Fiscal Policy and Business Cycle Characteristics in a Heterogeneous Agent Macro Model

Andre R. Neveu

James Madison University

November 30, 2010

Abstract

This paper evaluates the macroeconomic implications of changing tax policy and government spending using a Heterogeneous Interacting Agent ("HIA") model. The key contribution of the heterogeneous agent model in this context is to display the interaction between a progressive income tax structure and fiscal stimulus with respect to business cycle measurements. We contribute to the literature on HIA models and business cycles by expanding roles for both progressive taxation and redistribution. While fiscal stimulus is able to shorten recessions, it appears to do so at the cost of limiting future growth. Tax and spending cuts result in longer recessions, but faster growth relative to the baseline model. Instead of filtering techniques we use a non-parametric business cycle measurement algorithm to compare models across specifications.

1 Introduction

Theoretical heterogeneous interacting agent ("HIA") models are increasingly used for studying aggregate economic activity. Improvements in computing technology have allowed the agent-based approach to develop as a challenge to more orthodox general equilibrium models. Furthermore, the incorporation of complete economy features has helped reduce a gap between general equilibrium and HIA macroeconomics in studying policy applications. Examples of policy based macroeconomic HIA models include Russo et al. (2007) who develop and analyze the roles for taxes and the government transfers, and Delli Gatti et al. (2005b) and Giulioni (2007) who examine monetary policy. As the agent-based approach to macroeconomics gains credibility as an alternative to the general equilibrium approach, we might look for guidance on what can or should be done about fiscal or monetary policy during periods of crisis.
The agent-based model presented here is an HIA complex adaptive trivial system ("CATS" or "C@S") similar to those used in previous work such as [Russo et al. (2007)] and [Gaffeo et al. (2008)]. Previously developed CATS models have been shown to exhibit self-organizing stable states. While CATS models can exhibit stable states they are also able to display that small idiosyncratic shocks may push an economy into instability. Highly networked firms are allowed to fail, leading to lost jobs and income for workers, further declines in sales, and ultimately "avalanches" of bankruptcies.

The model we develop here incorporates progressive taxes on income, in addition to taxes on corporate profits. Tax revenue is redistributed to either the unemployed for the purpose of consumption or firms for the purpose of research and development ("R&D"). During a period of crisis, the government triggers tax policy and redistributive changes that may halt or extend recessionary periods. We examine how changes in fiscal policy aid in the slowdown of contagion. In summary we find evidence that fiscal policy results in shorter recessions relative to our baseline model. A tax policy which simultaneously reduces spending results in longer recessions, but ultimately faster growth and greater inequality.

1.1 Background

The HIA macroeconomic modeling approach has been used to help explain the actual process of collapse and contagion. Agent-based models can also help us understand what might lead to the arrest of contagion. The recent crisis in the U.S. displays the public’s desire for the government to “do something” while the public and policy makers debate about what should be done. Here we show how fiscal policy can be employed in a CATS model to help arrest a recession sooner than if no action were pursued.

Agent-based computational economies ("ACE") have been recently employed to study the effectiveness of fiscal and monetary policy. The CATS models have been developed as a specific type of agent-based computational economy. [Delli Gatti et al. (2008)] and [Gaffeo et al. (2007)] describe CATS as sequential economies founded on bounded rationality which result in spontaneous market order. CATS models are built on the foundation of individual rule-based behavior in a market envi-
ronment, and lack a centralized solving mechanism that would be observed in a general equilibrium model. Adaptive behavior is built into the model as agents use new information to update their satisficing rules in a manner described by Gaffeo et al. (2007) as “backward-looking, sequential, and path dependent.”

Delli Gatti et al. (2008) and Delli Gatti et al. (2007) describe and display numerous stylized facts that the agent-based approach can explain which representative agent general equilibrium models cannot. CATS models typically result in scale-free distributions observed in empirical data such as power laws in wealth, firm size, and income. Additionally, CATS models are able to display long periods of aggregate volatility and tranquility like those observed in most advanced economies before, during, and after the Great Moderation.

A major departure we make here from previous research using heterogeneous agent models is in our analysis of how we examine the business cycle. Previous research by Canning et al. (1998), Gaffeo et al. (2003), Di Guilmi et al. (2004), Gallegati et al. (2003a), Gallegati et al. (2003b), and Delli Gatti et al. (2008) each use heterogeneous agent models to study business cycle trends. In order to study business cycles, these previously mentioned HIA studies have settled on using filtering techniques that define cycles as departures from a permanent trend component. We instead chose to use classical cycle techniques advanced by Harding and Pagan (2002) that do not require filtering but rather focus on the levels of data and how to define turning points. While filtering has its place in macroeconomics, it is not clear what components one is actually studying when examining filtered data (Harding and Pagan (2005)). One of the apparent benefits of using HIA models is in the ability for the economy to settle into various states of stability rather than reverting to some statistically filtered natural rate of unemployment.

---

1 Satisficing can be thought of as a worker who looks for a job with a wage that exceeds their reservation wage. Any job offer which pays as much as or more than a worker’s reservation wage could result in matching a worker to an employer. Thus, rather than searching for the highest possible wage, satisficing behavior assumes that a worker can accept the highest wage available to them within search constraints. This behavior can be applied to product markets, wage markets, as well as financial markets.
2 Choice of CATS Model

There are a wide variety of HIA-CATS models which each tend to have a specific focus. The model employed here is a unique variant on the HIA models used by Gaffeo et al. (2008), Delli Gatti et al. (2005b), and Russo et al. (2007).

Russo et al. (2007) used a CATS model to examine how a policy of corporate taxation and redistribution could lead to increased macroeconomic performance. The primary model proposed by Russo et al. taxed firm profits, and redistributed the proceeds to individuals for consumption or to firms for future R&D. However, in practice the tax system imposed in the U.S. and most developed nations is not fully funded at the point of corporate profits, but rather at the level of individual income or expenditures. Here we propose an alternative tax system where government revenue comes from both income and corporate taxation. Government revenues are redistributed to either unemployed individuals or to firms for R&D as proposed by Russo et al. (2007).

The model of Russo et al. showed that redistribution to the unemployed reduced growth, while redistributing taxes to enhance productivity via R&D increased growth. By expanding the scope of taxation to include taxes on income, we are able to examine inequality in consumption and wealth when tax and redistributive policies are changed. We also explore the impact of imposing both an income and corporate tax structure in the same simulation. Additionally, we incorporate firm-level borrowing and while limiting the role of banks in the analysis. A related paper by Gaffeo et al. (2008) incorporates banks and borrowing into a variation on the sequential model from that of Russo et al.

We model production as a linear function of labor, similar to Russo et al. (2007) and Gaffeo et al. (2008). In contrast, other heterogeneous agent-based models like those proposed by Delli Gatti et al. (2008), Delli Gatti et al. (2005a), Gallegati et al. (2003a), and Battiston et al. (2007) model production as a linear function of capital only. The choice was made to model production as a function of labor here since we are specifically interested in how income taxes and redistributive policy might impact consumption and firm production decisions. A recognized issue with instituting
an income tax in this model is that workers are modeled here as inelastically supplying labor each
period. Thus changes in income tax rates cannot affect work effort, nor does effort adapt during
periods of collapse. We are however able to model some response to changing economic conditions
as wages adjust periodically based upon employment status.

Delli Gatti et al. (2005a) and Giulioni (2007) use capital in production, and also have endogenous
entry and exit so the number of firms can grow over time. Growth in the number of firms over
time is somewhat novel relative to the other articles in the HIA-CATS literature. However, Delli
Gatti et al. (2005a) and Giulioni (2007) have no labor market, and therefore no way of capturing
unemployment changes or taxes on labor. Delli Gatti et al. (2005a) also incorporates variable costs
which are proportional to financing costs.

Another CATS model with potential to extend the research presented here is by Delli Gatti
et al. (2005b) who uniquely model output as a function of capital and labor, where capital is a
direct reflection of total net worth. Delli Gatti et al. (2005b) was designed to specifically model
central bank behavior and responses, and their model is a candidate for future comparison including
automatic monetary policy responses to crises and booms. As the models mentioned here show,
the HIA-CATS approach still lags behind general equilibrium methods when it comes to modeling
the complete economy, but progress is being made.

3 Outlining the Model

The model is designed as a sequential decision model with decentralized markets in labor and goods.
Firms produce a homogeneous non-storable good ($Y_{i,t}$) that consumers purchase at variable prices.
Prices ($P_{i,t}$) are determined in a decentralized market where consumers shop at a number of firms
based on fixed search costs ($Z$). Search costs also play a role in the labor market as firms receive
applications from workers and sort them to find the lowest cost workers. Workers apply to a number
of firms ($M$) where higher search costs are represented by fewer applications being made in each
period. We also incorporate “loyalty” and “preferential attachment” by allowing consumers to shop
at larger firms with greater probability based on size. Rather than having complete search markets, this is essentially assuming that larger firms are less difficult for consumers to find. Loyalty also plays a role in the labor market where firms may choose to rehire workers whose contracts are expired even if their wages are higher than the other applicants.

3.1 Firms

Before each period of production each firm $F_{i,t}$ (firm index $i = 1, \ldots, I$; time index $t = 0, \ldots, T$) checks their net worth to determine if they are solvent. Solvency of a firm is determined by examining net worth of each firm $A_{i,t}$ which evolves as firms retain profits (or losses) from previous periods. A portion $\sigma_\Pi$ of any profits from each period is invested in research and development. We also allow the largest firms in terms of net equity to reinvest a portion of their retained equity ($\sigma^A$).

Capital evolution depends on whether or not individual firms meet specific cutoffs for profit ($\Pi$) or equity ($A$) each period. The values of $\chi_{\Pi}$ and $\chi_A$ are held fixed economy-wide throughout simulations presented here at the 50th percentile and the 90th percentile respectively. Thus because of the cutoffs we have firm-specific R&D investment rates.

$$
\begin{align*}
\sigma_{i,t}^\Pi &= \sigma^\Pi & \text{if } \Pi_{i,t-1} \geq \chi_{\Pi} \\
\sigma_{i,t}^\Pi &= 0 & \text{if } \Pi_{i,t-1} < \chi_{\Pi} \\
\sigma_{i,t}^A &= \sigma^A & \text{if } A_{i,t-1} \geq \chi_A \\
\sigma_{i,t}^A &= 0 & \text{if } A_{i,t-1} < \chi_A
\end{align*}
$$

\text{Section 3.2 has more detail.}

\text{We impose a profit-based R&D cutoff ($\chi_{\Pi}$) for firms with profits below the median. Firms below the cutoff cannot reinvest profits in R&D, while those above the cutoff spend a portion $\sigma^\Pi$ of profits on R&D in time $t$. In cases where the median profit is negative, the cutoff is set to allow for R&D for all firms with positive profits. The cutoff for equity reinvestment ($\chi_A$) has been set to the largest 10% of firms based on size.}

\text{Parameter values are summarized in Table tab:parms.}
Net worth evolves with R&D investment being withheld from retained profits reducing the immediate growth of net worth (Equation 1).

\[
A_{i,t}^f = A_{i,t-1}^f + (1 - \sigma_{i,t}^H)\Pi_{i,t-1} - (\sigma_{i,t}^A)A_{i,t-1}^f
\]

\[
A_{i,t}^f = (1 - \sigma_{i,t}^A)A_{i,t-1}^f + (1 - \sigma_{i,t}^H)\Pi_{i,t-1}
\] (1)

Firms that are solvent remain to produce, while those that are insolvent face bankruptcy and are replaced with a copy of another existing firm. Firms vary in size with respect to the number of workers employed as well as equity. Questions raised by Delli Gatti et al. (2010) about preferential attachment in goods markets between consumers and firms led us to also include firm replication from the most labor-intensive firms. By focusing replication on the most labor intensive firms we replace some of the need for preferential attachment in the model. The number of firms is held fixed throughout all simulations performed here (I = 100). Firms are initially endowed with a random amount of initial capital \(A_{i,0}^f \neq 0\). Newly entering firms use the amount of capital copied from an existing firm. If \(A_{i,t}^f > 0\) firm \(i\) continues to the production stage.

Each firm \(F_{i,t}\) has a linear production technology based on only the use of labor and a labor augmenting technology (Equation 2). Firm production is modeled similar to Gaffeo et al. (2008) as a linear function of labor \((L_{i,t})\). Heterogeneous individual firms \((F_{i,t})\) use a Cobb-Douglass technology to produce a homogeneous good with firm-specific technology \(\alpha_{i,t}\). Firms are randomly endowed from a uniform distribution for technology \(\alpha_{i,0}\) and expected demand \((Y_{i,0}^d)\).

\[
Y_{i,t} = \alpha_{i,t}L_{i,t}
\] (2)

Each firm’s production technology evolves over time as they make investments in R&D at a constant ratio of profits and previous equity. Investments in R&D have uncertain payoffs (Equation

\[5\text{See Delli Gatti et al. (2010) for further explanation on the need for preferential attachment in specific CATS models. While we still use preferential attachment here, the model is less sensitive to the assumption.}\]
Assuming a firm has passed the test for solvency, a fixed portion \( \sigma \Pi_{i,t} \) of nominal profits \( \Pi_{i,t} \) from the previous period are invested in R&D. In addition, for firms that are largest in terms of equity investment occurs at a rate of \( \sigma A_{i,t} \). Lastly, we add in government funded R&D \( \gamma_{i,t} \) based upon tax “rebates” received in time \( t-1 \) that are equally distributed among all firms at time \( t \) (See Equation 11 for further detail). Thus, R&D is determined as a random variable based on an amount of investment \( RD_{i,t} = \sigma \Pi_{i,t-1} + \sigma A_{i,t-1} + \gamma_{i,t} \).

\[
\alpha_{i,t} = \alpha_{i,t-1} + z_{i,t-1} \tag{3}
\]

The final \( z_{i,t-1} \) term in Equation 3 is a random variable drawn from an exponential distribution with mean \( \mu_{i,t-1} = \frac{RD_{i,t}}{\mu_{i,t-1} Y_{i,t-1}} \). By using an exponential distribution we typically see technology grow slowly for most firms, but quickly at times for a few firms.

Firms sequentially decide how much labor they will require to meet their expected product demand. Labor demand \( L_{d_{i,t}} \) is determined from expected demand and technology.

\[
L_{d_{i,t}} = \frac{Y_{d_{i,t}}}{\alpha_{i,t}} \tag{4}
\]

Expected demand and prices are functions of previous sales relative to previous output and adapt based upon bounded rational decision rules. Each period a firm is randomly assigned to adjust either prices or output but not both. Prices are also subject to a firm-specific minimum price \( P_{i,t}^{min} \) each period such that the entire wage bill could be recouped if all goods are sold.

\[
P_{i,t}^{min} = \frac{W_{i,t}}{Y_{i,t}} \tag{5}
\]

Price and expected demand evolution rules are borrowed from Russo et al. (2007). Managers would increase prices or production if all goods were sold \( Y_{s_{i,t}} \) in the previous time period (i.e., the surplus is of unsold goods is zero \( I_{i,t} = Y_{s_{i,t}} - Y_{d_{i,t}} \)). Only goods that are sold are counted in the determination of weighted average price each time period. If firms have a surplus \( I_{i,t} > 0 \),
they will either cut their prices or reduce output the next time production takes place.

\[
P_{i,t}^s = \begin{cases} 
\max\{P_{i,t}^{\min}, P_{i,t-1}(1 + \eta_{i,t})\} & \text{if } I_{i,t-1} = 0 \\
\max\{P_{i,t}^{\min}, P_{i,t-1}(1 - \eta_{i,t})\} & \text{if } I_{i,t-1} > 0
\end{cases}
\]  

(6)

\[
Y_{i,t}^d = \begin{cases} 
Y_{i,t}(1 + \rho_{i,t}) & \text{if } I_{i,t-1} = 0 \\
Y_{i,t}(1 - \rho_{i,t}) & \text{if } I_{i,t-1} > 0
\end{cases}
\]  

(7)

Shocks to prices and output are determined here based on positive uniform distributions over the ranges \([0, h_\eta]\) \([0, h_\rho]\). Shocks to desired output are translated into future labor demand. Since labor must be an integer demand for employment is rounded down so firms do not hire more than necessary.

Once a firm decides how many workers they would like to hire, they hire in a sequential and preferential way. Applications from potential workers are sorted into blocks such that previously hired employees are offered employment ahead of new applicants. If a firm’s labor demand falls from a previous period \((L_{i,t}^d < L_{i,t-1}^d)\), then the firm fires those workers with the highest remaining wages. When firms fire workers, they sever worker contracts at a cost of a percentage of the remaining contract. When firm labor demand rises \((L_{i,t}^d > L_{i,t-1}^d)\) managers turn to the applicant pool hiring applicants with the lowest wages. Workers that are hired enter into new contracts with the firm that vary by the individual worker.

Firms are allowed to borrow in order to meet their wage bills, but must repay their loan at the end of \(t\) or go bankrupt. Profits may be taxed at the rate \(\tau_c\) after revenue is collected, and firms have repaid lenders. Government revenue is set aside to pay unemployment benefits to workers without jobs and fund future R&D.

Labor \((L_t)\) is summed across workers. Workers at each firm produce according to their employers firm-specific technology. Because firms hire only enough workers to meet expected demand, it is

---

6In the baseline model, we use a contract length of one period, so no cost is incurred for severing a worker contract. Experiments comparing the maximum length of contracts include a 50% cost of the remaining contract.
likely that firms do not hire the entire population $N$. Those workers that are not hired are considered unemployed ($U_t = N - L_t$). As technology ($\alpha_{i,t}$) increases, firms need to hire fewer workers to meet the same level of expected demand. Expected demand is revised periodically upward as described below in Section 3.2 and the system reaches a semi-stable state.

### 3.2 Households

Individual households are infinitely-lived and fixed in number. The workers/consumers $N_{j,t}$ ($j = 1, \ldots, J$) shop for both employers and consumption in a decentralized market so that the rule of one price does not necessarily apply as it normally does in general equilibrium models. Consumers pay potentially different prices for a single homogeneous non-storable good and firms pay varying prices for labor. Firms each have differing production technologies and pay wages based on a random hiring process where the workers demanding the lowest wages are hired first. When shopping for an employer, workers supply a single unit of labor by applying to a set number of firms ($M$). Potential workers are randomly sorted and sign a contract of random length if selected by an employer. If firms fill their hiring needs, potential workers can be shut out of the labor market. Alternatively, firms might not fill all their openings since there are a limited number of applicants who apply to each firm. Wage setting is thus primarily set by workers who revise individual reservation wages each period. Reservation wages are slowly revised downward in the absence of work, or rise as workers remain employed.

We employ a binding minimum reservation wage ($\hat{w}_t$) set at 25% of the median reservation wage from time $t-1$. Reservation wages are set to change contingent on previous employment. For those workers who were employed at time $t-1$ with completed contracts, wages are revised up by a randomly determined amount $\xi_{j,t}$. When contract lengths are longer than one period, we allow for agreed upon wages to rise by an amount $\varphi_{j,t}$. Both $\xi_{j,t}$ and $\varphi_{j,t}$ are uniformly distributed random variables on the intervals $[0, h_{\xi}]$ and $[0, h_{\varphi}]$ respectively.
\[ w_{j,t} = \begin{cases} 
\max(\hat{w}_t, w_{j,t-1}(1 + \xi_{j,t})) & \text{if employed during } t-1 \text{ and no contract at } t \\
\max(\hat{w}_t, w_{j,t-1}(1 + \varphi_{j,t})) & \text{if employed during } t-1 \text{ and under contract at time } t \\
\max(\hat{w}_t, w_{j,t-1}(1 - \xi_{j,t})) & \text{if unemployed during } t-1 
\end{cases} \] (8)

Wages are paid immediately after hiring. Labor earnings are taxed at rate \(\tau_1, \tau_2,\) and \(\tau_3\) in order to fund government spending which will go towards maintaining a minimum level of consumption and R&D. Taxes are redistributed and given as deposits to individuals in the amount of \(v_{j,t}\) for all workers who did not find work in the same time period (Equation 12). Labor earnings and unemployment benefits are deposited at the beginning of a time period after firms pay their wage bill and are modeled to earn no interest. Thus, when redistribution is in place, all individuals have deposits \((D_{j,t} = w_{j,t} + v_{j,t})\) to fund consumption.

Those individuals that do not work receive unemployment compensation calculated as an equal proportion of tax revenue allocated to unemployment (Equation 12). Households use their after-tax wages to shop at a random group of firms \((Z)\) who are sorted by price. Households purchase consumption at the lowest available price. For example, if a consumer would like to purchase 20 units of consumption, and a firm only has 15 units available for sale, our consumer would purchase the remaining goods from this firm and then move on to the next firm they selected to shop at to see if they can purchase the remaining 5 units. Consumers can be locked out of consuming if the firms they shop at run out of goods. Consumers are programmed to have preferential attachment to the largest firms based on production.

Individuals with higher levels of net wealth consume at lower rates out of income than those with lower net wealth.\(^7\) Individuals allocate a portion of their income for consumption, and try to

---

\(^7\)In the baseline model, income taxes are collected at a 10% rate on the lowest third of the employed, 20% on the second third, and 30% on the upper third. Tax rates apply to all income and should not be interpreted as marginal tax rates. Corporate profits are taxed at a rate of \(\tau_c = 30\%\) in the baseline model.

\(^8\)We also experiment with marginal propensities to consume varying by income with only minimal differences in results.
Preliminary: Please do not quote or cite

spend that entire amount. Desired minimum consumption \(d_{j,t}\) is adaptive, adjusting each period based on previous consumption (Equation 9). Therefore if an individual has a high income for a period of time, and therefore high consumption, they would continue to consume at a high rate in the event of losing their job. Over time individuals with high consumption and low incomes would adjust their consumption down as they eat away at their savings.

\[
c_{d_{j,t}} = \begin{cases} 
    c_{d_{j,t-1}} + \nu(c_{j,t-1} - c_{d_{j,t-1}}) & \text{if consumption } > \text{ desired in } t - 1 \\
    c_{d_{j,t-1}} - (1 - \nu)(c_{d_{j,t-1}} - c_{j,t-1}) & \text{if consumption } < \text{ desired in } t - 1 
\end{cases}
\]

Net wealth of the consumer \((A_{j,t}^n)\) at any given point in time, is dependent on previous wealth \((A_{j,t-1}^n)\) and new savings. New savings are calculated as the difference between deposits and expenditures in the previous period \((S_{j,t-1} = D_{j,t-1} - C_{j,t-1})\). When consumers are faced with a shortfall in income relative to desired consumption, they can draw on their personal assets to meet their demands. If an individual’s net wealth is zero, they are unable to draw on any credit markets for fund consumption.

\[
A_{j,t}^n = \begin{cases} 
    A_{j,t-1}^n + S_{j,t-1} & \text{if } S_{j,t-1} > 0 \\
    A_{j,t-1}^n - S_{j,t-1} & \text{if } A_{j,t-1}^n > S_{j,t-1} 
\end{cases}
\]

3.3 Government

The role of the government in this model is mainly to collect and redistribute taxes for the purposes of (i) maintaining a standard of living during unemployment and (ii) funding R&D at the firm level. Income tax revenues \((R_{t}^n)\) are collected as a percentage of personal income at the beginning of time \(t\) following the payment of wages. Corporate taxes \((R_{t-1}^f)\) are paid out of profits at the end of time \(t-1\). After revenues are collected, they are redistributed during time \(t\) among consumers and firms. The “dole rate” \(\delta (0 < \delta < 1)\) is the percentage of tax revenue that goes towards unemployed workers, and the percentage \(1 - \delta\) goes towards firm R&D. Within the portion
of government spending allocated to consumers, all unemployed workers receive an equal share. Both existing firms and new entrants receive equal government funding for R&D in each period \( t \). Therefore as long as \( \delta \neq 1 \), all firms conduct at least a small amount of R&D each time period. In Section 5 we extend the model such that the government can make fiscal outlays of \( G_t \) during times of “crisis.” The addition of \( G_t \) increases or decreases the amount spent on unemployment or R&D at the government level.

The government supplies a percentage of revenue to R&D each period \( t \):

\[
\gamma_{i,t} = \frac{(1 - \delta)(R^f_t - 1 + R^n_t - 1 + G_t)}{F}
\]  

(11)

Individuals receive government support if they are unemployed. For all \( j \) workers that are not employed during time \( t \):

\[
v_{j,t} = \frac{\delta(R^f_{t-1} + R^n_{t-1} + G_t)}{U_t}
\]

(12)

By increasing spending or cutting taxes, fiscal policy can possibly helping to prevent or halt contagions. Allowing for fiscal deficits creates problems in considering the growth of government debt and the enforcement mechanism involved in repayment. Therefore we strictly enforce tax increases or debt repayment once a downturn has been declared over.

3.4 Banks

Banks exist in this model only to provide credit to firms for paying wages when internal capital is insufficient. Firm wages are often paid through by obtaining a line of credit which is repaid after firms sell their goods. If a firm does not sell enough goods to meet their repayment needs, they will declare bankruptcy at time \( t + 1 \). Credit is not limited in this model but the extension to a credit
By modeling firms with credit access, we allow for large firms in terms of employment and sales to collapse if their prices are not competitive or customers fill their needs through a different more efficient producer. By allowing large firms to collapse, we can observe extensive downturns when large employers fail. As workers lose their jobs, they react by adjusting their consumption downwards, hurting other firms possibly leading to further collapse.

### 3.5 Timeline

Briefly we summarize the model as it plays out in our simulations. The model is first populated at $t = 0$ using uniform distributions, and then behavior adapts in future time periods.

1. Randomly endow firms with net equity between a lower ($A_{0,lb}$) and upper bound ($A_{0,ub}$). All firms begin as solvent.

2. Randomly endow firms with technology between a lower ($\alpha_{0,lb}$) and upper bound ($\alpha_{0,ub}$).

3. Randomly endow firms with labor demands between a lower ($L_{0,lb}$) and upper bound ($L_{0,ub}$). Using initial technology and labor demands, we can now determine initial desired production. Desired production may not be met if the firm is unable to hire enough workers to produce their output.

4. Populate worker/consumers with original satisficing wages between $w_{0,lb}$ and $w_{0,ub}$.

5. Endow worker/consumers with net equity between a lower ($A_{n,lb}$) and upper bound ($A_{n,ub}$).

6. Firms check their net equity to see if they are solvent. If firm equity $A_{i,t} < 0$ then the firm exits the market and is replaced with a random copy of an existing solvent firm.

7. Firms conduct R&D by advancing technology through an uncertain random process. The amount of R&D spending for each firm is the sum of $RD_{i,t} = \sigma^{R_{i,t}}_{i,t} (\Pi_{i,t-1} - 1) + \sigma^{A_{i,t}}_{i,t} (A_{i,t-1} - 1) + \gamma_{i,t}$.

8. Firms determine their expected demand, labor needs, and prices based on a random draw and whether or not a surplus carried over from $t - 1$.

9. The labor market opens.

10. Randomly select firms for workers to apply for employment. Workers apply to $M$ number of firms including the one they were employed at previously if employed during $t - 1$. A higher value for $M$ indicates lower search costs. Firms are randomly selected to hire in sequential order. Those at the top of the hiring list rank the potential employees by their wage and hire...
the number of workers they desire beginning with the lowest wage. Workers and firms agree to contracts of a random length for each employee between a lower and upper bound ($C_{j, LB} \& C_{j, UB}$). Once an employee agrees to a contract they are removed from the pool of available workers. Firms that hire later in the time period may not be able to hire as many workers as they desire.

11. Workers are paid at the beginning of the time period. Taxes are collected and redistributed to those individuals that did not find a job. A portion of taxes are withheld to return to firms for R&D at time $t + 1$. If firms do not have enough equity to pay their wage bill, they borrow from a bank if necessary. Consumers deposit their wages, and use them to purchase goods at the end of the time period.

12. Firms produce their goods, and reset prices if minimum prices are greater than the price set in step 8. Firms set a minimum price so that they could recoup their wage bill ($W_{i,t}$) if they sell all of their output $Y_{i,t}$.

13. Consumers adjust their minimum consumption based on previous consumption relative to their previous minimum.

14. The goods market opens.

15. Individuals enter the market for goods, and select $Z$ number of firms to shop at. A higher value of $Z$ indicates lower search costs. Consumers are randomly selected to shop sequentially at the stores that are selected for them. Consumers have preferential attachment to larger firms in terms of previous production. Individuals set aside a portion of their income for consumption, and the remainder is saved for the future. Consumers purchase as much as their income allows, choosing to purchase at least a minimum amount of the good ($c_{j,t}^{d}$) if they have the income for it. Those individuals with higher incomes set aside a greater portion of their wages for savings than those at lower incomes. Consumers are allowed to use their retained net wealth to consume if their income is not high enough to afford them their minimum consumption. No maximum is set for consumption, so consumers with higher incomes will attempt to consume a greater amount. Individuals that shop later in the sequence may be shut out of the consumption market and save any unspent funds for future time periods. Consumers continue to purchase after they have reached $c_{j,t}^{d}$ until either the stores run out of goods or the individual runs out of income set aside for consumption. Households will not spend savings beyond $c_{j,t}^{d}$ in any period. Any money left over that is not spent on consumption is shifted into net worth for future consumption.

16. At the end of the time period, firms calculate their profits, repay any borrowed money plus interest, and dispose of any excess production at zero cost. Firms with positive profits pay a tax on profits. If a firm cannot repay their entire debt, they return to the bank any revenues they collected and immediately declare bankruptcy.

17. Workers update their satisficing wage based upon their employment status in $t$.

Table 1: Baseline Model Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>400</td>
</tr>
<tr>
<td>Firms (F)</td>
<td>100</td>
</tr>
<tr>
<td>Population (N)</td>
<td>500</td>
</tr>
<tr>
<td>M: Labor Search</td>
<td>2</td>
</tr>
<tr>
<td>Z: Product Search</td>
<td>2</td>
</tr>
<tr>
<td>pM: Persistence Labor</td>
<td>Yes</td>
</tr>
<tr>
<td>pZ: Persistence Product</td>
<td>Yes</td>
</tr>
<tr>
<td>Percent Dole $\delta$</td>
<td>70%</td>
</tr>
<tr>
<td>Investment Percent</td>
<td>30%</td>
</tr>
<tr>
<td>Low Tax Rate $\tau_1$</td>
<td>10%</td>
</tr>
<tr>
<td>Medium Tax Rate $\tau_2$</td>
<td>20%</td>
</tr>
<tr>
<td>High Tax Rate $\tau_3$</td>
<td>30%</td>
</tr>
<tr>
<td>Corporate Tax Rate $\tau_c$</td>
<td>30%</td>
</tr>
<tr>
<td>Low Consumption Rate</td>
<td>100%</td>
</tr>
<tr>
<td>Medium Consumption Rate</td>
<td>75%</td>
</tr>
<tr>
<td>High Consumption Rate</td>
<td>50%</td>
</tr>
<tr>
<td>$\sigma^\Pi$</td>
<td>0.1</td>
</tr>
<tr>
<td>$\mu$</td>
<td>0.1</td>
</tr>
<tr>
<td>$h_\xi$</td>
<td>0.1</td>
</tr>
<tr>
<td>$h_\varphi$</td>
<td>0</td>
</tr>
<tr>
<td>Cutoff Profit R&amp;D</td>
<td>Yes</td>
</tr>
<tr>
<td>Cutoff Percentile</td>
<td>50th</td>
</tr>
<tr>
<td>Equity R&amp;D Active</td>
<td>Yes</td>
</tr>
<tr>
<td>Equity R&amp;D Percentile</td>
<td>90th</td>
</tr>
<tr>
<td>Firm Loyalty</td>
<td>Yes</td>
</tr>
<tr>
<td>Fired</td>
<td>Yes</td>
</tr>
<tr>
<td>Buyout Percentage</td>
<td>0.5</td>
</tr>
<tr>
<td>Changing Minimum Consumption</td>
<td>Yes</td>
</tr>
<tr>
<td>Rate for Adaptation in Consumption: $\nu$</td>
<td>95%</td>
</tr>
<tr>
<td>Preferential Attachment</td>
<td>Yes</td>
</tr>
<tr>
<td>Replicate from Largest Firms</td>
<td>Yes</td>
</tr>
<tr>
<td>Replicate from Top Percentile</td>
<td>10</td>
</tr>
<tr>
<td>$\sigma^A$</td>
<td>0.025</td>
</tr>
</tbody>
</table>

3.6 Baseline

The baseline model uses the parameters from Table 1. The baseline model exhibits large swings in the values of measures like production, sales, and clusters of bankruptcies. Figures 2 through 5 display typical results from the baseline model. The baseline model simulation displayed here uses 100 firms and 500 consumer/workers who both pay taxes in this model.

The fiscal policy computational experiments we will perform with this model will have uncertain impacts since the fiscal and tax policy will be instituted using a rule that occurs after a downturn of a specified period. Additionally, we will be applying a classical cycle dating algorithm to measure the cyclical characteristics of the levels of the variables measured by the model. Proper accounting of the changes within the model will lead us to a better understanding of how tax policy impacts heterogeneous agent based models.
4 Comparing Business Cycle Characteristics

We compare models across specifications using Monte Carlo simulation methods to create 100 unique time paths each with 400 time periods. The first 100 time periods are discarded in our analysis as the model takes some time to adapt. Rather than filtering variables like output, sales, and expenditures, we use an algorithm to detect turning points in aggregate data. After running 100 replications the baseline model, we estimate the “business cycle” characteristics. We use similar methods to compare cyclical characteristics across specifications to see if downturns change significantly when policy changes.

The methods of comparing models here do not rely on calibration to fit replicated data to some desired time series. By looking at uncalibrated models, we recognize that results presented here are only suggestive of changes in business cycle characteristics. The most commonly suggested algorithm to detect turning points in aggregate data is one that declares peaks and troughs in levels of aggregate data where two consecutive periods display a reversal in trend.

It is unclear that “detrending” log differenced data using filtering methods actually leaves behind only the cyclical component. A primary concern using filtering techniques is that changes to rates of growth and distributional impacts are ignored when examining detrended aggregate data. Thus, we examine the classical cycle, and do not study growth cycles.

4.1 The Classical Cycle Algorithm

Work by [Harding and Pagan (2002)] adapted the dating algorithms of [Bry and Boschan (1971)] for quarterly data (“the BBQ algorithm”). The algorithm employs phases which last at least $k = 2$ periods, and full cycles which last at least $m = 5$ periods. The requirement that $m = 5$ serves as a censor limiting detected peaks and troughs to be a certain minimum distance apart. The values of minimum phase length and full cycle requirements are intended to match the description of a recession by [Burns and Mitchell (1946)] that recessions should last six months and full cycles should last at least 15 months. Also, the turning points are censored such that peaks and troughs
must alternate so that continuous cycles can be measured. Lastly, rather than use the typical rule of thumb “two consecutive quarters of negative growth signals a recession” a peak is found when $\Delta_2 y_t > 0$, $\Delta y_t > 0$, $\Delta y_{t+1} < 0$, $\Delta_2 y_{t+2} < 0$. A trough is found when $\Delta_2 y_t < 0$, $\Delta y_t < 0$, $\Delta y_{t+1} > 0$, $\Delta_2 y_{t+2} > 0$ where the value for $\Delta_2 y_{t-2} = y_t - y_{t-2}$. 

Figure 1: Defining the Classical Business Cycle

After peaks and troughs have been determined, the length of contractions (P→T “Peak to Trough”) and the length of expansions (T→P “Trough to Peak”) can be calculated. The amplitude between a peak and trough is calculated as the simple difference between the two levels of output in terms of 100 times the log difference. Cumulated amounts of output are calculated over the entire length of a recession or expansion as a percent change from the previous peak or trough. For example, if an economy has 5% growth during period $t+1$ and 0% growth in $t+2$ the flow of output at time $t+2$ is still 5% higher relative to time $t$ yeilding cumulative gains of 10% relative to time $t$. Lastly, percentage excess is calculated by measuring the difference between the triangle approximation of cumulated output and the actual path of the economy. A negative (positive) excess in a contraction implies that the actual data series decreased faster (slower) when compared to a straight line.

9Further description of the turning point algorithm described here is available in [Harding and Pagan (2002)].
4.2 Cycles in the Baseline Model and Observable Data

Even though we are using an uncalibrated model, it can be established that there are some similarities between cycles present in actual data and the baseline model. Table 2 shows the difference between U.S. business cycles as measured with the algorithm and the cycles in sales observed on average across 100 simulations of the baseline. The empirically estimated cycle characteristics for the simulated model show that actual business cycles in the U.S. for the past 50 years have had significantly shorter recessions and significantly longer expansions relative to the baseline model. Recession amplitudes ($P \rightarrow T$) in the U.S have been approximately 2.2% in lost production with a cumulative loss in GDP of 2.9%. The simulated baseline model averages approximately 2.7% in lost sales between peak and trough, and 5.7% in cumulative lost output. The measures of excess for both actual U.S. and simulated data show recessions occur in nearly a linear fashion while expansions are more “V-shaped” than “U-shaped.”

Table 2: Empirical Business Cycle Peaks and Characteristics

<table>
<thead>
<tr>
<th>Cycle Characteristics</th>
<th>U.S. 1947-2008</th>
<th>Simulations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$P \rightarrow T^a$</td>
<td>$T \rightarrow P^b$</td>
</tr>
<tr>
<td>Durations</td>
<td>2.8889</td>
<td>16.4444</td>
</tr>
<tr>
<td>Amplitudes(%)</td>
<td>-2.2380</td>
<td>18.9260</td>
</tr>
<tr>
<td>Cumulative(%)</td>
<td>-2.9379</td>
<td>238.2669</td>
</tr>
<tr>
<td>Excess(%)</td>
<td>0.0244</td>
<td>1.0412</td>
</tr>
</tbody>
</table>

All measures are in quarters

$^aP \rightarrow T$ refers to recessionary characteristics.

$^bT \rightarrow P$ refers to expansionary characteristics.

In simulations of the model we observe large swings in the values of measures like production, sales, and clusters of bankruptcies. Figures 2 through 6 display some results from one simulation of the baseline model after discarding the first 100 time periods. Redistribution is set to be an equal amount for all unemployed workers with 70% of tax revenue going to the dole and the remaining 30% being spent on R&D. In Figure 2 we see growth in both production and sales that contains cyclical activity. Production and sales growth are on average positive, but occasionally turn negative. Average firm level technology advances steadily, but will occasionally fall when a large high technology firm fails. Figure 3 shows that weighted prices steadily rise, faster at some times than others. We also see rising aggregate wealth, with periodic declines when large firms in terms
of equity are forced into bankruptcy. Both aggregate and inflation-adjusted average wages rise and
fall periodically, increasing more often than not (Figure 4). Unemployment fluctuates frequently,
varying by as much as 5 percentage points in this single simulation. Bankruptcies occur in nearly
every period with as many as 8 in a single period (Figure 5).

Figure 2: Baseline Production, Sales, and Technology

Figure 6 displays the estimated Gini coefficients over a single simulation for both wealth and
consumption. The Gini coefficient in this single simulation ranges between 0.2 and 0.3, representing
a figure closer to equality in income than most countries exhibit. In the U.S. for example, the Gini
coefficient is around 0.4 to 0.5, reflecting greater income inequality than shown in the simulation.
While the similarities are interesting to note, it is worth reiterating that this model is not calibrated
to match U.S. data. Wealth inequality is much greater than income inequality, ranging between
0.7 and 0.85. For comparison, the U.S. Gini coefficient for wealth is around 0.8. While the Gini
measure is not without its flaws, it is encouraging to see stable and realistic measures of inequality
Figure 3: Profit, Equity, and Price

Figure 4: Wages and Unemployment
in both income and wealth.

4.3 Parameter Choice

One of the most important parameter choices in this model turns out to be the percentage of tax revenue that is spent on unemployment. In the baseline model the choice was made to use $\delta = 0.7$ implying that 70% of tax revenue is spent on unemployment with the remaining 30% going towards firm-level R&D. Figures 7 and 8 display the distribution of consumption during the final period of a single simulation. If tax revenue is only given to the unemployed ($\delta = 1$) the vast majority of consumption is at the lower end. When $\delta = 0.7$ or $\delta = 0.5$ consumption is more heavily weighted towards upper incomes. If the unemployed receive no assistance ($\delta = 0$) nearly 20% of individuals have no consumption at all.

[1] Russo et al. (2007) produces the most comparable model to ours, but use only taxes on profits with redistribution to both unemployed workers and R&D. [Russo et al.] produced a model that showed increasing revenues spent on R&D led to greater growth, lower inflation, higher unemployment, and lower vacancy rates. In the model presented here, we observe modestly higher growth...
Figure 6: Gini Coefficients for Baseline Consumption and Equity

Figure 7: Rank-Size Plot of Consumption Based on $\delta$
and lower inflation when \( \delta \) is closer to zero, but vacancies and unemployment do not appear much different as \( \delta \) varies.\(^{10}\)

Table 3: Cycle and Simulation Averages for Varying \( \delta \) Values

<table>
<thead>
<tr>
<th>( \delta )</th>
<th>0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unemployment Rate</td>
<td>0.3237</td>
<td>0.3231</td>
<td>0.3200</td>
<td>0.3194</td>
<td>0.3179</td>
<td>0.3195</td>
<td>0.3187</td>
<td>0.3202</td>
<td>0.3187</td>
<td>0.3176</td>
<td>0.3205</td>
</tr>
<tr>
<td>Vacancy Rate</td>
<td>0.0129</td>
<td>0.0120</td>
<td>0.0117</td>
<td>0.0116</td>
<td>0.0106</td>
<td>0.0103</td>
<td>0.0100</td>
<td>0.0102</td>
<td>0.0097</td>
<td>0.0110</td>
<td>0.0099</td>
</tr>
<tr>
<td>Growth Rate</td>
<td>0.7602</td>
<td>0.7703</td>
<td>0.7992</td>
<td>0.7885</td>
<td>0.7649</td>
<td>0.7907</td>
<td>0.7649</td>
<td>0.7490</td>
<td>0.7674</td>
<td>0.7183</td>
<td>0.6998</td>
</tr>
<tr>
<td>Inflation Rate</td>
<td>0.0025</td>
<td>0.0032</td>
<td>0.0035</td>
<td>0.0044</td>
<td>0.0058</td>
<td>0.0055</td>
<td>0.0064</td>
<td>0.0063</td>
<td>0.0071</td>
<td>0.0073</td>
<td>0.0079</td>
</tr>
</tbody>
</table>

Contract lengths were set to a maximum of one. Models with contract lengths greater than one resulted in negative inflation and significantly higher unemployment across an average of simulations. Changing contract lengths does not change the fundamental findings of the remainder of the paper, so we used one for simplicity. It may be apparent that the model is sensitive to a large number of parameters and the “optimal” values can only be found through a calibration exercise. Ultimately, we are forced to make choices about parameter values and move on to discuss suggestive policy implications holding these parameter values fixed.

\(^{10}\) Formal tests of differences in means are available upon request.
Table 4: Cycle and Simulation Averages for Varying Contract Length

<table>
<thead>
<tr>
<th>Maximum Contract Length</th>
<th>Avg. P→T</th>
<th>Avg. T→P</th>
<th>Unemployment</th>
<th>Vacancy Rate</th>
<th>Growth Rate</th>
<th>Inflation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.5147</td>
<td>8.7264</td>
<td>0.3153</td>
<td>0.0077</td>
<td>0.5650</td>
<td>0.0106</td>
</tr>
<tr>
<td>3</td>
<td>3.8764</td>
<td>7.4821</td>
<td>0.3577</td>
<td>0.0060</td>
<td>0.4278</td>
<td>-0.0007</td>
</tr>
<tr>
<td>5</td>
<td>3.6901</td>
<td>8.8083</td>
<td>0.3935</td>
<td>0.0060</td>
<td>0.5885</td>
<td>-0.0039</td>
</tr>
<tr>
<td>7</td>
<td>3.5192</td>
<td>9.0317</td>
<td>0.4167</td>
<td>0.0047</td>
<td>0.6489</td>
<td>-0.0047</td>
</tr>
<tr>
<td>9</td>
<td>3.3344</td>
<td>9.7780</td>
<td>0.4307</td>
<td>0.0044</td>
<td>0.6998</td>
<td>-0.0055</td>
</tr>
</tbody>
</table>

5 Fiscal Policy

After developing the baseline model statistics in Table 2, we engage two different government policies aimed at ending recessions. Two popular policy choices that we can analyze within this model are fiscal stimulus and tax cuts. We create fiscal stimulus via a trigger mechanism. We employ the same algorithm used here to detect business cycle peaks. Given that in simulated real-time, the algorithm cannot detect a peak within two periods of the endpoint we limit intervention only to recessions lasting longer than four periods. When recessions are longer than four periods, we could think of this as a “bad” recession where the government might intervene with tax cuts or increased spending.

In the first treatment, we examine fiscal spending. Following a peak in the business cycle the government stimulates spending by giving additional unemployment benefits to workers and additional R&D to firms using the value of δ from the baseline model. We estimate the impacts of increases in government borrowing equal to 10% of \( t - 1 \) consumer expenditures. Until the end of the recession occurs in real-time–a two-period lag after \( t \)–government stimulus continues to accumulate. The government runs deficits each period accumulating a quantity of debt up to 100% of total expenditures in \( t - 1 \). As soon as the following trough in the business cycle is detected and two additional periods have passed (\( t+4 \) after the trough), the government reverses course and begins clawing back funds at a rate of 10% per period relative to the original aggregate debt. Debt repayment occurs every period as long as the economy continues to expand. In this treatment, the clawback occurs as the unemployed receive fewer benefits and R&D funding from the government is

\[ ^{11} \text{Changes to the debt ceiling and interest on the debt can be accommodated but have been left out intentionally in these simulations.} \]
A second treatment is created using tax policy. Using peak and trough detection as in the fiscal spending treatment, taxes are reduced 25% across the board during a recession. Thus the tax rates in our treatment change from $\tau_1 = 10\%, \tau_2 = 20\%, \tau_3 = 30\%$ and $\tau_c = 30\%$ to $7.5\%, 15\%, 22.5\%$, and $22.5\%$ respectively. Benefits to the unemployed and R&D are immediately cut reflecting tax reductions along with simultaneous spending reductions. After the end of the recession, tax rates are returned to their original level along with increased spending.

We compare the two treatments to the baseline model by examining distributional impacts at the conclusion of a single simulation and business cycle impacts across 100 simulations. The distribution of wealth and consumption vary across representative simulations. Figures 9 and 10 show evolution of the gini coefficients for consumption and wealth under each policy for a single simulation. Across these three simulations, the average gini coefficients are significantly different for both consumption and wealth.

Figure 9: Gini Coefficients for Consumption

We examine the distribution of recessions and expansions across the baseline and two treatments for 100 simulations. Figure 11 displays a histogram of recession lengths under each treatment and
Recessions appear to shorten in the fiscal treatment relative to both the baseline model and tax treatment. The tax policy treatment lengthens recessions relative to the baseline while also making recessions deeper. Growth in the tax treatment is significantly higher than in either the baseline or fiscal treatment. We also observe greater inequality and volatility with lower tax rates. These results suggest that the choice between equity and efficiency still plays a role when implementing fiscal policy in a heterogenous-agent model.
Table 5: Business Cycle Characteristics of the Baseline, Fiscal Treatment, and Tax Treatment

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Fiscal</th>
<th>Taxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>P→T</td>
<td>Duration</td>
<td>3.6717</td>
<td>3.5744</td>
</tr>
<tr>
<td></td>
<td>Amplitude</td>
<td>-2.7020</td>
<td>-2.7394</td>
</tr>
<tr>
<td></td>
<td>Cumulative</td>
<td>-5.7075</td>
<td>-5.2753</td>
</tr>
<tr>
<td></td>
<td>Excess</td>
<td>0.0023</td>
<td>0.0306</td>
</tr>
<tr>
<td>T→P</td>
<td>Duration</td>
<td>11.3900</td>
<td>11.1768</td>
</tr>
<tr>
<td></td>
<td>Amplitude</td>
<td>10.7443</td>
<td>10.3667</td>
</tr>
<tr>
<td></td>
<td>Cumulative</td>
<td>111.6891</td>
<td>99.5161</td>
</tr>
<tr>
<td></td>
<td>Excess</td>
<td>0.1095</td>
<td>0.1797</td>
</tr>
<tr>
<td></td>
<td>Unemployment</td>
<td>0.3145</td>
<td>0.3140</td>
</tr>
<tr>
<td></td>
<td>Vacancy Rate</td>
<td>0.0080</td>
<td>0.0081</td>
</tr>
<tr>
<td></td>
<td>Growth Rate</td>
<td>0.5544</td>
<td>0.5428</td>
</tr>
<tr>
<td></td>
<td>Inflation Rate</td>
<td>0.0098</td>
<td>0.0100</td>
</tr>
</tbody>
</table>

6 Conclusions

The HIA approach to macroeconomics shows promise as an alternative to the general equilibrium approach. The HIA model developed here follows in the CATS approach to examining a macroeconomy. Through the addition of taxation at the individual and firm level, we use redistributive policy to examine the business cycle effects of two different types of fiscal policy to stem the damage from recessions. It is shown here that fiscal stimulus equivalent to 10% of expenditures leads to shorter recessions. Alternatively a tax policy that simultaneously reduces redistribution leads to longer recessions on average. The same tax treatment leads to faster growth on average relative to both the baseline and fiscal treatment. These results suggest that fiscal policy to dampen the impact of recessions is effective in a HIA-CATS model. These results also suggest that tax policy relative to our baseline model leads to greater aggregate consumption and wealth in the long run. An analysis of Gini coefficients however displays a more unequal economy in terms of both consumption and wealth under the tax treatment relative to the baseline and stimulus treatment.
The approach taken here can be expanded in a number of ways to incorporate more policy choices as well as a financially fragile banking sector. Several HIA-CATS models seen to date have included individual features like monetary policy and capital constrained banks. The use of a business cycle dating algorithm here to compare different models is a unique approach to testing models against one another. We find it encouraging that even without calibrating these models to observable data, we are able to see business cycle features simulated here that are close to the quarterly business cycle characteristics observed in the U.S. for the past 65 years.

![Figure 11: Distribution of Recessions](image)

References


Figure 12: Empirical Distribution of Recession Duration

Figure 13: Empirical Distribution of Expansion Duration


_ , _ , and _ , *Complex Dynamics and Financial Fragility in an Agent Based Model*, Heidelberg: Springer-Verlag,

