

Title of Your Senior Thesis Proposal

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Abstract

Provide a concise summary of your proposed research. Remember that the abstract is *not* an introduction, it is a *summary* of the entire document. It makes sense to wait to write the abstract until the rest of the document has been written.

Introduction

This senior thesis aims to use an agent based model (ABM) to explore the effects of changes in minimum wage on the employment level, employment growth, and income distribution of the simulated economy. Similar to contemporary economic models and theory, the proposed research endeavors to explain observations in various economies in our world and shed light on the possible causal relationships that exist. The relationship between minimum wage and employment has been studied extensively in the labor economics literature, but typically through the use of empirical analysis using real world data. The ultimate goal of this thesis is to gain insight on the relationship between minimum wage and employment in an environment where variables can be controlled and all of the information related to the environment can be obtained.

ABMs are a useful tool that allows researchers to develop more sophisticated economic models because they allow the researcher to abandon the typical assumption of perfectly rational agents, and thus creates a model more closely resembling the real world. In an economics ABM, the researcher creates a set of typically heterogeneous agents with adaptive behaviors/heuristics and runs a simulation of the model over a specific length of time. For example these agents can represent households and firms, and their behaviors might include setting an expectation for wages, searching for potential employers/employees, and building networks with other households and firms.

Agents are made heterogeneous in order to more realistically resemble the real world, and also to create emergent characteristics of the macro economy represented in the model. In typical economic models, the behaviors at the agent level are thought to scale up to the macro level in predictable ways [23]. Agent based models take advantage of heterogeneity at the agent level in order to implement a system where the macro level characteristics are still born from the interactions at the agent level, but in a way that is not linear and predictable [23]. Agents are not given perfect information and are typically implemented using heuristics in order to move away from the assumption of perfect rationality, since that assumption is typically the most unrealistic part of any economic model and research has shown that people typically do not make perfectly rational and optimising decisions [23].

The ABM proposed in this paper uses the ABM detailed by Caiani et al. as a starting point and benchmark and includes heterogeneous agents that represent households, firms, banks, the

Government, and a Central Bank [10]. The actions taken by the agents will run in discrete time, so the simulation will move in periods instead of being an asynchronous simulation. During these periods the agents will interact with each other in specific ways at specific times. The agents will interact in ways that are abstractions of interactions that occur in our world; households will receive wages from firms, firms will buy goods from each other and produce their own at a price they set, banks will provide services to both households and firms, the Government will collect taxes, and the Central Bank will regulate the money supply. Their behavior will not be perfectly rational, because they will not have perfect information of the market and environment they operate within. Additionally, agents will use past information to make decisions in the current period. For example, if a firm producing consumption goods had too much inventory left over from the previous period, they will adjust their price accordingly in order to attract more customers [10]. This method of implementation allows the ABM to step away from the traditional assumptions of representative and rational agents.

The main motivation behind the proposed research is to gain insight on the impacts of minimum wage levels in order to better understand the consequences that populations might face when their Government enacts new legislations. Inequality is a major problem in the United States, and many people are frustrated with the current standard of the labor market in our country. This research aims to provide insight into the potential effects of this kind of policy in order to help insure good outcomes for those it is trying to help.

Related Work

This section of the paper will focus on the literature relating to agent based models - in general, and in the context of economics - and inequality, both independent of each other and their intersection. It concludes with a discussion about the similarities and differences of approaches taken by the aforementioned authors and the proposed research.

Economics has a rich history of a variety of models used to abstract and explain the complicated interactions we observe in economies. One type of model that gained popularity in the early 2000s is the Dynamic Stochastic General Equilibrium (DSGE) model. This type of model applied the basic supply and demand mechanism described in general equilibrium theory to model a changing model that accounted for the random occurrence of specific events in the economy. [23] These models were inspired by the belief that characteristics of the macroeconomy should be built by the interactions of agents on the micro level [23]. These agents were assumed to be rational and optimize their decisions using typical rules provided by contemporary economic literature - for example, the use of budget constraints. [23]. DSGE models were particularly popular among the central banks of various countries [29]. The DSGE models created by Smets and Wouters from the European Central Bank and the National Bank of Belgium were made to simulate the European and United States economies, and were soon held as the benchmark DSGE models in the DSGE literature with both having been cited more than 4,000 times [34] [35] [29]. Post 2008 DSGE models came under heavy scrutiny. Despite their use as tools to explore the affect of shocks to the economy, they were unable to predict the possibility of a financial crisis [34] [35] [29]. Smets et al. published a follow-up paper in 2016 addressing the difficulties faced by current DSGE models in explaining various parts of the financial crises.

In this paper Smets et al. extend the benchmark model in order to account for the financial crisis and state:

“ We conclude that these extensions go some way in accounting for features of the Great Recession and its aftermath, but they do not suffice to address some of the major policy challenges”

Other shortcomings of the typical DSGE model were presented by other authors. The most important of these critiques is that the assumption that agents in an economy are perfectly rational, make optimal choices, and have a perfect understanding of the structure of the market in which they operate [23] citeGualdi-tipping-paper. This assumption is obviously a large one to make, and does not represent the reality observed in the economy. Other points of critique for DSGE models are their assumptions related to linearizing micro behavior to macro behavior, difficulty in being extended, and inability to portray markets that display disequilibrium [23] citeGualdi-tipping-paper.

Agent Based Models (ABMs) provide a potential alternative to DSGE models and are able to address the critiques made towards DSGE models. ABMs are models where agents are heterogeneous, have disperse interactions with one another, and their behaviors are adaptive and implemented with heuristics [23]. As a result, ABMs do not necessarily make the assumption that agents are homogenous, rational, optimising, and have perfect information. The heterogeneity of the agents in ABMs also doesn't assume that the behavior at the micro level translates perfectly to the macro level; the characteristics of the macro level behaviour in ABMs are a result from the many interactions happening at the agent level and gives the possibility of unexpected and emergent behaviour [23].

The literature of ABMs is large and varied and includes a wide array of years and subjects, including physics, ecology, biology, and computer science [23]. In economics, ABMs have been studied in many different ways. There are papers that focus on the use of ABMs from a theoretical perspective, and comment on their history, applications, and legitimacy as a method of modelling in economics, see Haldane and Gualdi for examples of these kinds of papers [23] [21].

Another kind of paper in the economic ABM literature aims to implement an ABM with the specific goal of capturing some kind of characteristic about the construct that it is modelling. These papers don't necessarily ask a question, but rather aim at creating a model that matches real world data as closely as possible. In his paper, Lengnick proposes an ABM to serve as a baseline model that includes households and firms as heterogeneous agents [28]. The ABM presented is able to reproduce a number of stylized facts, includes market equilibrium as a consequence - not an assumption - of agents interactions that arises endogenously from the model, includes coordination failures when allocating households to firms, and endogenous crises [28]. Caiani et al similarly propose a benchmark model for macroeconomic ABMs that includes households, firms, banks, and the government as heterogeneous agents [10]. The ABM detailed in their paper uses the accounting concept of balance sheets to retain internal consistency and is able to reproduce a number of stylized facts including those related to standard deviation of GDP, investment, unemployment, and consumption [10]. The ABM proposed in this paper will attempt to extend the ABM presented by Caiani et al., and as a result their ABM will serve as the

starting point and benchmark. The Caiani paper and benchmark ABM will be discussed in more detail in the methods of approach section. Kinsella et al. propose another ABM that also uses balance sheets to insure internal consistency, and also include a role for technology in education among the households, firms, and banks in the model [27]. This paper aims to recreate the income inequality observed in empirical literature endogenously and is not necessarily attempting to provide a benchmark model for other researchers. [27]. Similarly, a paper written by Assenza et al. explores how the simulation results from a benchmark ABM are changed when concepts of capital and credit are introduced, and to what extent the inclusion of these concepts help the ABM to reproduce a crisis similar to the one observed in 2008 [6]. While there are a number of papers that all present various ABMs aimed at replicating different markets and analyzing the microbehaviours that contribute to the overall structure, ABMs have been used to study other kinds of problems.

ABMs have also been used as a method to analyze how a certain policy or change in the economy will impact certain groups, characteristics, or distributions. A paper by Guerini et al. explores not only the relationship between DSGE models and ABMs, but also investigates the role that real wage has on the failure of an economy to perfectly coordinate firms seeking employees and households seeking employment [22]. ABMs have also been used extensively in finance and questions related to the efficacy of monetary policy. Braun-Munzinger et al. used an ABM of the corporate bond market to investigate the performance of different fund strategies and propose policy to help the market overall [9]. Erlingsson et al. investigate the housing market through an ABM and focus on the effects of credit and credit policy on housing bubbles and the business cycle observed in the model economy [15]. There are also a number of papers that explore the characteristics of the model economy by instead shifting focus to changes in the agent behaviour and the impact it has on the economy. Kim and Kim explore to what extent the differences in agent rationality impact the effects of monetary policy on the economy [26]. Alfi et al. endeavour to create a minimal ABM to simulate a financial market and focus on analyzing the effect of two different types of agent behaviour on the trends observed in the market [4]. Bertella et al. create a similar ABM to the one used by Alfi et al., but also include heterogeneity among the agents confidence levels and memory, further increasing the ‘irrationality’ of the trading agents [8]. Delli Gatti and Desiderio, Popoyan et al., and Assenza et al. all use ABMs to study the effects of different approaches to monetary policy on the stabilization of the economy when it is subject to a shock, and all find similar results [18] [33] [5].

Inequality in all forms has been studied in labor economics for a long time, and there are many different types of papers that all tackle different aspects of the issue. There are papers like the one written by Kaufman that provide a survey of the literature of labor economics and a revisionist interpretation of the classical “Wealth of Nations” [25]. There are also papers that investigate the impact of different variables on income and wealth inequality. For example, Bakhtiari and Meisami study the impacts of health and education on the income inequality of Islamic countries [1]. Najman et al. conduct a 30 year study observing over 2000 Australian families to investigate the impact of poverty and its affect on the hardship of children’s lives and finds a bidirectional correlation [31]. Papers that investigate possible policy options at reducing inequality are also popular; Alam analyzes the economy of Bangladesh to find the factors that influence poverty and suggests that policy should be created in order to address these underlying factors [3].

There is one area of labor economics that garners much attention in the literature, and remains a contentious subject with many different and opposing results.

One of the largest debates in labor economics is the potential affect that minimum wage increases have on the level of employment. Traditional economics suggests that an increase in the minimum wage is synonymous with an increase in the price floor for employment, and will lead employers to reduce their demand of workers, and the level of employment will fall [25]. There have been many papers investigating these effects and many paper provide opposing results, with some suggesting that there is a negative effect on employment associated with higher minimum wage, and some suggesting that there is no effect at all [2]. For example, Fang and Lin conduct an empirical study using a merged panel to investigate the effects changes in minimum wage had on the employment level of Chinese provinces during 2002-2009 and find that there were significant negative effects to employment during the time period [16]. Long and Yang similarly conduct an empirical analysis to investigate how firms respond when there are changes to the minimum wage in China, and focus on changes in employment and fringe benefits - like insurance - and find that there is a negative effect to employment [30]. Kanellopoulos uses data from Greece to conduct an empirical analysis of the effects that minimum wage changes had on the size and recovery of the economic crisis in Greece [24]. This study finds evidence that minimum wage increases drastically reduced employment in Greece, and suggests that minimum wage decreases across many sectors of the Greece economy would have likely helped with economic recovery [24]. Meer and West study the effects of minimum wage on employment growth and find that there is evidence that minimum wage increases lead to lower employment growth [2]. Conversely, Ferraro et al. conduct an empirical study using data from Estonia and find that minimum wage increases in Estonia had no impact or very little impact on employment in the following time period [17]. Giuliano studies the affect of minimum wage on the employment of both adults and teenagers and finds that there was evidence that increases in minimum wage had no affect on adult employment, and sometimes had a positive affect on teenage employment and participation [20]. Lastly, Dube et al. conducted an empirical study comparing restaurant workers from pairwise counties at state borders with different minimum wage levels and found that there was no significant affect on employment [14].

ABMs have been applied in labor economics as an alternative approach to answering some of the questions in the literature. The type of papers encountered in this intersection are similar to those in general economic ABM literature. Ballot et al. create an ABM of the French labor market with the goal of reproducing observations and stylized facts of the market and focuses on the characteristics of the market and the actions of the agents [7]. Cardaci uses an ABM to investigate the effects of inequality on the market as a whole, and finds that the ABM is able to show the pressure of inequality on households and the resulting affect it has on the economy [11]. There are also papers that ask the reverse; how do other variables impact inequality? Dawid and Gemkow, and Gemkow and Neugart both look into the effects that social networks and hiring through referral have on income inequality by using an ABM to model the labor market [12] [19]. Palagi et al. build an ABM and use heterogenous households to investigate the affect of inequality shocks on the households and to measure the efficacy of various fiscal policy responses [32]. Lastly, Dosi et al. use an ABM to explore the consequences of structural labor market reform on the inequality and employment of heterogenous households [13]. Clearly, there is a

place for ABMs in the inequality literature and vice versa. A discussion of the similarities and differences between the proposed research and a selection of the aforementioned papers follows.

To begin, this research will share many similarities with the paper written by Caiani et al., since the proposed research extends the work done by Caiani et al. Specifically, the proposed research will likely have the same types of agents (households, firms, banks, and the government) with very similar behaviours/heuristics. The proposed research will likely have different household heuristics and behaviours in order to implement wealth based consumption decisions. The proposed research will also have different levels of heterogeneity at the firm level to account for different kinds of goods, as the Caiani et al. paper has a homogenous consumption good and a homogenous capital good. The question and issue being explored in the proposed research is different; Caiani et al. aimed to create a benchmark model and contribute novel methods of calibration and validation [10].

The largest differences between the ABM models discussed and the proposed research are the aim of the research and the models used to explore the questions asked in the research. The papers discussed that use an ABM are not exploring the effects of changes in minimum wage on employment levels, growth, and inequality. Additionally, the ABMs in the papers discussed will differ from the one in the proposed research as well as the one in the benchmark described in Caiani et al., while they may have similar types of agents, the heuristics used to implement their behaviours are different. Rather than describing every single difference in detail, key differences will be presented. The ABM presented in the paper by Kinsella et al. takes into account the role of education and technology and adjusts the behaviours of firms and households to take those dimensions into account, and the proposed research does not incorporate these concepts [27]. The ABM presented also does not differentiate between capital and consumption firms, while the ABM in the benchmark paper implements this differentiation [27] [10]. The paper by Kinsella et al. also focuses more on recreation of trends observed in the empirical literature. The ABM presented by Assenza et al. is similar in that not only is it an extension of a previous ABM, but it includes roles for capital and credit like the benchmark ABM presented by Caiani et al. [6] [10]. Assenza et al. also use their ABM to explore crisis dynamics, and do not focus on labor economics. The paper written by Guerini et al. is different in that it is interested in exploring the differences between ABM and DSGE models, as well as focusing more on the allocation of households and firms and the frictions introduced when heterogeneity and irrational agents are taken into account [22]. In addition, the ABM model described in the paper does not include an agent to represent banks or the government, while the benchmark and proposed research include these agents [10]. Braun-Munzinger et al., Kim and Kim, and Alfi et al. all focus on the application of ABMs in finance, while the proposed research focuses on labor economics. Similarly, the papers by Delli Gatti and Desiderio, Popoyan et al., and Assenza et al. focus on monetary policy instead of labor economics. The papers discussed as part of the labor economics and inequality literature have reverse similarities and differences than the ABM papers; while the ABMs differed from the proposed research mostly in their goal, the papers discussed that relate to labor economics and inequality mostly ask similar questions but use different methods. The papers by Fang and Lin., Long and Yang, Kanellopoulos, Meer and West, Ferraro et al., Giuliano, and Dube et al. all ask the same fundamental question as the proposed research- what is the effect of changes in minimum wage on employment? These papers answer this question by conducting

empirical studies on a wide variety of data from different countries and industries, while the proposed research will answer them by looking at a simulated economy.

The papers discussed in the intersection between ABM literature and labor economics literature ask questions in the same realm, but are not exactly the same as the proposed research. Dawid and Gemkow and Gemkow and Neugart both investigate other sources of income inequality and employment, and so create their ABMs to tailor to those questions and include social networks and leave out banks and government as agents. Palagi et al. and Dosi et al. focus more on redistributive policies and structural reform respectively, though their ABMs have a similar mix of agents. The paper by Ballot et al. is similar in the agents used and scope of the model; the ABM presented by Ballot et al. and the benchmark detailed in Caiani et al. contain agents to represent households, firms, and banks [10]. Ballot et al. implement a different method of allocating households and firms than the proposed research and benchmark. Ballot et al. has the allocation occur through a searching behavior by the households and firms, while the benchmark provided by Caiani randomly assigns a pool of possible matches to firms and households [7] [10].

Overall, the proposed research has the most similarities with papers discussed in the ABM literature as a result of both using an ABM. The specifications of the models, agents included and their behavior, as well as the questions asked are all different to varying degrees. The proposed research aligns closely with the questions asked by papers presented in the inequality literature, but departs from the method used to explore these questions by using an ABM instead of relying on an empirical analysis.

Method of Approach

Use technical diagrams, equations, algorithms, and paragraphs of text to describe the research that you intend to complete. See the \LaTeX source file for the proposal to learn how Figure 1 and Table 1 were included. Be sure to number all figures and tables and to explicitly refer to them in your text.

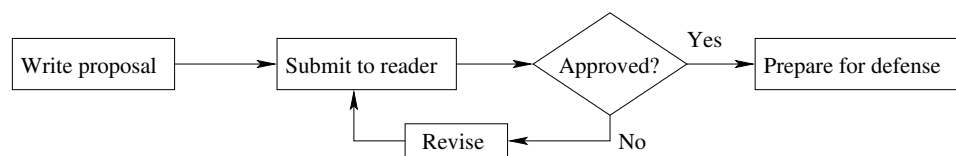


Figure 1: Flow graph for proposal-writing

Evaluation Strategy

Explain what steps you will take to evaluate your proposed method. If you intend to conduct experiments, then you must clearly define your evaluation metrics.

Task	Begin Date	End Date
First draft	Now	20 Sept
Second draft	20 Sept	27 Sept
Third draft	27 Sept	4 Oct
Fourth draft	4 Oct	11 Oct
Fifth draft	11 Oct	18 Oct

Table 1: Illustrative Example of a Proposed Work Schedule

Research Schedule

Identify the main phases and tasks of your research project and set deadlines for when you will be able to complete each of these items.

Conclusion

Provide a summary of your proposed research and suggest the impact that it may have on the discipline of computer science. If possible, you may also suggest some areas for future research.

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