Agent-Based Modeling to Analyze the Effect of the 2009 Government Stimulus Package on the Labor Market

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Abstract

The unemployment rate can more than double during a recession, and to combat the negative effects of a recession the government stimulates the economy by using various combinations of three primary stimulus methods. These methods−− tax cuts, government-funded projects and increasing the duration of unemployment insurance−−are not equally effective. In this project I used an agent-based model to analyze the effectiveness of the different components of the stimulus package in improving the labor market. To reflect the U.S. market and the 2008 recession, I adjusted an agent-based model of a simple labor market using NetLogo multi-agent programmable modeling environment. Using this modified model, I ran experiments on individual aspects of the stimulus methods and combinations thereof. The results showed that decreasing tax rate can decrease unemployment, as it makes work more attractive to workers and makes it easier to match workers and employers. Similarly, increasing government funding of projects increases job vacancies, thus decreasing unemployment, because government-funded projects increase demand and create employment opportunities. On the other hand, increasing the duration of unemployment insurance has a detrimental effect on labor market recovery, as it decreases the workers' willingness to agree to employment. Also, based on the results, we can conclude that agent-based modeling is an effective method for stimulus package analysis. During recessions, such analysis can help maximize the positive effect of government stimulus by balancing various components of the package.

Contents

1 Introduction

Economic recessions and ways to combat them have been the focus of much economic research. A recession is "a significant decline in economic activity spread across the economy, lasting more than a few months" [24]. Researchers hope to discover the most efficient way to minimize the negative effect of recessions and to speed up economic recovery. The most recent period of economic downturn, now known as the Great Recession, began in December 2007 and lasted until June 2009 [24]. In order to combat the recession, the U.S. government passed a stimulus package that took effect in January 2009. The stimulus package consisted primarily of a combination of three key components: tax cuts, government funded projects and increased duration of unemployment insurance. One of the biggest concerns during and following the Great Recession was the dramatic slowdown of the labor market and increase in unemployment. While

the 2009 stimulus is considered successful overall, there is the question whether a different combination of components would have achieved a greater decrease in the unemployment rate.

In this paper I will analyze the effects of the government stimulus of 2009 and components thereof using a computer model of the labor market. I modeled the 2008 labor market and the 2009 government stimulus in order to answer the following question: How efficient were the components of the 2009 stimulus package in addressing the issues with the labor market caused by the economic recession of 2008?

The condition of the labor market is an important measure of the economic health. If the labor market is unstable, people are less willing to spend money and more likely to save, which restricts the flow of capital, preventing economic growth. The condition of the labor market also has a strong influence over confidence in the government. If the unemployment rate is high and brings hardship to the workers' families, the government loses the trust of its subjects, which further destabilizes the economy. Therefore, when the economy enters a recession and the labor market falters, the government usually chooses to intervene and apply measures to stabilize the economy, focusing on stabilizing the labor market. These government measures must be carefully planned in order for the stimulus package to be effective.

Agent-Based modeling of the labor market can be used to analyze and predict the effect of the stimulus package. Traditional economic modeling assumes the workers and employers are homogenous, so that the problem can be solved mathematically. To make modeling more realistic, an agent-based model can be used. With such a model, a researcher can create a set of heterogeneous agents and have them interact in a simulation, instead of just applying a predetermined mathematical formula. Labor market models deal with a set of agents called employers and a set of agents called workers. These models mimic the interaction of the employers demand for labor and the workers supply of labor. By using an agent-based computer model to simulate the labor market, the workers and employers can be heterogeneous, as the computer doesn't require the model to be simple in order to solve the problem. Agent-based modeling makes up for the lack of flexibility found in traditional economic models, as it can handle heterogeneity that traditional modeling cannot. I will present the results of applying such an agent-based modeling method to the 2008 recession and the 2009 stimulus package to show the range of effectiveness the three primary components have on the labor market and economic recovery.

2 Background

2.1 What is Agent-Based Modeling

Agent-based modeling allows for the creation of multi-agent models with heterogeneous populations. Because of this flexibility, agent-based modeling is being used for a wide variety of disciplines, from biology to the social sciences. In economics, agent-based models are primarily used to perform predictive modeling.

Two major components of agent-based models are agents and procedures [25]. Agents correspond to people or organizations that the model is representing. Agents have associated characteristics, i.e. variables that constitute their identity. Agent-based models typically have multiple types of agents, for example, employers and workers. The procedures in the model are the actions that are being carried out by the agents. The way these procedures are carried out often depends on the characteristics and type of the corresponding agent. The procedures of the model take place in pseudo time measured in ticks.

For example, a simple agent-based model of a labor market would have two types of agents: pools of workers and employers. Workers have associated characteristics such as employment history, duration of unemployment, age and wage history. Employers have associated characteristics such as a list of workers, vacancies and associated offered wage. The primary procedure is the match-up between unemployed workers and employers with vacancies. At each tick of time, unemployed workers and those employers with vacancies negotiate wages and fill some subset of the vacancies with some subset of unemployed workers (Figure 1).

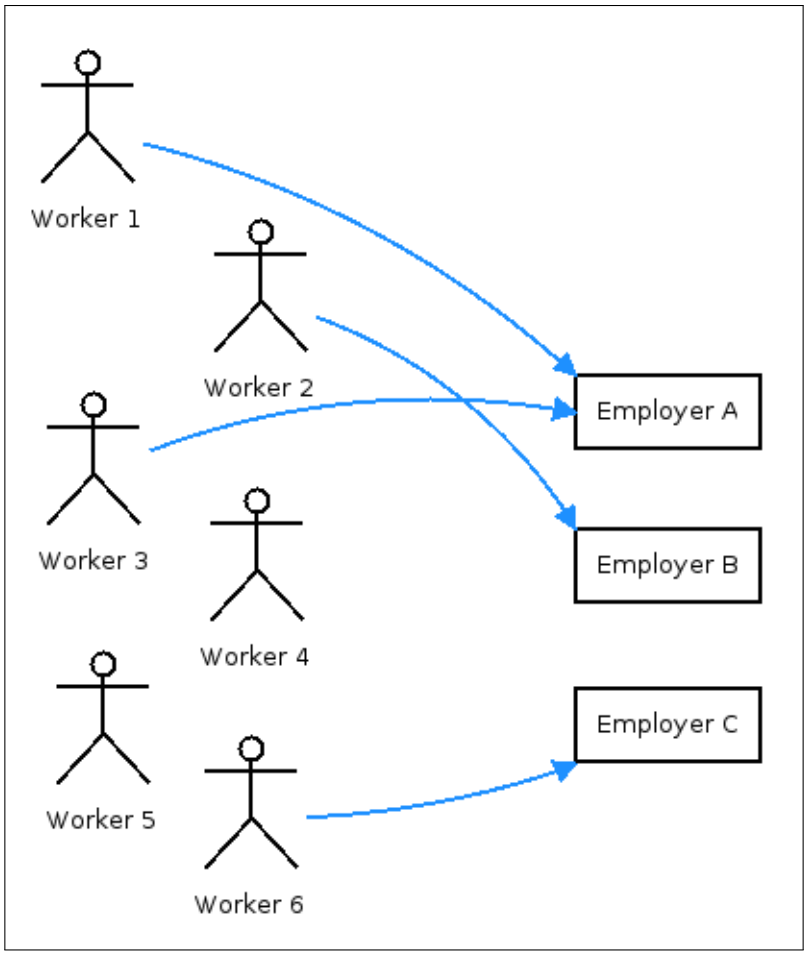

Figure 1: A Simple Labor Market Agent-Based Model

The process for building an agent-based model can be broken down into the following steps. First, a model is built that simulates the agents and their interactions. The researcher creating the model can extrapolate agents' behavior from known empirical rules of behavior or prior theoretical experiments. Then, the researcher calibrates the model so that it provides an accurate representation of real world behavior. This is done by comparing the results of the model with the known data from the past and adjusting the model's variables until the model's result and the real data match within a reasonable margin of error. This step can be iterative until a desirable level of match is achieved. After the model has been adjusted, the actual predictive experiment is done. These experiments can be run for different periods of time, population sizes, or with different sets of experimental variables [17].

2.2 Overview of the Economic Context of the 2008 Recession

The 2008 recession was caused by a loss of trust in U.S. investments. Before the recession, the housing market was booming, and the value of housing was continuously increasing. Because houses, the collateral for mortgages, were increasing in value, banks were approving riskier clients for mortgages and other loans that had the house as collateral. The banks then sold the securities for the mortgages to firms that then bundled them together with other lower risk mortgages and resold them, often to foreign investors. When the housing market crashed, those investments lost their value. The economic results were dramatic, leading to increasing unemployment, decreasing manufacturing, decreasing retail sales and declining gross domestic product for the duration of the recession [24].

During the recession, the unemployment rate increased from 5 percent to over 9 percent (Figure2). In response, the government developed and passed the economic stimulus package that took effect in January, 2009. The stimulus package consisted of three major components: tax cuts and government funded projects meant to create new employment opportunities and an increased duration of unemployment insurance aimed to provide relief to the unemployed. In this project, I used agent-based modeling to evaluate the effect of these three components of the governmental stimulus package on the economy and the labor market in particular.

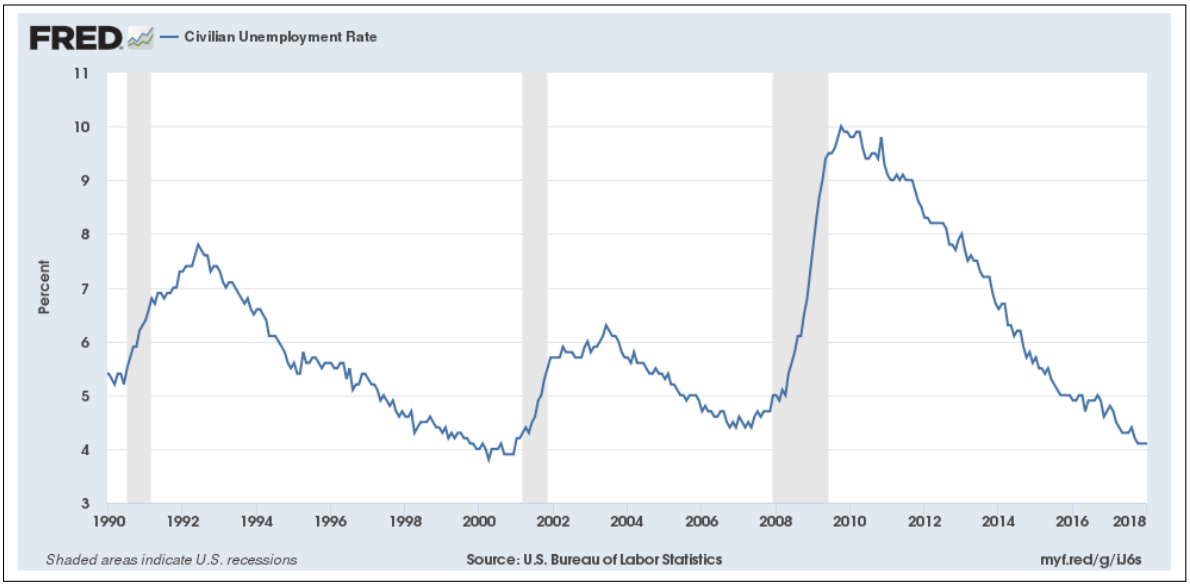

Figure 2: Civilian Unemployment Rate 1996-2016 [23]

3 Previously Published Related Works

3.1 Agent-Based Modeling for Labor Markets

Agent-based modeling has been successfully used to perform computer simulations to analyze the behavior of the labor market. In their paper *Rule-Based Modeling of Labor Market Dynamics: An Introduction*, Kuhn and Hillman [14] advocate the use of agent-based modeling for labor market simulation. The authors successfully performed an analysis of the labor market using a rule-based model, a type of agent-based model.

Several research groups have used agent-based modeling to examine the impact of various government policies on the labor market. Luca Riccetti, Albert Russo, and Mauro Gallegatti [18] created an agent-based model to examine the effect of government intervention in the form of unemployment benefits on the Italian economy, as measured through aggregate demand, financial conditions, inflation rate and the ratio between public deficit and nominal GDP. They found that an increase in unemployment benefits provided by the government sustains economic expansion, given that the central bank collaborates by buying the outstanding public debt. The researchers also state that their model could improve understanding of the 2008 recession and the following slowed economic growth. In particular, they found that the increase in taxation and cuts in government spending was a direct cause of the rising unemployment.

Economist have also used agent-based modeling for creating models of the economy as a whole to test economic theories. For example, Joseph E. Stiglitz and Mauro Gallegatti [21] argue that the current most common approach to analyzing modern macroeconomies is not sufficient to provide a deep understanding of the complex interactions that occur within them and instead recommend using agent-based modeling. They argue that comparative models cannot account for key aspects of the economy, whereas agent-based modeling can.

3.2 Further Exploration of Uses for Agent-Based Modeling

Economists have found agent-based modeling useful for simulating the effects of various policies and analyzing the degree of intended effects. Mehmet Gencer and Bulent Ozel [9] provide an overview of the EURACE project, which was a groundbreaking project in agent-based modeling. The project designed an agent-based model for macro economic policy simulation using a heterogeneous agent population of regions in Europe. The first step towards the creating the EURACE project was a paper written by H. Dawid et al. [5] in which the authors address the drawbacks of the existing economic models and the ways an agent-based model could be used to avoid those issues. The EURACE project proved that agent-based

modeling can create successful simulations of economic systems that can be of use in policy making [9] .

Jonathan Busch et al. [2] built an agent-based model in order to study policy impacts on developing heating infrastructure. The authors believe that the lack of policy support was preventing the delivery and operation of heating infrastructure. Using an agent-based model, the authors were able to identify the issues that impacted the infrastructure project success and the specific types of policies needed.

Kathrin Happe, Konrad Kellermann, and Alfons Balmann [11] designed an agent-based model in order to examine the effects of an agricultural policy change, the decoupling of subsidiary payments, on a range of indicators, such as income and production. They designed an agent-based model, where the agent population was a heterogeneous collection across many attributes, such as location, size and structure. The authors found that the policy change hardly affected the agricultural structure.

Ileana Ciutacu [3] used the modeling software NetLogo to build an agent-based model to study the impact of government taxes on the labor market of Romania over a time period of 10 years. For simplicity, their model assumes Romania to be a closed economy. The authors found that increases in taxation had a strong negative influence on labor market growth. The model was also able to successfully predict economic cyclicality by using the correlation between GDP and marginal productivity of labor.

Some other examples of agent-based modeling being used to examine policy options include the works of Lilit Popoyan, Mauro Napoletano, and Andrea Roventini [17], who built an agent-based model to examine how different monetary policies mixed with various regulations might stabilize the banking sector. Also, Chris Silvia and Rachel M. Krause [20] built an agent-based model to examine the effects of three different possible policies and hybrids thereof on the adoption of electric vehicles in urban areas. In a more generalized use, Giovanni Dosi et al [6] built an agent-based model to analyze the effectiveness of fiscal policies for different income distributions, and various related effects. Later, a paper by H. Dawid et al. [4], based on the EURACE project, examined the effects of policies designed to improve the skills of the population have on the labor market.

Agent-based modeling has been primarily used in economics for analyzing and for forecasting financial markets. For example, Eero Immonen [12] ran many sample scenarios using the agent-based model they built to verify the behavior of certain types of market efficiency. The paper argues that, since modern financial markets have a very diverse population of decision-makers that use agent specific trading strategies, it is necessary to use agent-based modeling when simulating their behavior.

Stephan Leitner, Alexandra Rausch, and Doris A. Behrens [15] used an agent-based model to analyze the impact of errors on investment forecasting. They prove that sometimes being overconfident can minimize the negative effects of errors in forecasting. Using an agent-based model, the authors were able to run simulations to compare the effects of portfolio managers being systematically wrong versus non-systematically

wrong.

Matteo Serri, Guido Caldarelli, and Giulio Cimini [19] created an agent-based model to study the instability of the interbank market before the 2008 financial crisis and its post crisis resiliency. They found that the speed at which a crisis breaks out has reached a new maximum, and showed that knowing this speed is essential for effective intervention by the authorities. The model was implemented based on a data set of 183 European banks that covers the period of 2004-2013, i.e. four years before and four years after the 2008 recession. The researchers tested the model using market shocks generally associated with oncoming crises.

4 Methods and Experimental Design

The labor market is a complex system, consisting of many different employers and workers interacting to reach an agreement. Therefore, an Agent-Based Model (ABM) is needed to represent the labor market because workers will behave differently based on their history and other unique factors, as will employers. An ABM of the labor market has at least two agent pools, the workers and the employers. These agents will interact, where the employers hire workers and negotiate each individual wage. The rules followed by the agents will differ depending on the complexity and focus of the model.

4.1 The Original Guildford Labor Market Model

The model in this project was built upon the existing "Guildford Labor Market" model presented in *Agent-Based Modeling in Economics* [10]. This simple model describes the basic mechanisms of a labor market, taking into account employer sizes and worker history. Worker history includes key factors that affect likelihood of unemployment such as age, time of last unemployment period and duration of current unemployment period. The authors chose to not include gender, due to lack of evidence of a significant difference in likelihood of unemployment. In the model, workers cycle between unemployed and employed (Figure 3), and employers go in and out of business. In the cycle for workers, the following flows are taken into account: retirement, new workers, and frictional unemployment. This model assumes that the number of vacancies is equal to the number of unemployed, i.e. for every worker there exists a job. Also, tax rate is assumed to be zero percent.

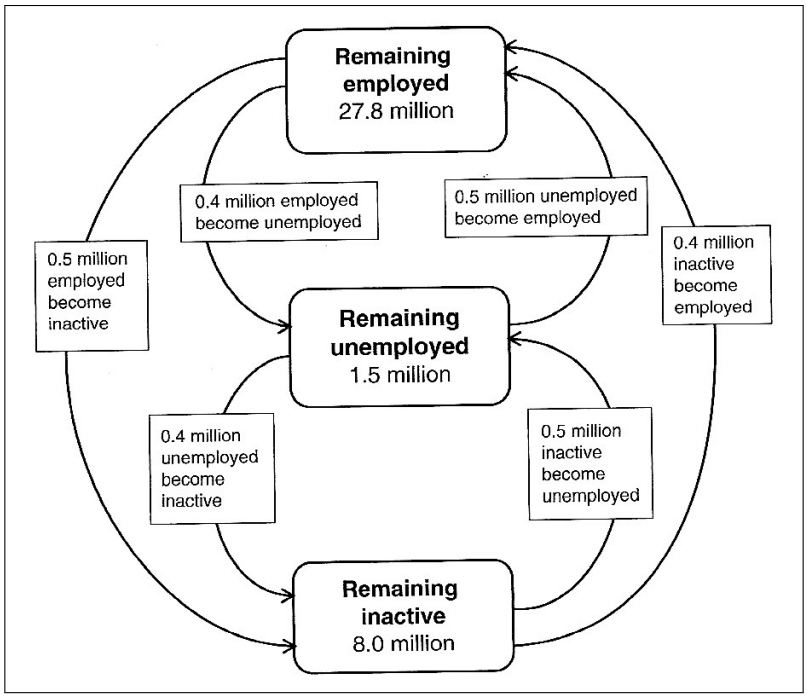

Figure 3: Guildford Labor Force Flows [10]

The model is implemented within the NetLogo programmable computer modeling and simulation environment. The NetLogo modeling environment was designed as an educational tool [14] for creating simple ABMs [25].

The original model is interactive and allows the user to customize the following five variables: percent employed leaving their job (the quit rate), the percent of unemployed leaving the labor force, the percent of employed leaving the labor force, the maximum wage increase (percent), and the maximum wage decrease (percent). The first three variables deal with the key flows in and out of the labor market, as mentioned above. The variables maximum wage increase and maximum wage decrease affect the negotiation process, which is the primary driver of the labor market model.

This function runs as follows:

Employers with vacancies look for unemployed workers, starting with the employer offering the highest wage (Figure 4).

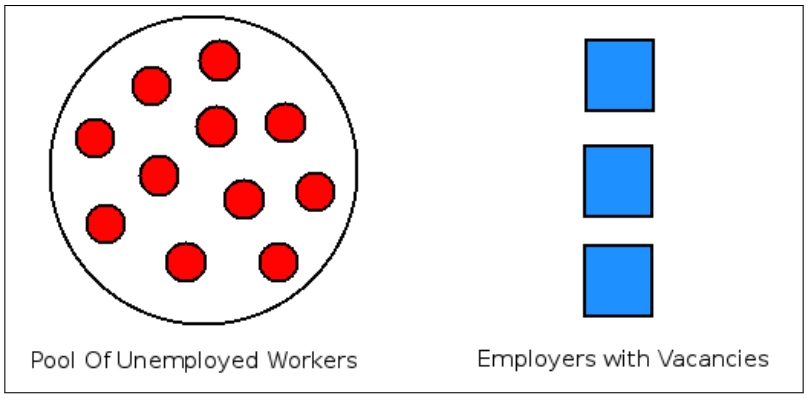

Figure 4: The Negotiation Function: Participating Agents

The unemployed workers set their minimum acceptable wage as their last wage times (1 - maximum wage decrease), and the maximum possible wage of the unemployed worker is set to their last wage times (1 - maximum wage increase).

If the maximum wage offer of the employer is less than or equal to the maximum possible wage of the worker and the minimum acceptable wage of the worker is less than or equal to the maximum wage offer of the employer (Figure 5), the worker is added to the pool of possible workers for the given vacancy. The employer will choose the worker with the highest previous wage out of the pool of possible workers.

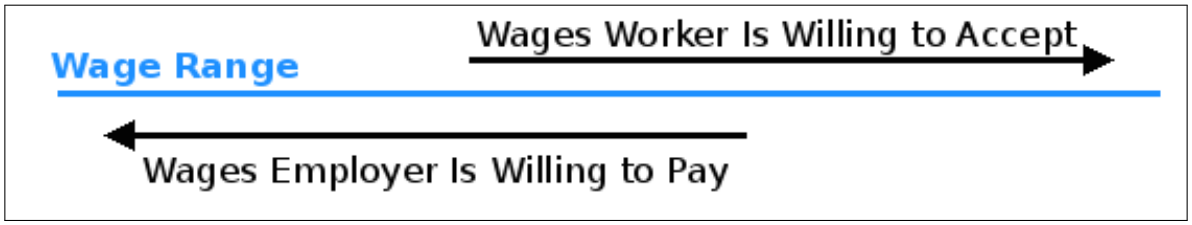

Figure 5: The Negotiation Function: Agreement can be reached

If the maximum wage offer of the employer is greater than the maximum possible wage of the worker or the minimum acceptable wage of the worker is greater than the maximum wage offer of the employer, the employer and worker cannot reach an agreement, and the worker remains unemployed (Figure 6). If the employer cannot reach an agreement with any of the unemployed workers, the vacancy will remain open.

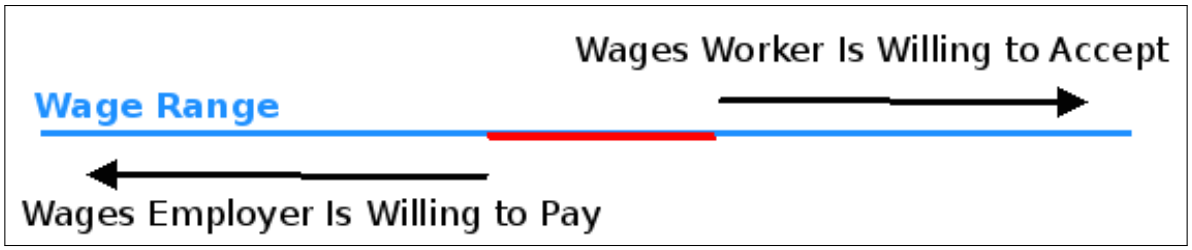

Figure 6: The Negotiation Function: Agreement cannot be reached

4.2 Modifications Made to the Simple Guildford Model

The simple Guildford Labor Market model of the labor market described above assumes that the number of vacancies is equal to the number of unemployed. Also, this model assumes that the tax rate is 0. Both assumptions are oversimplifications and do not reflect reality. Thus, I developed a new model by introducing several modifications to the simple Guildford Labor Market model as described below.

The original simple model consist of two scenarios, "Guildford" and "Homog," Guildford being the experimental model and Homog being the control model. In both scenarios, the number of workers is 1000, the number of employer is 100, and the number of jobs is equal to the number of workers. As the primary goal for this project was to analyze the labor market of the United States in the context of the 2008 recession, and the subsequent 2009 stimulus package, I created a third scenario titled "USA2008." To do this, I made the following changes.

The First Modification: Business size distribution. Businesses come in a range of sizes, with small businesses employing as little as one worker and larger businesses employing over 500 workers. Each economy will have businesses distributed mostly within this range, with some large businesses, and each economy will be distributed differently based on the prevalence of small or larger businesses. For the USA2008 scenario, I abridged the U.S. Small Business Administration data on firm sizes [8]. This scenario has 987 workers and 231 employers, therefore, the number of jobs is less than the number of workers.
The distribution is as follows:
2 employers with 60 workers (from 18,469 firms with 500+ workers)
9 employers with 30 workers (from 90,386 firms with 100-499 workers)
53 employers with 6 workers (from 526,307 firms with 20-99 workers)
63 employers with 2 workers (from 633,141 firms with 10-19 workers)
104 employers with 1 workers (from 1,044,065 firms with 5-9 workers)
The 3,617,764 firms with 0-4 workers were too small to include in the abridged model.

I also included a fourth scenario "USA2008big" that is similar to "USA2008" except the business size distribution favored larger businesses (e.g. it had 10357 workers and 595 employers). Accordingly, the number of employers closing on a regular basis was increased to reflect the increased business sizes.

The Second Modification: Wages. Some additional smaller changes were made to the model to customize it to the USA2008 situtation. For wages, the "USA2008" scenario has a mean of 2.8923 and a standard deviation of 0.62515 [1], where the original Guildford had a mean of 1 and a standard deviation of 0.7 [10].

The Third Modification: Time Scale. Also, as we are looking at a shorter period of time, the ticks were set as weeks, rather than quarters. In addition, the user could set the number of weeks for which an unemployed worker was able to be on unemployment insurance.

The Fourth Modification: Turning points and the Recession Index. In order to simulate and study a particular recession and the corresponding stimulus plan, the new model needed events to occur at certain relative points in time. In particular, the most important time points were: first, when a shock to the market that prompted a recession occured, and second, when an action meant to correct the results of the recession was introduced. The user interface developed for the new modified model allowed for options to be chosen for these time points.

The recession is represented in the new model by the number of employers suddenly closing their businesses. For simplicity, this was set as a one-time occurrence. The number of employers closing is determined by the recession index, which is an arbitrary number ranging from 0 to 100, and is used to calculate the number of employers closing as follows:

$$((RecessionIndex/5) * numberOfEmployersClosingUsually)/4.$$

The Fifth Modification: Tax rate. One of the biggest changes to the model was the inclusion of tax rate. In the original negotiation function in Section 4.1, it is assumed that there is no tax rate. However, tax rate is always a factor when considering wage in the real-world labor market and lowering tax rate is one of the primary methods to combat a recession. When included in the model, the tax rate especially affects the lower end of the wage range. While looking at a potential job, a rational worker will deduct taxes from the wage being offered to evaluate the "real wage." They then proceed to compare the calculated "real wage" to their minimum acceptable wage. If the wage offer of the employer is still greater than or equal to their minimum acceptable wage even after deducting tax rate, the offer is accepted. Therefore, if tax rate decreases, the range of wages a worker is willing to accept increases. When workers are more willing to accept lower wages, the employers can afford to hire more people. That is why in response to a recession, taxes are often lowered to stimulate the job market by increasing worker-employer match-up likelihood

and to increase the number of jobs in total.

The introduced tax rate is represented in the model by an interactive function where the user can change the tax rate at the time when the simulation starts. As part of the stimulus package, there is also an interactive variable called the "change in tax rate". It assigns a new value to the tax rate. For example, if the tax rate at the beginning of the model is 19.6 percent, and the change in tax rate is -5 percent, the new tax rate is 18.6 percent. This is calculated using a manipulation of the percent change equation:

$$NewTaxRate = ((PercentChange/100) * OriginalTaxRate) + OriginalTaxRate.$$

In the model's user interface, tax rate can be changed within the range of -50 percent to +50 percent. However, just as a negative change in tax rate widens the range of wages a worker is willing to accept and thereby stimulates the creation of new jobs, a positive change in tax rate shrinks the range of wages a worker is willing to accept. Having workers demanding higher wages, the employers cannot afford to hire more workers, and if the change is large, the employers must lay-off some of their existing workers.

The Sixth Modification: Government funding index. Another part of the stimulus package is the government funding index, which is an arbitrary number ranging from 0 to 100 and is used to calculate the number of new employers created. In the real world, this is caused by a chain of events triggered by the government funding of projects such as infrastructure development and other public works. When the government funds a project, the total market demand for the materials and services increases. In response to the increase in demand, existing companies that produce the materials and provide the services will hire more people, and new companies will be created. This phenomenon is represented in the model by a proportional increase in employers being created. The calculation is as follows:

$$((GovernmentFundingIndex/5) * numberOfEmployersClosing)$$

The Seventh Modification: Duration of the pre-existing unemployment. In the original model, workers started with no unemployment history. To reflect the real-world situation, in the modified model, the workers are initialized with a random duration of unemployment between 0 and 30 weeks.

The Eighth Modification: Duration of the unemployment insurance. As mentioned earlier, in the new version of the model the user can set the number of weeks the unemployed workers can claim unemployment insurance. As a part of the stimulus package, the user can set this to a new value. During a recession, the duration of unemployment insurance is increased to provide relief for unemployed workers, however for the duration of time during which workers are on unemployment insurance, they are generally unwilling to accept a job that offers lower wages than their previous job. This is another factor that affects the negotiation function mentioned above. When the duration of unemployment insurance is increased,

the range of wages a worker is willing to accept remains smaller for a longer period of time, thus slowing down the labor market.

Graphs that track the workers on unemployment insurance and the tax rate were added to the model's user interface.

4.3 Model Calibration

Before running experiments with the model, the model has to be calibrated by setting the initial parameters in such a way that the model represents the 2008 recession and subsequent stimulus within an acceptable margin of error compared to the real-world values (Figure 7).

The parameters described below were used for the model calibration:
The average quit rate, as a percent of employed workers leaving their jobs, for 2007-2009 was 1.8 percent of total employed [13]. The average percent of unemployed leaving the labor force for 2007-2009 averages to 0.8 percent of total unemployed [7]. The average percent of employed leaving the labor force for 2007-2009 averages to 1.7 percent of total unemployed [7]. Maximum and minimum wage increase percent is another complex number that is difficult to find data on for a large economy such as the U.S. economy, therefore, after experimentation they were both set to 50 percent.

Before the stimulus package was introduced, the federal tax rate was 19.6 percent [22], and the duration of unemployment insurance was 26 weeks [16]. According to The National Bureau of Economic Research, the recession began in December of 2007, and the stimulus took place in January 2009, which is 56 weeks after the recession officially began [24]. For modeling, only the distance between the two time points −− when the recession starts and the stimulus package is introduced −− matters, so the week at which the recession begins can be set arbitrarily. The recession was set to begin after initial process of getting the labor market up and running from zero had completed and a real-world trend begins to show. This occurs around week 150. If the recession is set to occur in week 250, then the stimulus should be set to occur in week 306.

The stimulus decreased the tax rate by 5 percent to 18.6 percent[22] and increased the duration of unemployment insurance to 99 weeks[16]. According to the Federal Reserve Economic Data, the unemployment rate increased from 5 percent in December 2007 to 7.8 percent in January 2009. In the model, if there are 231 employers, and the unemployment rate is to increase from the initial 5 percent to 7.8 percent, the number of employers closing their businesses is 9. In order to reach the Recession Index, the number of employers closing is multiplied by 5 to reach 45.

As the government funding index covers all forms of project funding and small business tax cuts, it is

difficult to calculate exactly how many jobs were created by government funding alone, so the government funding index has been set at 26 as an approximation discovered through experimentation.

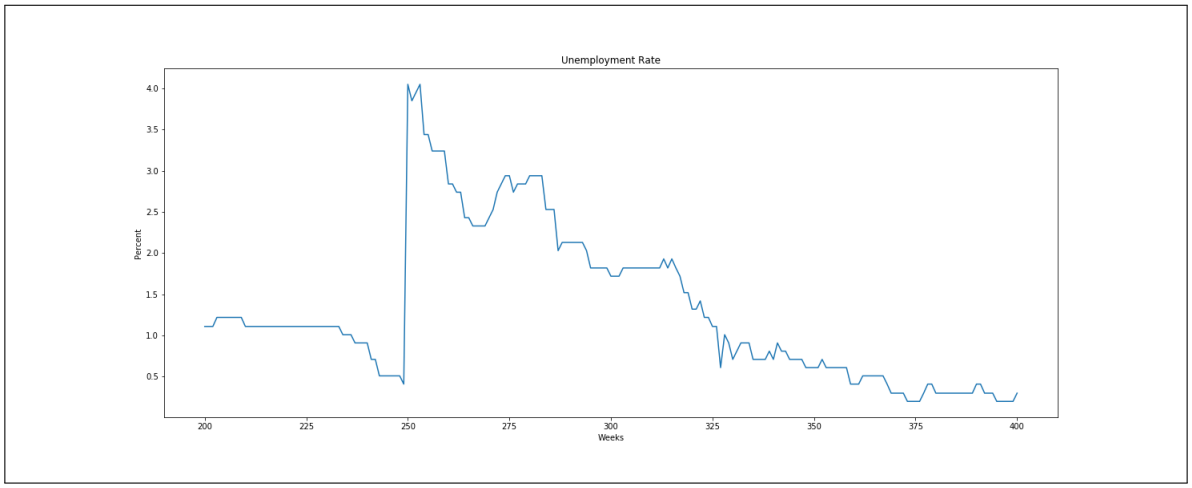

Figure 7: Relative Effect of Real Stimulus on Unemployment Rate (Y-axis). The recession starts in week 250 (X-axis). Stimulus is introduced in week 306.

5 Experiments and Results

To analyze the effect of the different components of the stimulus package on the labor market, I ran targeted simulation experiments on a labor market representative of the middle of the 2008 recession. The model was set to run for 500 weeks, following the percent of workers entering and leaving the labor force, wage changes and quit rates determined during the calibration period. The extent of the recession, the distance between the recession and the stimulus, the initial tax rate and the initial duration of unemployment insurance were set to the real 2008 numbers, based on the initial Calibration of the model described in Section 4.3 above. For comparison, an experiment where the government took a laissez-faire approach and did not pass a stimulus package was also run (Figure 8).

Due to the time-consuming nature of these simulations, the experiments in the project were pilot experiments, with only a few runs for each parameter set. Consequently, statistical analysis cannot be made at this time. Therefore, in this project, only labor market trends were analyzed, and representative experimental results are shown in the tables and figures below.

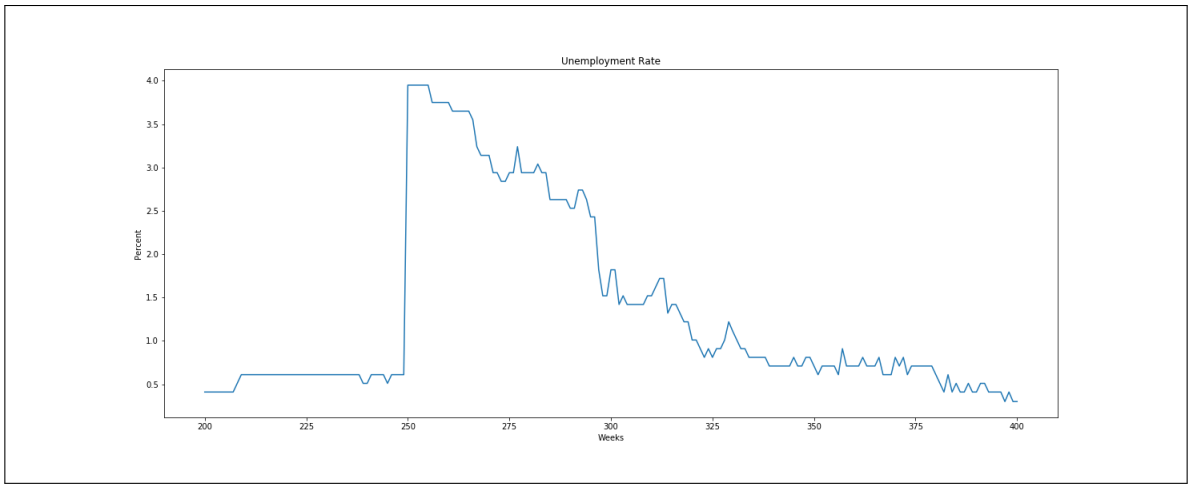

Figure 8: The effect of the Laissez-faire on Unemployment Rate. The recession starts in week 250. No government stimulus measures were introduced.

5.1 Modeling the Effect of Tax Rate Changes

The first round of experiments was designed to determine the effect of tax cuts alone. To isolate the tax rate variable, unemployment insurance was set to have no change and the government funding index was set to zero. I ran experiments where tax rate changed by -5, -10, -20, -25 and -50 percent. Representative experimental results from the -5 and -25 percent experiments are shown in Table 1 and Figure 9, demonstrating an unemployment rate trend as a result of a decrease in tax rate. From the results, we can conclude that decreasing tax rate influence the unemployment rate.

Tax Cut	**UE drops below 2% in:**	**UE drops below 1% in:**
0%	1 week	16 weeks
5%	2 weeks	4 weeks
25%	1 week	* weeks

Table 1: Tax Cuts effect on Unemployment Rate (UE). * The value was not calculated due to the time period being too long.

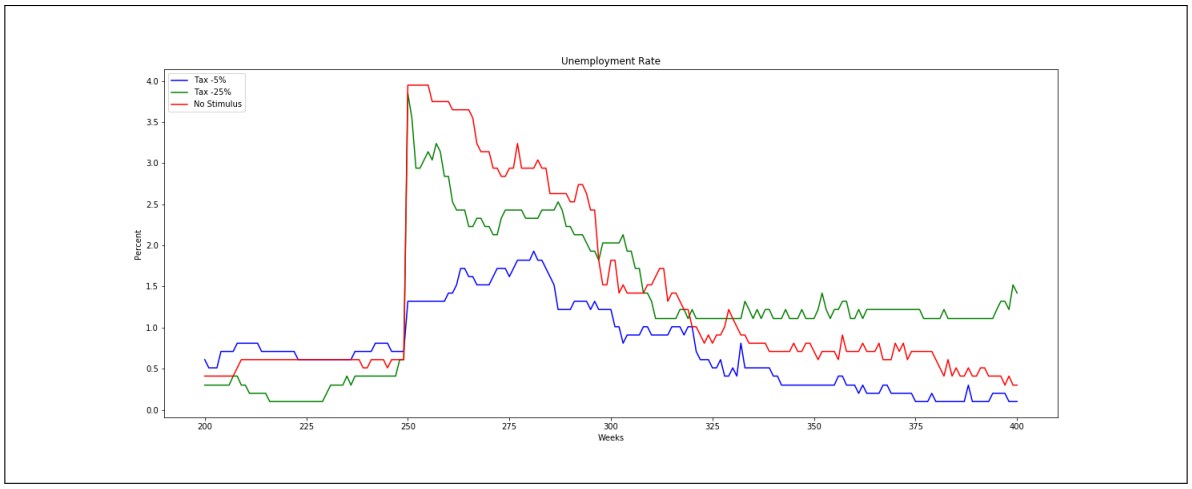

Figure 9: Tax Cuts effect on Unemployment Rate (Y-axis). The recession starts in week 250 (X-axis). Stimulus occurred in week 306. Red line: no stimulus (Laissez-faire approach); Green line: tax reduced by 25%; Blue line: tax reduced by 5%.

5.2 Government Funding of Projects

The second round of experiments was designed to determine the effect of introducing government-funded projects alone. To isolate the government funding index, both tax rate and unemployment insurance was set to have no change. In the experiments, the government funding index was set to 10, 25, 50, 75 and 100. The results of the modeling show that government funding causes job vacancies to increase, however there is no strong evidence for a corresponding decrease in unemployment rate (Table 2 and Figure 10).

Government Funding	**UE drops below 2% in:**	**UE drops below 1% in:**
0	1 weeks	16 weeks
10	1 weeks	22 weeks
50	0 weeks	0 weeks

Table 2: Government Funding of Projects effect on Unemployment Rate (UE)

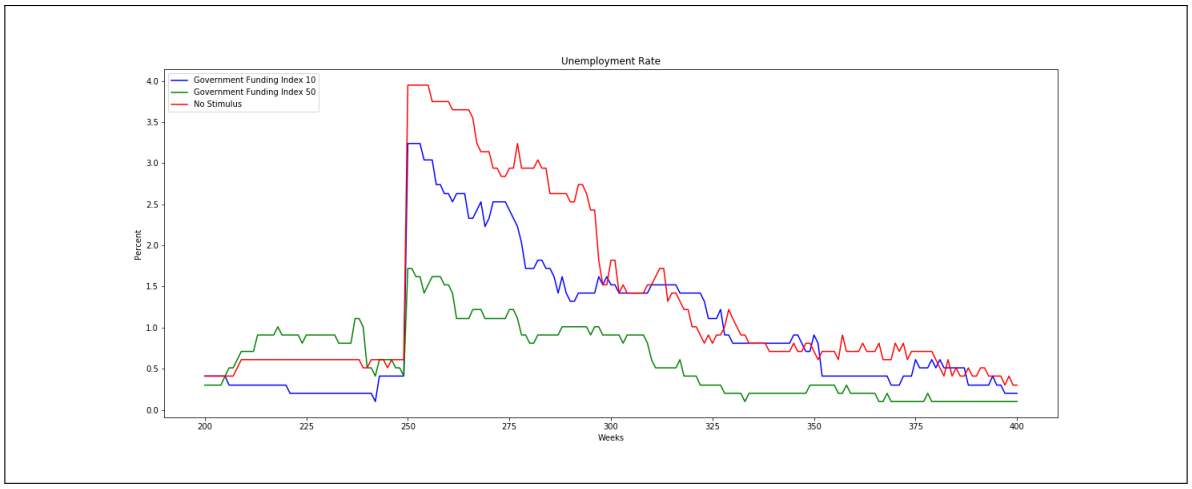

Figure 10: Government Funding of Projects effect on Unemployment Rate (Y-axis). The recession starts in week 250 (X-axis). Stimulus is introduced in week 306. Red line: no stimulus (Laissez-faire approach); Green line: Government funding index 50; Blue line: Government funding index 10.

5.3 Combination of Tax Cuts and Government Funding of Projects

The third round of experiments was designed to determine the combined effect of government funding and tax cuts. To isolate the pair, unemployment insurance was set to have no change. I ran experiments where (tax rate, government funding) was equal to (-5,25), (-5,50), (-10,10), (-10,25), (-10,50), (-20,10) and (-20,25) (Table 3 and Figure 11).

Tax Cuts	**Gov't Funding**	**UE drops below 2% in:**	**UE drops below 1% in:**
0%	0	1 week	16 weeks
10%	25	0 weeks	0 weeks
25%	10	1 week	8 weeks

Table 3: A combination of Tax Cuts and Government Funding and the effect on Unemployment Rate (UE)

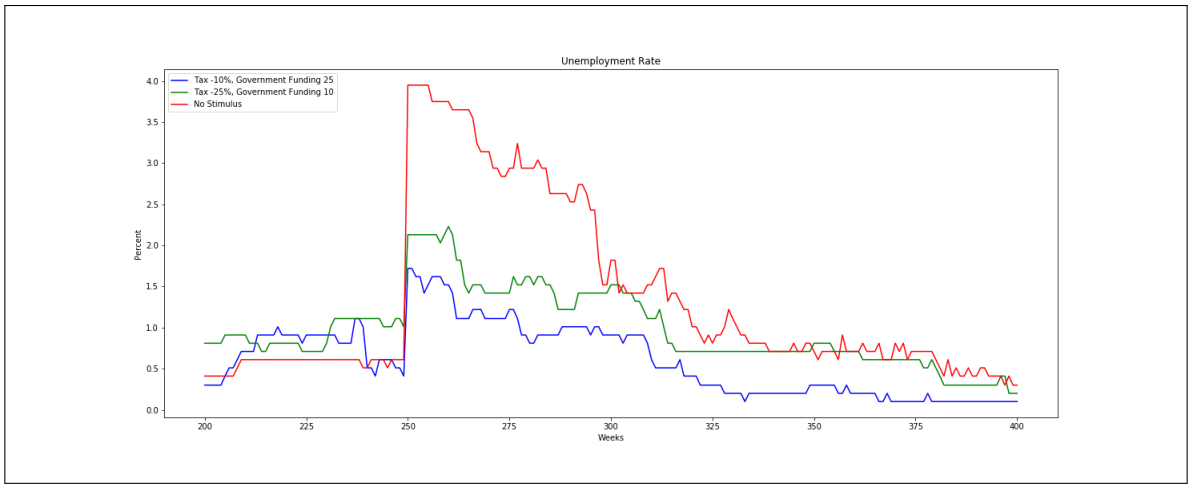

Figure 11: A combination of Tax Cuts and Government Funding and the effect on Unemployment Rate

5.4 Unemployment Insurance Duration

The final round of experiments was designed to determine the effect of unemployment insurance on the labor market when an increase in duration of unemployment insurance was a part of the stimulus package. I ran experiments where the 26 weeks of unemployment insurance was extended to 60 and then to 100 weeks, and compared those to the experiments with the same stimulus package but no change in unemployment insurance. The stimulus packages these experiments were run with include: tax cut (50%) only; government funding (75) only; a combination package of a 10 percent tax cut and a government funding index of 25. The results show that, a greater the length of the unemployment insurance causes a slower the decrease in unemployment rate (Table 4 and Figure 12)

Increase in UI	**UE drops below 3% in:**	**UE drops below 2% in:**
0 weeks%	0 weeks	0 weeks
34 weeks%	11 weeks	36 weeks
74 weeks%	1 week	29 weeks

Table 4: A with and without an expansion of Unemployment Insurance (UI) and the effect on Unemployment Rate (UE)

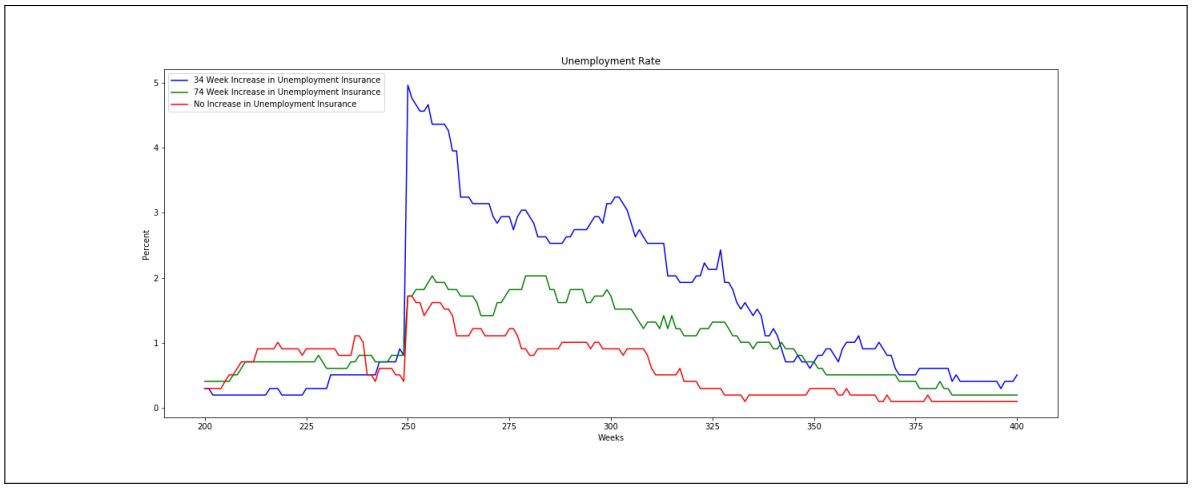

Figure 12: The effect of a stimulus package with and without an expansion of Unemployment Insurance on Unemployment Rate.

6 Discussion

The goal of this project was to: (1) develop a model to simulate the U.S. 2008 recession and (2) use the developed model to evaluate the efficiency of the components of the governmental stimulus package. The stimulus package was assessed from the point of view of improving the labor market by lowering the unemployment rate. To achieve these goals, I used the agent-based simulation of the economy within the NetLogo multi-agent programmable modeling environment. The model developed in this project was based on the Guildford Labor Market model, a simple labor market model described in [10]. The original simple model was modified by introducing several important changes, made in order to make the model more realistic and to reflect the actual state of economy in the 2008 recession.

The developed new model, USA2008, was calibrated for the simulation to arrive close to the real-world parameter values. Then, the developed model was used to assess the influence of the three components of the stimulus package: tax cuts, government-funded projects and an increase in the duration of unemployment insurance. The simulations demonstrated that these components were not equally effective in addressing the issues with the labor market, in particular, the unemployment rates.

6.1 Economic Implications of the Experimental Results

The results show that cutting taxes and increasing government-funded projects are beneficial to the labor market. Moreover, a combination of tax cuts and government funding is more effective than either individually. Also, a small tax cut and a large amount of government funding is less effective than a large tax cut

and a small amount of government funding. Therefore, when using fiscal policy to combat high unemployment, both tax cuts and increases in public expenditure should be used, with a heavier emphasis on public expenditure.

On the other hand, increasing the duration of unemployment insurance has a negative effect on the labor market. When the period of unemployment insurance is lengthened, the unemployment rate takes longer to decrease. Thus, although unemployment insurance is beneficial to improving public sentiment, it can slow down overall economic recovery. This implies that, if at all possible, increasing the duration of the unemployment insurance as a part of stimulus packages should be avoided.

6.2 Successes and Limitations of the Model

The agent-based model developed in this project successfully reflects the heterogeneity of the labor market, and models the recession of 2008. As expected, the experiments that were run using the model demonstrated the relative effectiveness of the different stimulus components.

However, the developed model has some limitations. Even though several modifications to the model have been introduced to reflect the real-world economy, the model is still simplified. For example, in the real world, recessions involve much more than a one week increase in the number of businesses going out of business. An economy will experience the lasting effects of a recession for a period of many weeks, sometimes even more than a year as seen in the recession of 2008. Also, an economy is a complex structure of many social, political and monetary factors, thus a more complex model that simulates an entire economy, beyond the labor market, would be useful in analyzing the other effects of a recession, such as decreased production.

In addition, in the real world, any component of the stimulus, such as government funded projects, does not show its effect immediately and directly, rather the effect is delayed and continuous for a period of time, which should be taken into account in the simulations. Another example of real-world complexity is that the real descision process for accepting or rejecting job match-ups is complex. For example, an important factor in determining the maximum wage decrease the worker is willing to accept is the length of their pre-existing unemployment. If a worker has been unemployed for a longer period of time, they are more willing to accept a lower wage.

Another significant limitation of the model is that though it demonstrates relative effectiveness of the different stimulus components, it does not show their absolute effects. To show the absolute effect, a longer and more precise calibration will be necessary. In addition, the model assumes that government-funded projects create jobs, but a simplified model cannot calculate the direct relation between a dollar amount

of project funding and the exact number of jobs created solely due to that reason. Determining the exact relation would require a much more complex model that simulates the entire economy. For a larger more complex model, a different software designed specifically for larger projects, such as BioNetGen, would offer more flexibility and processing power [3].

The modeling experiments in this project were time-consuming, therefore, due to time constraints, the experiments in this paper were run only a few times. Most of the data presented here is from single-run experiments. Therefore, during analysis, only general trends can be observed. For a more thorough quantitative analysis, many runs would need to be done, and the resulting data would need to go through statistical analysis.

6.3 The Big Picture

Working on this project was very instructive and provided much information on the behavior of economic recessions and about the various approaches the government can take to deal with their negative consequences. Recessions are a period of economic downturn with serious economic and social effects. While the economy is in decline, unemployment rate rises and contributes to further decline. Though there are many factors that contribute to a recession, rising unemployment rate is the factor most feasible for the government to directly influence.

The government has several methods to combat rising unemployment. The government can support projects that then stimulate demand and the creation of new businesses, adding more jobs to the job market, or it can cut taxes to both business and individuals. Both forms of tax cuts work in similar ways, by widening the range of acceptable wages (Section 4.2). If taxes on businesses are cut, the employers are willing to pay workers higher wages, so more jobs become attractive to more workers. If taxes on workers are lowered, the workers are willing to except a lower pay, which also leads to a reduction of unemployment (Section 4.2).

During a recession, the government is not only concerned with speeding up economic recovery, but also providing relief to those affected. During normal economic periods, the government provides relief to unemployed workers and their families via unemployment insurance, which pays the workers a certain percentage of their last wage for the first few months of their unemployment. During times of recession, the average length of unemployment is apt to be longer, thus, to provide additional relief to workers affected, the government lengthens the period of unemployment insurance.

Although the above measures all aim to improve economic conditions and fight the negative consequences of a recession, individually, the measures are not equally effective, and might even be counter

productive. In reality, the government can speed economic recovery, but the government must carefully weigh the trade-offs between increased spending, decreased income, and the negative consequences. Additional concerns include budget limitations and political issues such as federal debt and public sentiment. Considering all of the above, a thorough economic modeling should be done before making policy decisions, with attention to statistical considerations and validity.

6.4 Future Work

In the future, several expansions can be made to the project. First, confirming the conclusions by running many experiments and averaging the results, to achieve proper statistical validity of the data interpretations. This would strengthen the analysis and arguments made. Second, including greater complexity to the model would bring the model closer to the real-world economic situation. For example, increased complexity may include things like extending one-time events into prolonged ones that last for many weeks and months. Another example is adding more heterogeneity to the workers and employers in areas such as industry. Third, reproducing and running the model in other modeling environments designed for more complex simulations, to allow for further increases in complexity and scale.

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