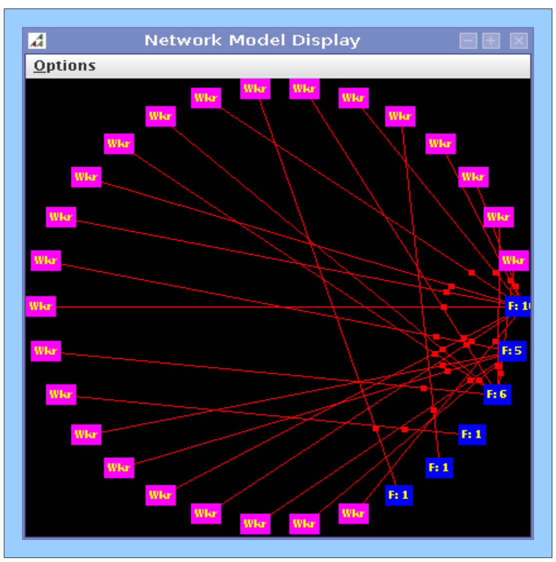


Figure 5.3: Firms assigned to workers with no central market

Figure 5.3 shows a graph of employment relationships. Coloured boxes represent firm and worker nodes. An edge from a worker to a firm indicates that the worker is employed by that firm.

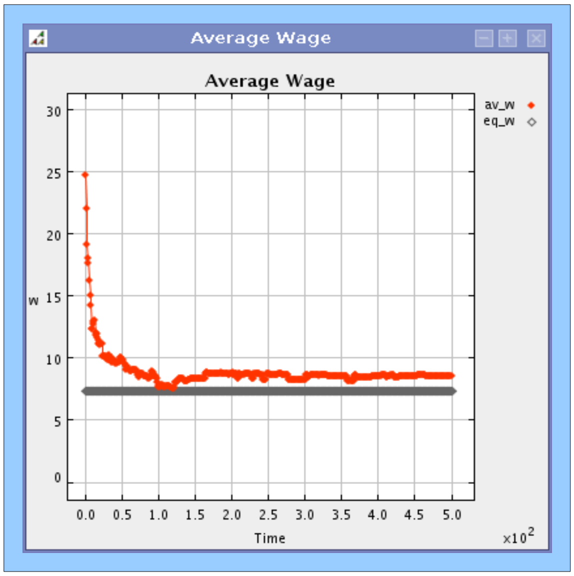
Figure 5.4 shows time series for average wage $\bar{w}$ and employment L. The grey series represents predicted[1] (w^*, L^*) from Section 5.1.1; the coloured series show the simulated values.

The average wage has a spike early in the simulation. Firms start with no employees; when labour ℓ is low, marginal product $mp^+(\ell)$ is high, and so firms offer early employees high wages. Once employment is higher, these initial wages are above $mp^-(\ell)$. The high-wage workers are fired, and the average wage falls to its equilibrium level.

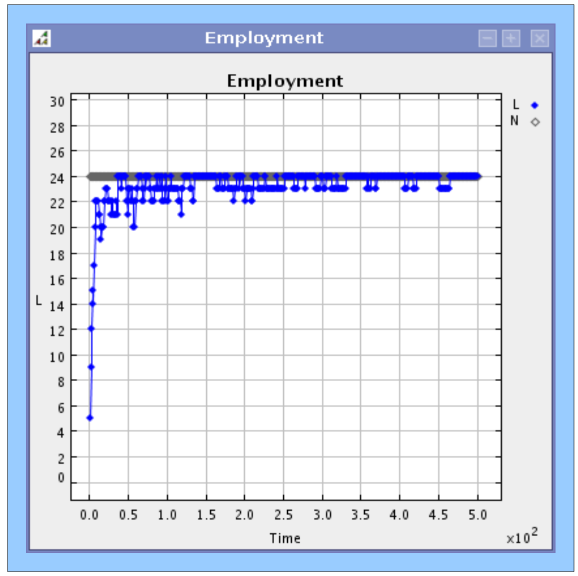
The simulation settles into an equilibrium with an average wage higher than

[1]Minus the assumption of homogeneity; the predicted wage is actually $w^* = \frac{1}{2}\sqrt{\frac{\sum_i A_i^2}{N}}$.

Figure 5.4: Predicted and actual equilibrium



(a)



(b)

predicted. This is due to workers supplying indivisible labour. The average wage is higher than the instantaneous marginal product $\frac{dq}{d\ell}$, but not the discrete marginal product $mp^{-}(\ell)$.

5.2.2 Monopsony Power

(N, F) was varied over $[15, 50] \times [1, 10]$ in steps of 5 workers and 1 firm, with the other parameters unchanged from section 5.2.1. Define

$$I := \frac{\bar{w}L}{w^* L^*} = \frac{\textit{total wage income}}{\textit{predicted total wage income}}.$$

Figure 5.5: Increased concentration decreases total income.

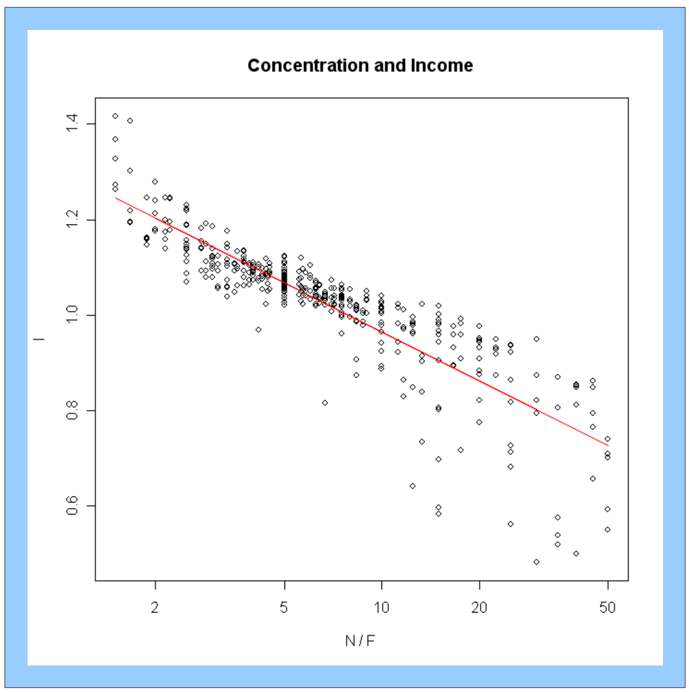


Figure 5.5 shows the variation in I as the (log of) concentration N/F increases. The line-of-best-fit has a clearly[2] negative slope, evidence that the model gives monopsony power to firms as concentration increases. At low concentration the indivisibility effect from section 5.2.1 dominates; at about $N/F = 8$ monopsony and indivisibility effects balance; and at high concentration the monopsony effect dominates.

[2] A t-test gives a p-value less than 0.1%.

5.2.3 Minimum Wage Effects

To test the effect of a minimum wage,(N, F, w_{min}) was varied over $[15, 50] \times [1, 10] \times [0.0, 20.0]$, with the minimum wage increased in steps of 0.2.

Let $\Delta I := \hat{I} - I$, where $\hat{I} = \hat{\alpha}_0 + \hat{\alpha}_1 \log(N/F)$, and $\hat{\alpha}_0$, $\hat{\alpha}_1$ are (OLS) estimates of α_0, α_1 from the formula $I = \alpha_0 + \alpha_1 \log(N/F)$.

Figure 5.6: A minimum wage reduces income.

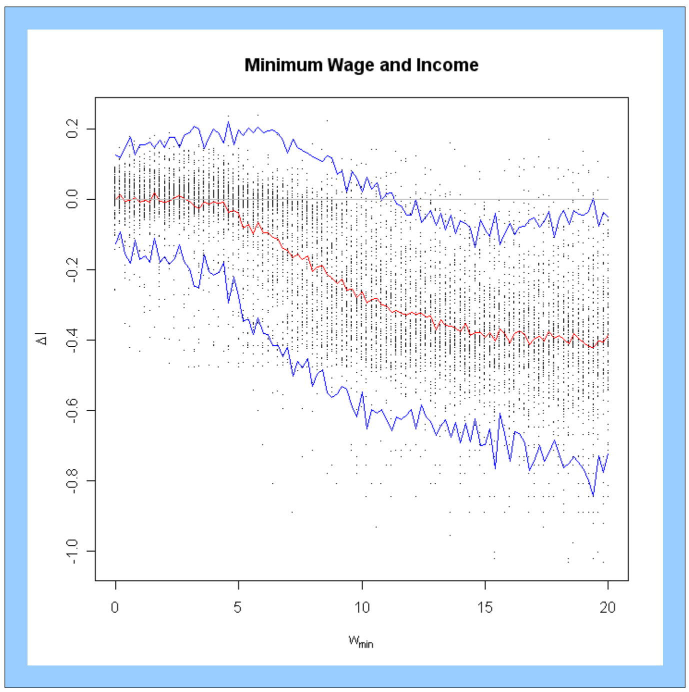
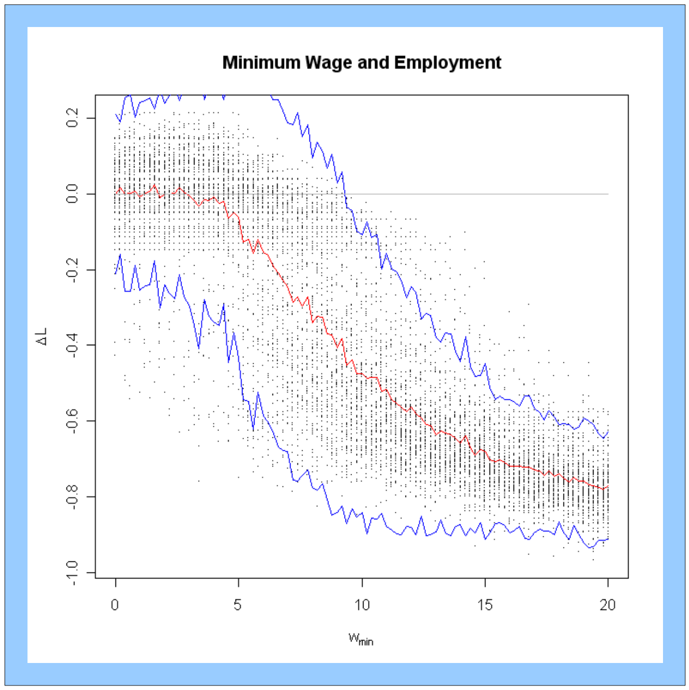


Figure 5.6 graphs ΔI against w_{min} for the 8080 data-points from the simulation. The red and blue lines are means and 95%[3] confidence intervals for ΔI with the data restricted to a single w_{min}.

[3] Assuming normal distribution

Figure 5.7 uses the same strategy, but with L/L^* (simulated employment relative to predicted employment) in place of I.

Figure 5.7: A minimum wage reduces employment.



Low values of w_{min}, from zero to about 5, have no effect, as they are below the already offered or reservation wages. For w_{min} high enough to have an effect, the effect is negative. For w_{min} greater than about 10, the effect is significant at 2.5% comparing only the data at that point and zero; the p-value will be even lower if all the data is taken into account.

Conclusions

A simple agent-based labour market model was built for this project. Experiments were performed on the model to determine the presence of monopsony power for firms, and the effects of minimum wage policy on the market.

The simulations showed evidence for employer monopsony power within the model. However, there was no evidence that a minimum wage policy could be beneficial, and evidence that a high minimum wage could be harmful to workers' employment and income.

A minimum wage that is optimal for one firm is not going to be optimal for other firms. If a single minimum wage is applied to all firms, the efficiency gain at one firm can be offset by losses in the rest of the economy. Even if a there existed a minimum wage that resulted in a net gain, it would be difficult to determine such a wage with sufficient accuracy. This agrees with Stigler's (1946) claim that inefficiencies due to monopsony will not be corrected by a blanket minimum wage.

These simulations only allowed a minimum wage policy to correct for monopsony power. Minimum wage policy might also be used to transfer income from employers to low wage workers or to encourage productivity growth. Simulation would also be useful for considering these effects.

A minimum wage would be expected to also transfer income from the least productive workers to other workers. The least productive workers might lose their jobs, slightly more productive workers will get their wage increased to the new minimum, and other workers will get increases do to substitution toward high-skilled labour. Agent-based modelling allows heterogeneity to be handled as easily as the homogeneous special case, so simulations could be used to investigate the distribution of wins and losses from the policy.

A minimum wage policy could encourage productivity growth, both by focusing the scarce “computational” resources of employers away from cost-cutting toward productivity improvement, and by favouring “good” jobs over “bad”. Simulation would make it possible to simultaneously model dynamics, boundedly rational expectations, and heterogeneity in the quality of jobs, firms and workers.

REFERENCES

Acemoglu, D. (2001), 'Good Jobs versus Bad Jobs', *Journal of Labor Economics* **19**(1), 1–21.

Acemoglu, D. & A.F. Newman (2002), 'The labor market and corporate structure', *European Economic Review* **46**(10), 1733–1756.

Altman, M. (1998), 'A High-Wage Path to Economic Growth and Development.', *Challenge* **41**(1).

Altman, M. (2000), 'Labor rights and labor power and welfare maximization in a market economy-Revising the conventional wisdom', *International Journal of Social Economics* **27**(12), 1252–1269.

Boal, W.M. (1995), 'Testing for Employer Monopsony in Turn-of-the-Century Coal Mining', *The RAND Journal of Economics* **26**(3), 519–536.

Boal, W.M. & M.R. Ransom (1997), 'Monopsony in the Labor Market', *Journal of Economic Literature* **35**(1), 86–112.

Brown, C., C. Gilroy & A. Kohen (1982), 'The Effect of The Minimum Wage on Employment and Unemployment', *Journal of Economic Literature* **20**(2), 487–528.

Burdett, K. & D.T. Mortensen (1998), 'Wage Differentials, Employer Size, and Unemployment', *International Economic Review* **39**(2), 257–273.

Cahuc, P. & P. Michel (1996), 'Minimum wage unemployment and growth', *European Economic Review* **40**(7), 1463–1482.

Card, D. & A.B. Krueger (1994), 'Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania', *The American Economic Review* **84**(4), 772–793.

Card, D. & A.B. Krueger (1995*a*), *Myth and Measurement: The New Economics of the Minimum Wage*, Princeton University Press.

Card, D. & A.B. Krueger (1995*b*), 'Time-Series Minimum-Wage Studies: A Meta-analysis', *The American Economic Review* **85**(2), 238–243.

Card, D. & A.B. Krueger (2000), 'Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania: Reply', *The American Economic Review* **90**(5), 1397–1420.

Chaturvedi, A., S. Mehta, D. Dolk & R. Ayer (2005), 'Agent-Based Simulation for Computational Experimentation: Developing an Artificial Labor Market', *European Journal of Operational Research* **166**(3), 694–716.

Cubitt, R.P. (1999), 'Minimum Wage Legislation, Investment and Human Capital', *Scottish Journal of Political Economy* **46**(2), 135–157.

Fagiolo, G., G. Dosi & R. Gabriele (2004), 'Matching, Bargaining, and Wage Setting in an Evolutionary Model of Labor Market and Output Dynamics', *Advances in Complex Systems* **7**(2), 157–186.

Fagiolo, G., G. Dosi & R. Gabriele (2005), 'Towards an Evolutionary Interp. of Aggregate Labor Market Regularities', *Working Paper* .

Gates, W.R. & M.E. Nissen (2001), 'Designing Agent-Based Electronic Employment Markets', *Electronic Commerce Research* **1**(3), 239–263.

Green, P. (2007), 'An Introduction to Agent-based Modelling', *Research Project for MBus, Department of Economics, University of Otago* .

Hirsch, BT & EJ Schumacher (1995), 'Monopsony power and relative wages in the labor market for nurses.', *J Health Econ* **14**(4), 443–76.

Kennan, J. (1995), 'The Elusive Effects of Minimum Wages', *Journal of Economic Literature* **33**(4), 1950–1965.

Klein, Daniel B. & Stewart Dompe (2007), 'Reasons for Supporting the Minimum Wage', *Econ Journal Watch* **4**(1), 125–167.

Leibenstein, H. (1979), 'A Branch of Economics is Missing: Micro-Micro Theory', *Journal of Economic Literature* **17**(2), 477–502.

Leombruni, R. & M. Richiardi (2006), 'LABORsim: An Agent-Based Microsimulation of Labour Supply–An Application to Italy', *Computational Economics* **27**(1), 63–88.

Macy, M.W. & R. Willer (2002), 'From Factors to Actors: Computational Sociology and Agent-Based Modeling.', *Annual Review of Sociology* pp. 143–167.

McKenzie, R.B. (1980), 'The Labor Market Effects of Minimum Wage Laws: A New Perspective', *Journal of Labor Research* **1**.

Neugart, M. (2004), 'Endogenous Matching Functions: An Agent-based Computational Approach', *Advances in Complex Systems* **7**(2), 187–201.

Neumark, D. (2006), 'Minimum Wages and Employment: A Review of Evidence from the New Minimum Wage Research', *Presentation at the American Enterprise Institute* .

Neumark, D. & W. Wascher (1995), 'The Effect of New Jersey's Minimum Wage Increase on Fast-Food Employment: A Re-Evaluation Using Payroll Records', *Working Paper* .

Neumark, D. & W. Wascher (1996), 'Is the Time-Series Evidence on Minimum Wage Effects Contaminated by Publication Bias?', *Working Paper* .

Neumark, D. & W. Wascher (2000), 'Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania: Comment', *The American Economic Review* **90**(5), 1362–1396.

Neumark, D. & W. Wascher (2006), 'Minimum Wages and Employment: A Review of Evidence from the New Minimum Wage Research', *Working Paper* .

North, M.J., T.R. Howe, N.T. Collier & J.R. Vos (2005), 'Repast Simphony Runtime System', *Proceedings of the Agent 2005 Conference on Generative Social Processes, Models, and Mechanisms, ANL/DIS-06-1, co-sponsored by Argonne National Laboratory and The University of Chicago, Oct* pp. 13–15.

Richiardi, M. (2004), 'A search model of unemployment and firm dynamics', *Advances in Complex Systems [A Multidisciplinary Quarterly Journal]* **7**(2), 203–221.

Richiardi, M. (2006), 'Toward a Non-Equilibrium Unemployment Theory', *Computational Economics* **28**(4), 421–446.

Robinson, J. (1933), *The Economics of Imperfect Competition*, Macmillan.

Rosen, S. (1972), 'Learning and Experience in the Labor Market', *The Journal of Human Resources* **7**(3), 326–342.

Shapiro, C. & J.E. Stiglitz (1984), 'Equilibrium Unemployment as a Worker Discipline Device', *The American Economic Review* **74**(3), 433–444.

Staiger, D.O., J. Spetz & C. Phibbs (1999), 'Is There Monopsony in the Labor Market? Evidence from a Natural Experiment', *Working Paper* .

Stanley, TD (2001), 'Wheat from Chaff: Meta-Analysis as Quantitative Literature Review', *The Journal of Economic Perspectives* **15**(3), 131–150.

Stigler, G.J. (1946), 'The Economics of Minimum Wage Legislation', *The American Economic Review* **36**(3), 358–365.

Sullivan, D. (1989), 'Monopsony Power in the Market for Nurses', *Journal of Law and Economics* **32**(2), 135–178.

Tesfatsion, L. (1997), 'How Economists Can Get Alife', *Working Paper* .

Tesfatsion, L. (2001*a*), 'Hysteresis in an Evolutionary Labor Market with Adaptive Search', *Evolutionary Computation in Econ and Finance* .

Tesfatsion, L. (2001*b*), 'Structure, Behavior, and Market Power in an Evolutionary Labor Market with Adaptive Search', *Journal of Economic Dynamics and Control* **25**, 419–457.

Tesfatsion, L. (2002), 'Agent-Based Computational Economics: Growing Economies From the Bottom Up', *Artificial Life* **8**(1), 55–82.

Tobias, R. & C. Hofmann (2004), 'Evaluation of free Java-libraries for social-scientific agent based simulation', *Journal of Artificial Societies and Social Simulation* **7**(1), 6.

Webb, S. (1912), 'The Economic Theory of a Legal Minimum Wage', *The Journal of Political Economy* **20**(10), 973–998.