MONETARY POLICY AND LABOR SUPPLY

By

Patrick Burke

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Economics—Doctor of Philosophy

2022

ABSTRACT

MONETARY POLICY AND LABOR SUPPLY

By

Patrick Burke

The first chapter gives an overview of the current literature on participation in the labor market. Special attention is paid to trends in participation since 2000. The role of demographic change in those trends is compared against other explanations. With the increasing focus on labor market participation at the United States Federal Reserve, the history of monetary policy changes and participation is also examined.

The second chapter estimates a labor market matching model to get a more accurate measure of the market tightness elasticity of the job finding rate and unexplained residual. The estimation strategy in the second chapter follows the approach in Borowczyk-Martins et al. (2013) which models the autocorrelation structure of the unobserved component in the matching function to address simultaneity bias. This chapter then uses asset data present in the Survey of Income and Program Participation. This allows for the use of average household debt as an additional instrument to correct for measurement error. These results help characterize the recent shifts in the Beveridge curve and the decline of the matching rate between job seekers and job openings between 2008-2013.

How important is labor supply for the ability of monetary policy to influence inflation and employment? Hiring costs alter the response of inflation to monetary policy. As shown in Kurozumi and Van Zandweghe (2010), adjustments in employment can make it difficult for monetary policy to reach its price stability and full employment targets. As the policy response is more vigorous in maintaining inflation around a target, that target becomes impossible to maintain. Recent fluctuations in the participation rate have led to a growing concern about the role of labor supply in monetary policy. This chapter shows that as labor supply becomes more elastic, the monetary authority is more likely to be able to stabilize the economy around its steady state targets. The central bank's response to cyclical unemployment is important for price level stability regardless of business cycle goals. Journal of Economic Literature codes: E12 E24 E31 E32 E52.

ACKNOWLEDGMENTS

I would like to thank Antonio Doblas-Madrid, Luis Araujo, Qingqing Cao, Soren Anderson, Kirt Butler, Dale Belman, and the participants of the Graduate Student Seminar for their helpful advice and constructive criticism.

TABLE OF CONTENTS

LIST OF TABLES vi

LIST OF FIGURES vii

1 Labor Force Participation and Monetary Policy 1
  1.1 Introduction 1
  1.2 Historical Trends in the Participation Rate 3
  1.3 Labor Supply during Business Cycles 7
  1.4 Skills Mismatch 10
  1.5 Monetary Policy and the Labor Force 13
  1.6 Conclusion 17

2 Accounting for Simultaneity and Measurement Error in Aggregate Measures of Mismatch 18
  2.1 Introduction 18
  2.2 Data 25
  2.3 Estimation Design 26
    2.3.1 Asset Holdings as an Instrument for Search Intensity 32
  2.4 Conclusion 34

3 Taylor Determinacy and Labor Supply 36
  3.1 Introduction 36
  3.2 Model 40
    3.2.1 Households 42
      3.2.1.1 Household First-Order Conditions 44
    3.2.2 Wholesale Firms 44
    3.2.3 Matching 46
    3.2.4 Nash Bargaining 47
      3.2.4.1 Nash Bargaining Solution 47
    3.2.5 Calvo Firms 48
    3.2.6 Taylor Rule 49
    3.2.7 Steady State 50
  3.3 Linear Approximation around the Steady State 51
  3.4 Calibration 52
  3.5 Results 53
    3.5.1 Baseline Model Impulse Response 53
    3.5.2 Taylor Determinacy 55
  3.6 Labor Supply Elasticity 56
  3.7 The Role of Matching Frictions 58
  3.8 Conclusion 62

REFERENCES 66

LIST OF TABLES

Table 1.1 Participation Rates by Age in 2000 11

Table 1.2 Participation Rates by Age in 2019 12

Table 1.3 Participation Rates from 2000, Age Distribution of 2019 13

Table 2.1 Results (2nd Stage) - Lagged Variables 29

Table 2.2 Results (1st Stage) - Lagged Variables 29

Table 2.3 Results (2nd Stage) - U3 31

Table 2.4 Results (2nd Stage) - Debt 33

Table 2.5 Results - 95% Confidence Intervals - Debt 33

LIST OF FIGURES

Figure 1.1	Discussion of Labor Supply during FOMC Minutes	3
Figure 1.2	Participation Rate 1948 - 2022	4
Figure 1.3	Participation Rate of Men and Women 1948 - 2022	5
Figure 1.4	Participation Rate for 15 - 30 Men and Women	6
Figure 1.5	Participation Rate for 30 - 49 Men and Women	7
Figure 1.6	Participation Rate by Age, Under 40	9
Figure 1.7	Participation Rate by Age, Over 40	10
Figure 1.8	Percent of Population* by Age Group, Under 50	11
Figure 1.9	Percent of Population* by Age Group, Over 50	12
Figure 1.10	Percent Change in Fed Assets and the Participation Rate	15
Figure 1.11	Percent Change in Fed Assets and the Participation Rate	16
Figure 2.1	The Beveridge Curve from 2001 - 2021	19
Figure 2.2	The Job Finding Rate and Implied Matching Efficiency	20
Figure 2.3	In and Outflows in the Labor Market	24
Figure 3.1	The Agents in the Model and the Associated Markets	42
Figure 3.2	Impulse Response of Baseline Model	54
Figure 3.3	Taylor Determinacy in the Baseline Model	55
Figure 3.4	Elastic and Inelastic Labor Supply, Taylor Determinacy	57
Figure 3.5	Elastic and Inelastic Labor Supply, Impulse Response	59
Figure 3.6	New Keynesian Impulse Response	60
Figure 3.7	Taylor Determinacy in the New Keynesian Model	61
Figure 3.8	Taylor Determinacy Boundaries	62

Chapter 1

Labor Force Participation and Monetary Policy

1.1 Introduction

Recent changes in the participation rate[1] have brought increased focus from economic research. After a long period of growth, the participation rate reached its peak in 2000. Since then it has been falling. Recent recessions have had large drops in the participation rate which has led to a debate about underlying causes. How much of the recent declines in labor supply were caused by the aging United States population as opposed to temporary cyclical factors? What role, if any, does a shortage of workers with specific skills play? Are there other changes in the labor market that could cause this shift? The Federal Reserve now carefully considers the labor force participation rate as part of their full employment mandate. For a long time, labor supply changes have been treated as being of second order in importance in most macroeconomic

[1]The participation rate is the percent of a population, typically the working age population, that is either employed or actively looking for work.

models of the business cycle, but recent events and research have shown that it is important to consider even in the short run.

At the Federal Reserve (henceforth the Fed) attention on labor supply has grown considerably since early 2000. Figure 1.1 shows the number of times labor supply topics were discussed in the official minutes of the Federal Open Market Committee (henceforth FOMC) meetings. While overall labor market conditions have always received extensive focus, the Greenspan Fed in the early 2000s spent much more time considering labor demand issues. The increased focus on labor supply also aligns with more concerns about labor shortages in the official minutes. Many of these concerns were focused on companies having difficulties finding workers with specific skills during 2004 - 2006 and now again since early 2022. Starting in 2009 and continuing well into 2014 there was also a significant concern in the FOMC minutes about reallocation of workers, skills mismatch, and long-term damage to the labor force caused by lengthy unemployment spells. With the end of the post-war growth in the participation rate and falling participation during recessions, there has been more attention to labor supply in recent years at the Fed. For example, the persistent decline in the employment to population ratio during 2014 - 2017 prompted concerns at the Fed of falling short of its mandate despite gains against unemployment. There was a debate at the Fed about whether unemployment was a sufficient measure of tightness and slack in the labor market. Giving a speech at the Economic Club of New York in February 2021, Chairman Powell referenced the prime age labor force participation as a core component in his analysis of the Labor Market:

> The labor force participation rate, for example, had been steadily declining from 2008 to 2015 even as the recovery from the Global Financial Crisis unfolded. In fact, in 2015, prime-age labor force participation—which I

focus on because it is not significantly affected by the aging of the population—reached its lowest level in 30 years even as the unemployment rate declined to a relatively low 5 percent.

As that quote and figure 1.1 make clear, the current Fed pays close attention to changes in the labor force.

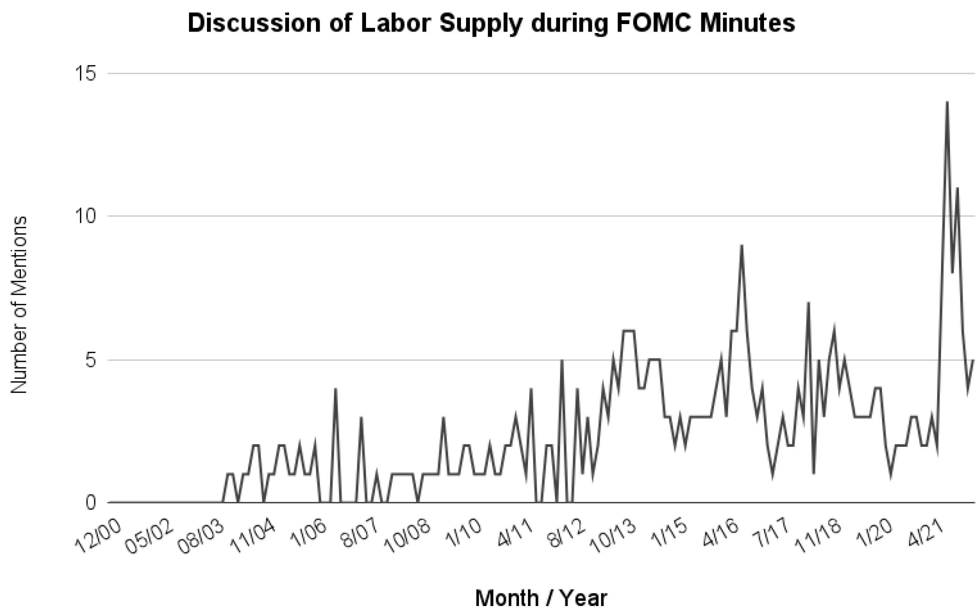


Figure 1.1: Discussion of Labor Supply during FOMC Minutes
The graph reports the total count of times labor force participation, the employment to population ratio, labor supply, entry, exit, or attachment to the labor force were mentioned in the released minutes for the FOMC meetings conducted in each corresponding month. The minutes were obtained from the archive on the Federal Reserve website.

1.2 Historical Trends in the Participation Rate

In the post-war era, labor force participation experienced several decades of growth from increases in women's labor force participation. Figure 1.2 shows the changes

Figure 1.2: Participation Rate 1948 - 2022
This graph reports the overall participation rate each month from the Current Population Survey (Bureau of Labor Statistics, 1948 - 2022).

in the participation rate since 1948. Labor force participation reached a peak in 2000 after growing substantially since 1960. In 1970 the overall participation rate was 60% and growing. The participation rate reached a high point of 67% in 2000. As shown in figure 1.3, the increase in the overall participation rate was caused by the substantial increase in the participation rate of women. In 1970 the female participation rate was 43.5%. By 2000 it had increased to just above 60%. Instead, male participation has actually declined in the post-war era. In 1970 the participation rate for men was 80% and by 2000 it had declined to roughly 75%. The life-cycle of labor force participation for women has also been flattening over time. Relative to the past, women's participation during young adulthood and pre-retirement has been increasing. Now the life cycle labor supply for women is more similar to men, although at slightly lower rates Goldin and Mitchell (2017).

Of particular interest is the cause of the falling participation rate since 2000.

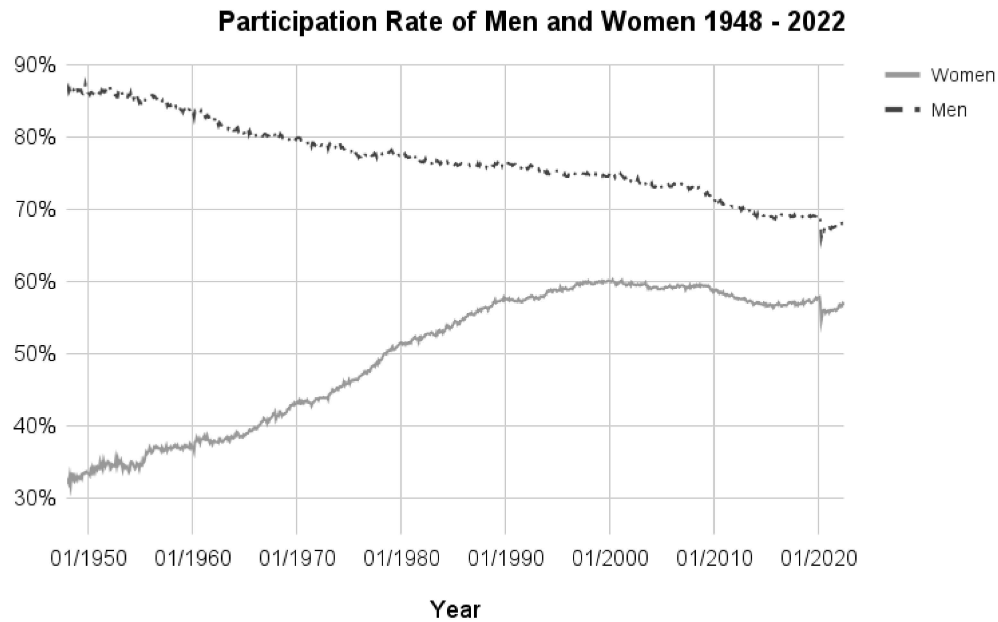


Figure 1.3: Participation Rate of Men and Women 1948 - 2022
The labor force participation rate for men and women in the post-war era from the monthly Current Population Survey (Bureau of Labor Statistics, 1948 - 2022).

Aaronson et al. (2006) describe and fit a model to the labor force participation rate. Their model largely matches the actual data since 2006 when it was published. Outside of those older than 55, participation has been falling for most demographics in this period as shown in figure 1.6. The sharpest decline is perhaps among the ages of 15-19, whose participation rate fell from 54% to 39% between 2000 and 2019. While the given reason in surveys by teenagers out of the labor force is schooling, the percentage of teenagers in school has only adjusted modestly Hipple (2016), leading some economists to hypothesize that the increasing competition for college entrance has led to higher school intensity. Figure 1.4 and figure 1.5 show the labor force participation rates for younger men and women since 2000 separated in 5-year age bins. It shows that for younger Americans, women's labor force participation has begun to surpass men's. Female labor force participation in the 15-19-year-old group surpasses men by

2001. Women's labor force participation passes men's in the 20-24 age group by 2013. Women's participation in younger age groups has continued to grow while men's has continued to fall.

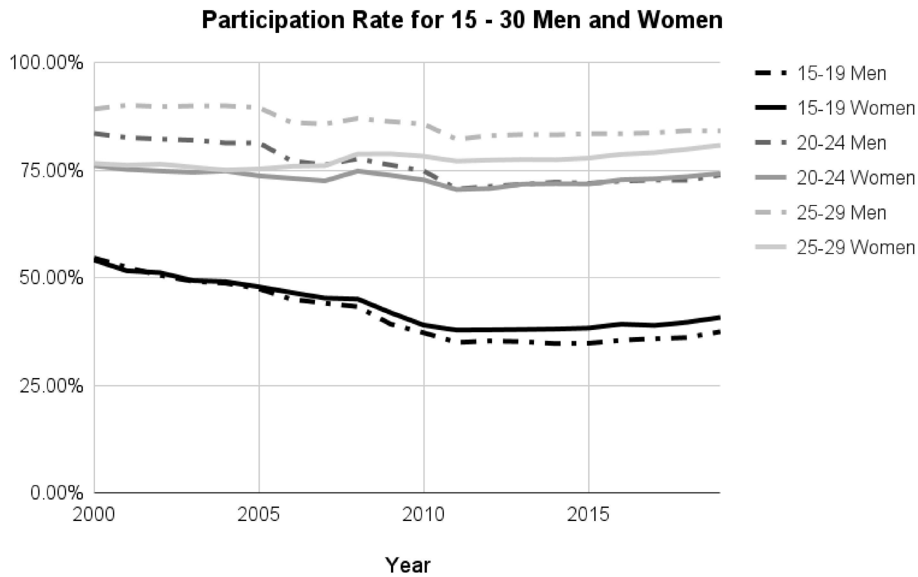


Figure 1.4: Participation Rate for 15 - 30 Men and Women
This graph reports the percent of the people in the labor force for men or women in each of the labeled 5-year age groups from the yearly American Community Survey. The American Community Survey data was obtained through IPUMS (Ruggles et al., 2022).

There has also been a growing share of the adult population out of the labor force due to disability. In 1985 2.2% of the adult population was receiving disability benefits, by 2005 it had eclipsed 4% David and Duggan (2006). In part, disability benefits seem to be fulfilling a long-term unemployment role in the United States. There has been declining health documented in middle-aged Americans including rising mortality in recent years Case and Deaton (2015).

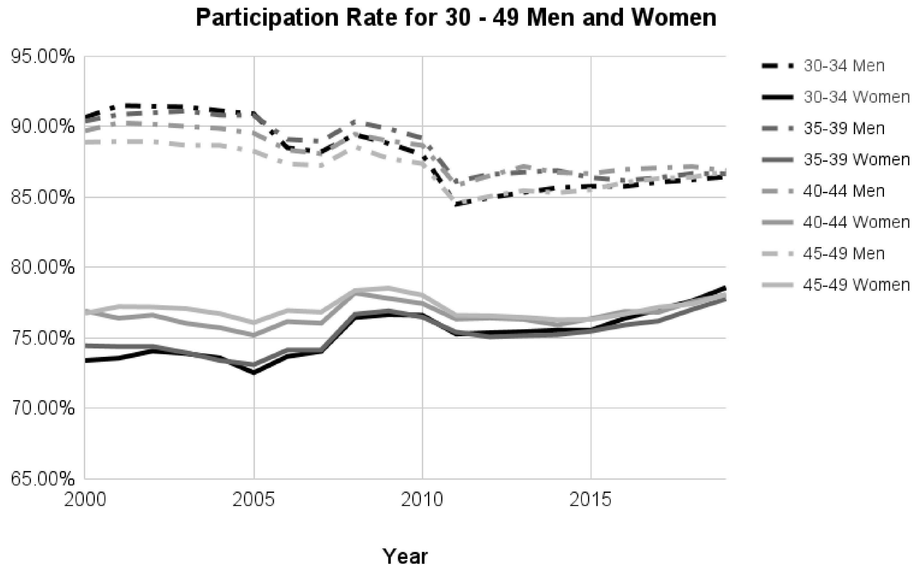


Figure 1.5: Participation Rate for 30 - 49 Men and Women
This graph reports the percent of the people in the labor force for men or women in each of the labeled 5-year age groups from the yearly American Community Survey. The American Community Survey data was obtained through IPUMS (Ruggles et al., 2022).

1.3 Labor Supply during Business Cycles

The participation rate is mildly procyclical. Notable drops in the participation rate have also occurred after each recession since 2000. During both the Great Recession and during the Covid Pandemic, there were large drops in the participation rate. After the great recession, the participation rate dropped 2.5 percentage points Erceg and Levin (2014). Erceg and Levin (2014) also find that cyclical factors are able to fully explain the drop in prime-age participation rate from 2007 to 2010. In the spring of 2020, the participation rate dropped by 3 percentage points from 63.4% in February to 60.2% in April, before stabilizing around 61.5% between June of 2020 till October of 2021.

The participation decision is important for cyclical unemployment. Elsby et al.

(2015) shows that about 1/3 of the variation in unemployment can be explained by changes across the participation margin despite the relatively low volatility of the labor force across the cycle. The inflow to unemployment from out of the labor force accounts for about 10% of the variation in cyclical unemployment while exits from unemployment to non-participation are about 25% of the change in unemployment. The average unemployed person during a recession tends to have much stronger links to the labor force, such as being more recently employed. Elsby et al. (2009) show that unemployment inflows are important to consider not just outflows. Krusell et al. (2012) also shows in a theoretical macroeconomic model that even though equilibrium volatility in participation is small, the option to enter or exit the labor force has large impacts on other macroeconomic variables. Given these results in the literature, the Fed's recent more comprehensive approach to the full employment mandate that includes a focus on participation seems justified.

There is an ongoing debate in the literature on whether the majority of the decline in participation between 2007 to 2014 was from cyclical causes or demographic change.[2] The composition of the United States workforce has been aging as the large Baby Boom generation has been getting older. In 2000 the average age of people over 15 in the United States was just over 45, by 2019 that had increased to just under 49. Since labor force participation generally declines for individuals older than 55, this demographic shift naturally reduces the headline participation rate as well.

Figure 1.6 and 1.7 show the changes in the participation rate split into 5-year age groups. As can be seen, the changes in participation evident in the overall rate since 2000 look much more muted when viewed by each age group. The participation

[2]Bullard et al. (2014) give an overview of this debate. Fujita et al. (2014) and Kudlyak (2013) are generally supportive of the demographic side while Erceg and Levin (2014), Aaronson et al. (2012), Van Zandweghe (2012), Hotchkiss and Rios-Avila (2013) generally support cyclical factors as being dominant.

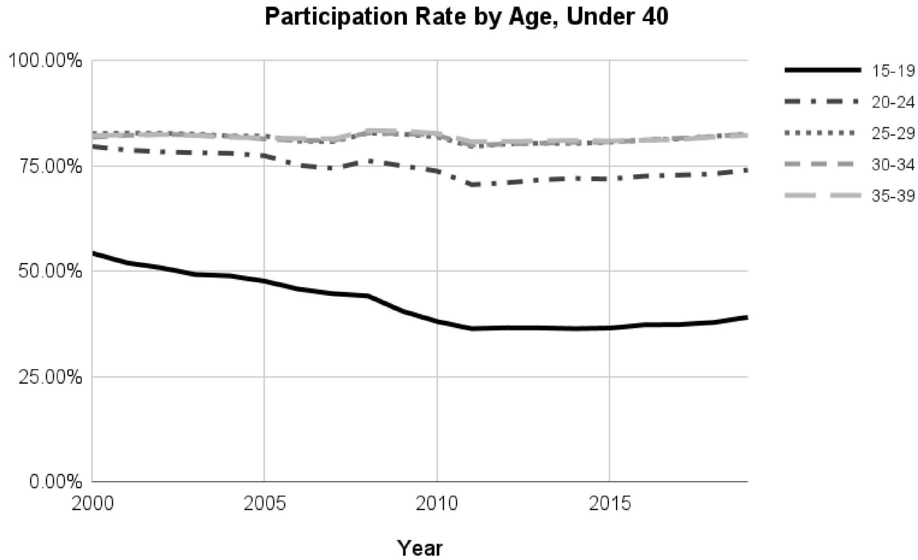


Figure 1.6: Participation Rate by Age, Under 40
Labor force participation rate by age groups under 40 since 2000. There was a sharp decrease in participation in the 15-19 age group and a decrease in participation in the 20-24 age group. Each of the labeled 5-year age groups was calculated from the yearly American Community Survey. The American Community Survey data was obtained through IPUMS (Ruggles et al., 2022).

rate of young adults declines slightly, older workers' participation rises slightly, and teenage participation declines somewhat dramatically. The drop in participation from the pandemic is also easy to see and most severe for people in their early 20s. This together suggests that demographic shift has much to explain for the changes in the average participation rate since 2000 as the population ages and people enter the phase of their life cycle of labor participation that is lower.

Aging of the average American is leading to a decline in the participation rate. As can be seen in the trends in the age distribution in figure 1.8 and figure 1.9, the average American is older since 2000. Table 1.1 and table 1.2 show the participation rate and percent of the over 15-year-old population for each age group in the American Community Survey (Ruggles et al., 2022) for 2000 and 2019. Calculation of the

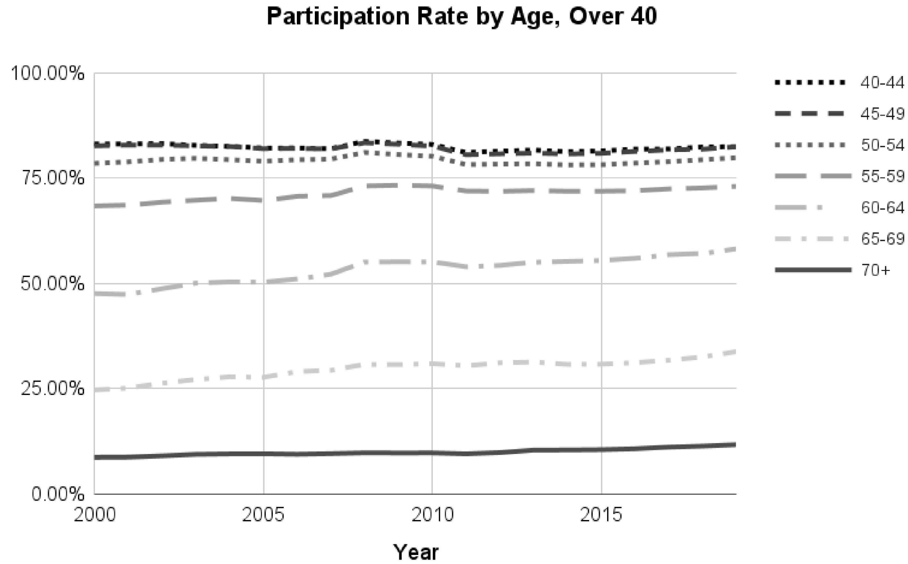


Figure 1.7: Participation Rate by Age, Over 40
Labor force participation rate by age group over 40 since 2000. There were slight increases in participation in the older population during this period. Each of the labeled 5-year groups was calculated from the yearly American Community Survey. The American Community Survey data was obtained through IPUMS (Ruggles et al., 2022).

implied overall participation rate from the age distribution across the 5-year bins the participation rate in 2000 is 65% and 59% in 2019. As shown in table 1.3, using the age distribution for 2019 with the average participation rates in 2000, the overall participation rate falls to 58%. The change in the age distribution alone is able to account for the majority of the change in the overall participation rate.

1.4 Skills Mismatch

The large shift in the Beveridge curve[3] also spawned research about the possibility of structural mismatch in the United States labor market. Between 2012 and 2014 a

[3]The Beveridge curve is a graph of the number of job openings against the number of people looking for work. See figure 2.1.

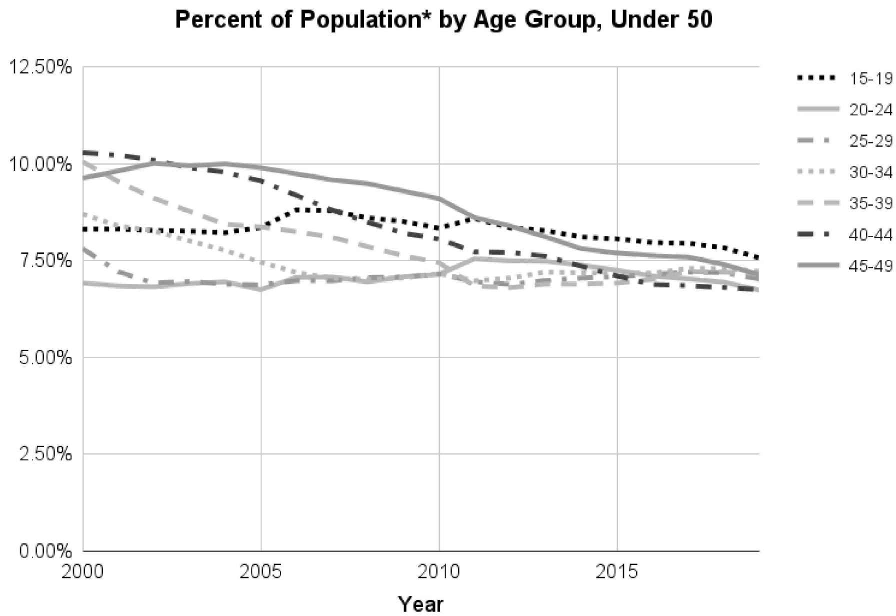


Figure 1.8: Percent of Population* by Age Group, Under 50
This graph shows the declining population share of the younger than 50 age group, excluding people under 15 years old. Since 2000 the population composition in the United States has aged fairly significantly. Each of the labeled 5-year age groups was calculated from the yearly American Community Survey. The American Community Survey data was obtained through IPUMS (Ruggles et al., 2022).

Table 1.1: Participation Rates by Age in 2000

Age Group	LFPR	Percent of Population
15-19	54.3%	8.3%
20-24	79.6%	6.9%
25-29	82.6%	7.8%
30-34	81.8%	8.7%
35-39	82.1%	10.0%
40-44	83.1%	10.3%
45-49	82.7%	9.6%
50-54	78.5%	8.6%
55-59	68.3%	6.7%
60-64	47.5%	5.5%
65-69	24.6%	4.9%
70+	8.6%	12.6%
Overall Participation Rate		65%

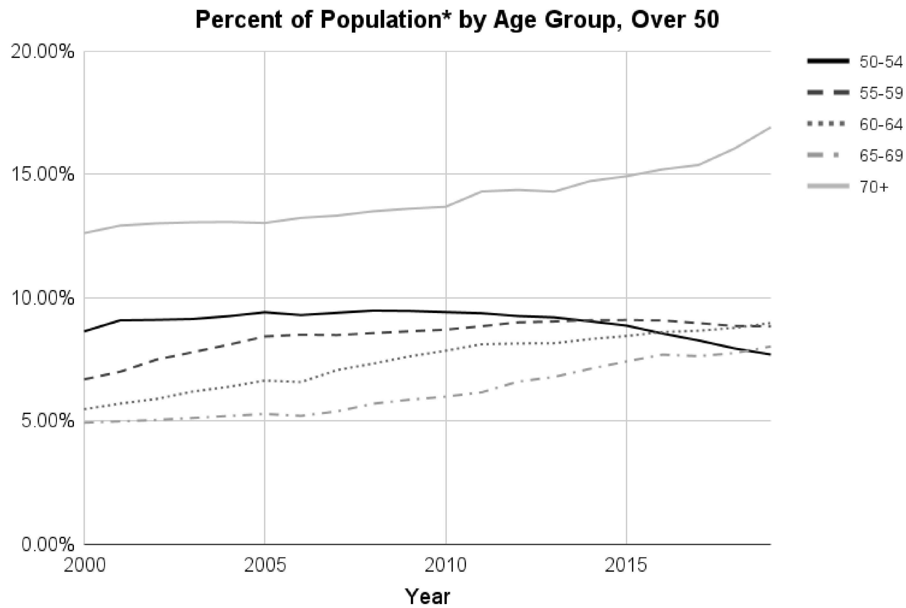


Figure 1.9: Percent of Population* by Age Group, Over 50
This graph shows the increasing population share of the older than 50 age groups, excluding people under 15 years old. Since 2000 the population composition in the United States has aged fairly significantly. Each of the labeled 5-year age groups was calculated from the yearly American Community Survey. The American Community Survey data was obtained through IPUMS (Ruggles et al., 2022).

Table 1.2: Participation Rates by Age in 2019

Age Group	LFPR	Percent of Population
15-19	39.1%	7.6%
20-24	74.0%	6.7%
25-29	82.4%	7.0%
30-34	82.5%	7.2%
35-39	82.2%	7.2%
40-44	82.4%	6.7%
45-49	82.4%	7.1%
50-54	79.8%	7.7%
55-59	73.0%	8.8%
60-64	58.1%	9.0%
65-69	33.8%	8.0%
70+	11.6%	16.9%
Overall Participation Rate		59.5%

Table 1.3: Participation Rates from 2000, Age Distribution of 2019

Age Group	LFPR 2000	Population 2019
15-19	54.3%	7.6%
20-24	79.6%	6.7%
25-29	82.6%	7.0%
30-34	81.8%	7.2%
35-39	82.1%	7.2%
40-44	83.1%	6.7%
45-49	82.7%	7.1%
50-54	78.5%	7.7%
55-59	68.3%	8.8%
60-64	47.5%	9.0%
65-69	24.6%	8.0%
70+	8.6%	16.9%
Overall Participation Rate		58.3%

concern at the Fed was whether structural changes in the labor market were changing the natural unemployment rate. The Fed was also concerned that mismatch and exit from the labor force was causing unemployment to be misleading about the current state of the labor market. Elsby et al. (2011) review the recent literature in this area and, while measurable, they find the amount attributable to a skills mismatch is a relatively modest one percentage point and appears to be transitory. Likewise, Elsby et al. (2011) does not find support in the literature for strong effects from house lock or geographic changes despite the evidence of changes in labor market fluidity, as observed by Davis and Haltiwanger (2014). Again, demographic change is a significant part of the story but there appear to be other significant factors.

1.5 Monetary Policy and the Labor Force

How does Monetary Policy impact participation? This is particularly important because of the increased focus of the Fed on the participation rate as part of a more comprehensive consideration of the labor market. Do the actions of the Fed have significant impacts on the participation rate or employment to population ratio? Even if the ability of the Fed to change labor supply is small, it may still be important to understand how participation evolves to get a better read on future changes in unemployment for the Fed.

A reasonable first guess might be that participation has a similar response to monetary policy that employment does. A monetary policy change could be merely in anticipation of a changing labor market and therefore have a positive correlation. The Fed's policy can signal information about future trends in the economy and cause changes in behavior because of that information. For example, if the fed thinks the labor market is going to be hot in the future it may make sense to hire now causing the prediction to be self-fulfilling. Finally, it may just reflect that participation should not be expected negatively correlated with Fed policy theoretically.

These questions are related to the monetary surprises and channels literature that discuss the non-neutrality of monetary policy. Bernanke and Blinder (1992) use the Federal Funds Rate (FFR) and show that is both predictive of monetary policy and real variables. Using their Structural Vector Autoregression (SVAR) approach. The results suggest that unemployment moves expectedly, increasing with tightening policy, but is delayed. The effects on unemployment are low until 1-2 years from the policy change. As noted in Romer and Romer (2000) information effects of monetary policy changes are relevant and cause changes in variables that run counter to expected theory. Jarociński and Karadi (2020) is able to differentiate from the information and policy shock attributed to unexpected Fed moves by using high-frequency information on 3-month Fed Funds futures and the S&P 500 index. Jarociński and Karadi (2020) also show a simple heuristic that attributes all of the shocks that are in line with standard theory as policy shocks and those with the opposite movement as solely from an information shock rather than a potential of these two shocks performs decently. It performs better for policy shock since they tend to be larger, for the impulse function the correlation between the heuristic and their SVAR results for policy shocks is 0.88, for information shocks it is a correlation of 0.55. Their impulse response functions for real gross domestic product, gross domestic product deflator, and even bond yields tend to also be long-lived and play out over 1 - 2 years. Given these facts, a structural model, such as Christiano et al. (2005), seems necessary to get an accurate measure of the overall impact on participation from monetary policy.

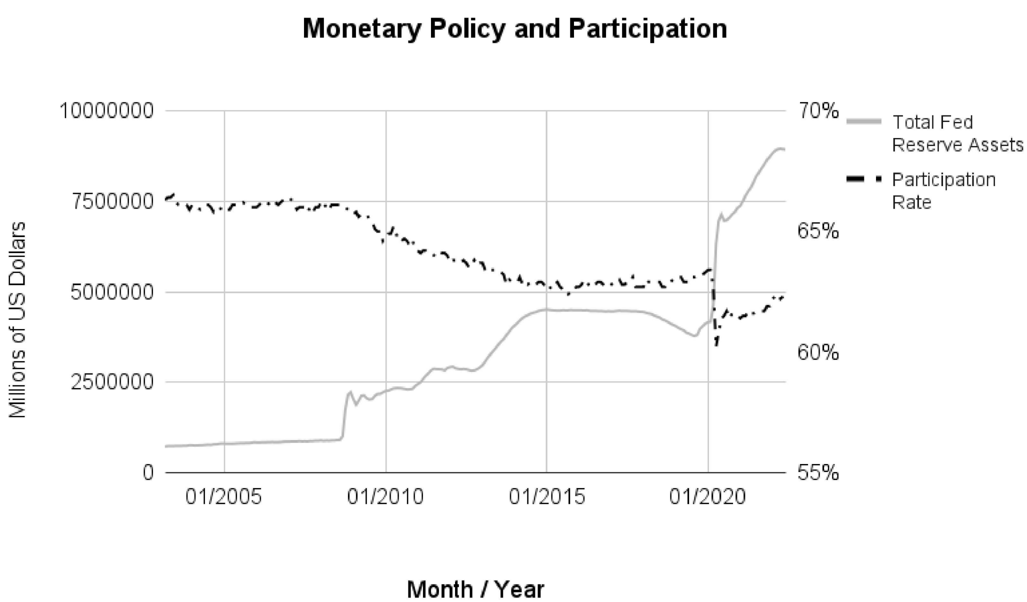


Figure 1.10: Percent Change in Fed Assets and the Participation Rate
The timeline of the participation rate, corresponding to the right vertical axis, compared against the timeline of the total value of the Federal Reserve's assets, corresponding to the left vertical axis. The total assets are calculated as a monthly average of the weekly H.4.1 release, retrieved from FRED (Board of Governors of the Federal Reserve System, 2003 - 2022).

Figures 1.10 and 1.11 show the evolution of the overall labor force participation rate compared to the average size of the Fed's balance sheet each month. Figure 1.11 shows the participation rate against the percent change from a year ago in

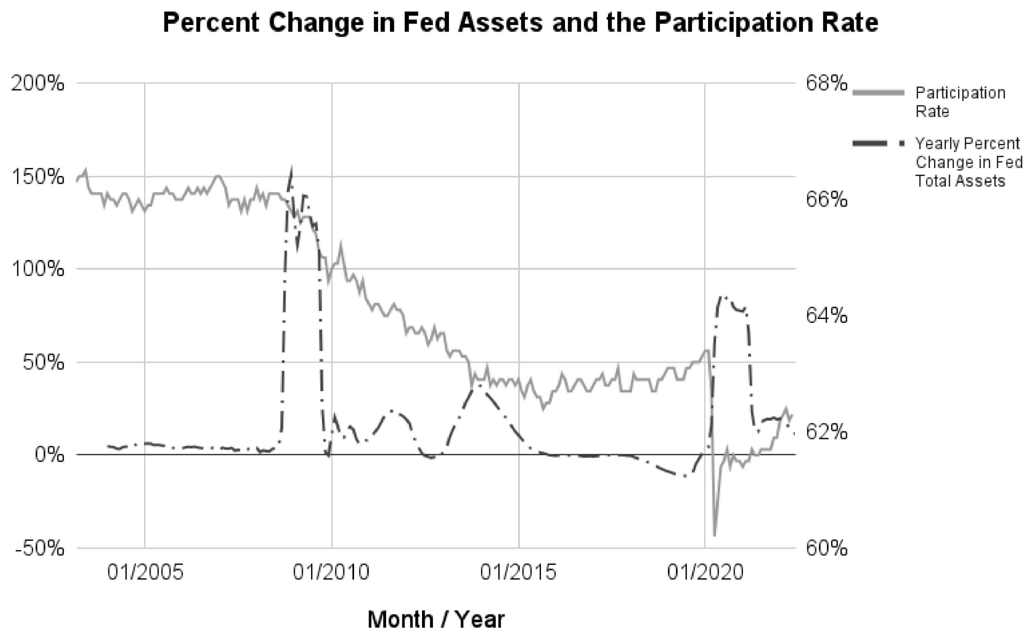


Figure 1.11: Percent Change in Fed Assets and the Participation Rate
The timeline of the participation rate, corresponding to the right vertical axis, compared against the timeline of the year-over-year percent change of the Federal Reserve's assets, corresponding to the left vertical axis. The total assets are calculated as a monthly average of the weekly H.4.1 release, retrieved from FRED (Board of Governors of the Federal Reserve System, 2003 - 2022).

the total assets held by the Fed. At first glance participation and monetary policy seem to be inversely correlated. As the Fed increases the size of its balance sheet participation tends to be lower than its average. Figure 1.11 makes it easier to see the relative timing, for example in early 2020 the fall in the participation from the Covid pandemic clearly starts before the asset purchases by the Fed. Overall it is clear the immediate impact of asset purchases on the participation rate is small.

1.6 Conclusion

This chapter discussed recent developments in the participation rate. After increasing drastically in the post-war era in the United States, the participation rate has been declining since the start of the new millennium. This is largely caused by demographic change as the Baby Boom generation enters retirement ages. During each of the last two recessions labor market participation has dropped dramatically, demonstrating the importance of labor supply during recessions. At the United States Federal Reserve, the participation rate has begun to take a more central part in their analysis of labor market health. Like unemployment, the influence of monetary policy on labor supply seems to be very delayed. This remains a promising area for future research. It could reflect a precautionary working motive. Breaking out the changes in participation by age group shows that for most age groups the change in participation since 2005 is quite muted. Youth participation has dropped fairly substantially during this period. These recent events have emphasized the importance of labor supply in business cycle research.

Chapter 2

Accounting for Simultaneity and Measurement Error in Aggregate Measures of Mismatch

2.1 Introduction

After the 2008 recession and into the recovery there was a growing concern about the degree of long-run unemployment and how it might be related to long-term skills mismatch. In the Beveridge curve[1] shown there is an evident shift around 2009 after the 2008 recession.

In theoretical models of the labor market, a Beveridge curve arises from a steady state relation between inflows and outflows from employment. This chapter will define mismatch as changes in the hiring rate that can not be explained by direct

[1]The Beveridge curve is the graph between unemployment and job openings. As can be seen in figure 2.1 they are negatively correlated and are clustered together. In most theoretical matching models the Beveridge curve is a single curve based on an equilibrium between job inflows and outflows.

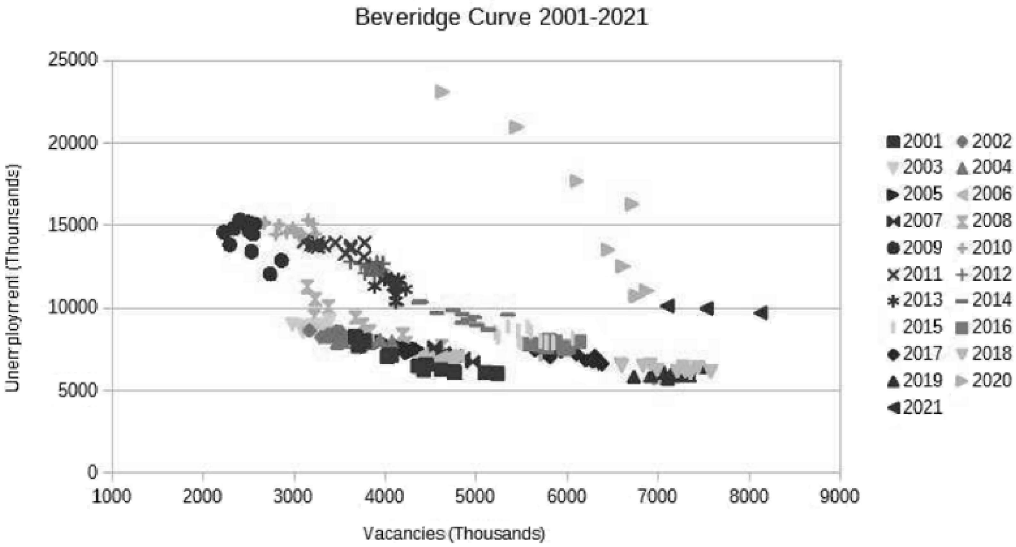


Figure 2.1: The Beveridge Curve from 2001 - 2021
This graph shows the Beveridge curve, which is the statistical pattern between unemployment and job openings. The apparent curve shows a large shift to the right around 2009 and again around 2020. The data for the figure comes from the Job Opening and Labor Turnover Survey (Bureau of Labor Statistics, 2001 - 2021).

changes in the number of job openings or in the number of people looking for work. Is the apparent increase in the number of unemployed per vacancy statistical noise? Could the large shifts be evidence of other underlying changes in the labor market? A convenient modeling device for the hiring rate which accounts for various labor market frictions is the matching function made famous by Diamond, Mortensen, and Pissarides.[2] This matching function is often modeled as a Cobb-Douglas function that relates the ratio of job vacancies to job seekers, called the market tightness, to the probability of getting hired. Completely analogous to a productivity shock in an aggregate production function, the matching efficiency accounts for the variation in hiring that can not be attributed to changes in the market composition between job seekers and job openings. Letting F_t denote the job finding rate, Θ_t denote the ratio

[2]See Petrongolo and Pissarides (2001) or Yashiv (2007) for a survey. The excellent Pissarides (2000) is a good introduction to these models.

of job vacancies to job openings, and A_t be the matching efficiency. This chapter will address estimates of the function in equation 2.1.

$$F_t = A_t \Theta_t^{\alpha} \tag{2.1}$$

This chapter then tries to quantify this shift by getting a consistent estimator of the observed components and analyzing the fitted residuals for the unobserved matching efficiency variable.

There is an extensive empirical literature [3] that finds modest support for a constant returns to scale, Cobb-Douglas matching function with an elasticity (e.g. α in equation 2.1) between 0.6 - 0.8. Figure 2.2 shows that the residuals from using a matching function show a large drop in the matching efficiency in 2009. There are two obvious sources of endogeneity in estimating the model in equation 2.1 using ordinary least squares (OLS) that may cause naive estimates of matching efficiency to be biased.

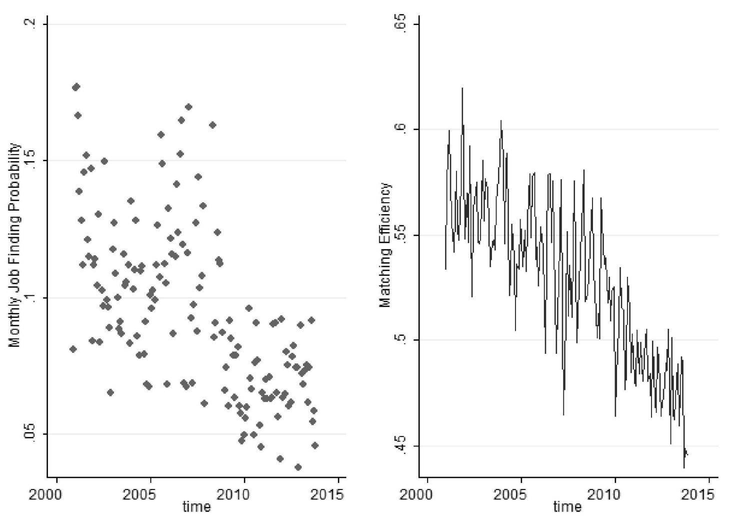


Figure 2.2: The Job Finding Rate and Implied Matching Efficiency

[3]See Petrongolo and Pissarides (2001) or Yashiv (2007) for a review.

OLS estimates of the model in equation 2.1 suffer from simultaneity bias since changes in matching efficiency also modify the returns for a worker's job search and the returns for a firm's job posting. Therefore, innovations in matching efficiency are correlated with movements in market tightness. A quasi-differencing generalized method of moments (GMM) approach advocated by Borowczyk-Martins et al. (2013) is one approach to deal with this bias. They assume that the unobserved residual is well modeled by an autoregressive moving average (ARMA) model and then are able to use differencing to account for correlation with the autoregressive components and instrumental variables to cover the remaining endogeneity from the moving average components of the error.

One source of measurement error is caused by imperfect aggregation. Vacancies and unemployment are aggregated over a period of time are biased by depletions caused by hires during that period. For example, suppose the number of unemployed and the number of job openings are measured at the end of the period, then hires during the period reduce the number of measured vacancies and unemployed actually present in the market that created those hires. This would mean the job finding rate used in the analysis is always too high, even more so during periods of increased hiring. This may be partly to blame for the "strange cyclicality" observed by Barnichon and Figura (2015) who find that the aggregate matching efficiency reaches a peak at the tail end of recessions and troughs entering recessions. This also leads to bias in the measurement of market tightness.[4]. With a full knowledge of the number of hires, it would be simple to add the number of hires back into the ex-post measures to get the correct measurement of job seekers. However, because of other possible sources

[4] In this particular example with full depletion of hires, the multiplicative bias is $\frac{1-\frac{f_t}{\theta_t}}{1-f_t}$, so that the bias is in the direction of sign$(1-\theta_t)$ and increasing as the labor market becomes less balanced or as the job filling rate increases.

of mismeasurement and different forms of time aggregation, it is more apt to think of the issue as a non-standard error in variables problem where the measurement error is correlated with other contemporaneous labor market variables.

The solution proposed by Berman (1997) is to find an instrument that is uncorrelated with the hiring rate, specifically their paper uses other lagged measures. A different approach is advocated by Shimer (2012) which uses a measure of short-term unemployment spells that enter or exit inside the observation period as a correction so that the analysis is only based on fully observed spells of unemployment. Additionally, differencing proposed for fixing the simultaneity bias also exacerbates measurement error. To address this the closely related Schulhofer-Wohl et al. (2014) uses additional instruments such as real gross domestic product. The approach in this chapter instead attempts to get more information by using the savings-consumption decision of individuals to yield an instrument for search intensity.

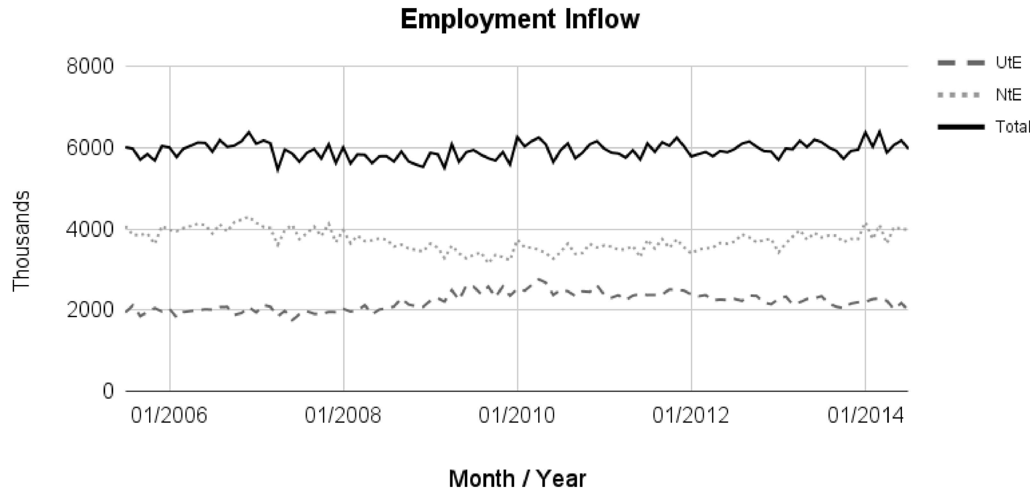
Another source of measurement error is the difficulty in applying the theory to data. In many theoretical models, a flow from out of the labor force to employment does not exist. Taking this perspective, a flow from non-participation to employment is a number of short unemployment spells that have been characterized incorrectly; consequently, a better approach may be to consider these issues as an additional source of measurement error. An alternative view would be that the flow from non-participation to employment is a very different labor market than the one that governs observed unemployment to employment transitions which necessarily have strong effects on each other. Concerns about how to apply the theoretical definition of unemployment to measures of unemployment are not novel and are, for instance, discussed in Blanchard et al. (1989) or more recently in Sedlácek (2016).

The apparent large shift in the Beveridge curve spawned other research about the possibility of structural mismatch in the United State's labor market. Elsby et al.

(2011) reviews the recent literature in this area and, while measurable, the amount attributable to a skills mismatch is typically found in other papers to be a relatively modest one percentage point. This skills mismatch also appears to be transitory. Likewise, Elsby et al. (2011) do not find support in the literature for strong effects from house lock or geographic changes despite evidence of changes in labor market fluidity in Davis and Haltiwanger (2014). Sedlácek (2016) is focused on quantifying and addressing the omission of non-unemployed job seekers in the estimation of the matching function. Their approach uses a Kalman filter to get a series for the number of people looking for work from each employment state. They find the effective search from employment fell drastically during the 2008 recession while the effective search from inactivity remained relatively unchanged. Taken together this means that the congestion in search caused by non-unemployment fell during the recession biasing the estimates of mismatch to unemployment down when estimated without taking the fall in employment transitions into account. These estimates find that nearly 30% of unemployment variation is attributed to mismatch and about 50% of the variation in job finding rate can be attributed to changes in mismatch. Elsby et al. (2015) estimates the elements of the transition matrices between the three employment states. Another strand of the recent literature[5] focuses on trying to quantify the changing labor market in 2008 - 2014 by looking at dis-aggregated estimates of the matching function. These papers find that the majority of the decrease in the job finding rate in 2008 - 2014 was strongly correlated with increases in unemployment duration and in the number of permanent job losses.

Looking at the gross flows into employment and out of non-participation from the Current Population Survey in figure 2.3 shows several things. The transitions

[5]Barnichon and Figura (2015) is the major paper. Şahin et al. (2014) finds similar results but is focused on a slightly different notion of mismatch–the deviation from an optimal allocation of seekers across labor market pools.



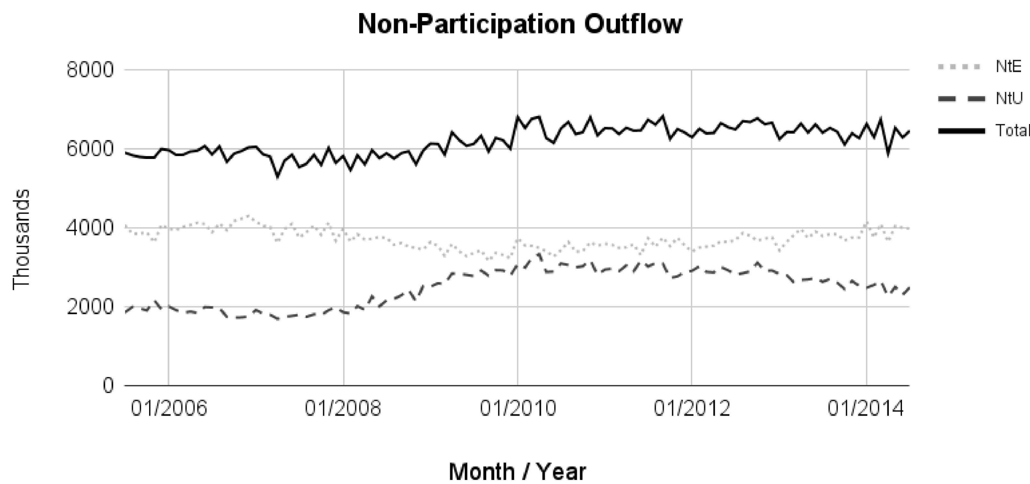


Figure 2.3: In and Outflows in the Labor Market

This graph plots the gross labor flows recorded in the Current Population Survey between 2000 and 2014 (Bureau of Labor Statistics, 1948 - 2022).

from out of the labor force into employment (NtE) declined. Combined with the rise in non-participation to unemployment (NtU) transitions, this suggests that the job finding probability fell. If NtE transitions are several brief unobserved unemployment spells, then the number of those spells decreased during the recession. This implies that job finding rate estimates which do not account for these job seekers should be attenuated as suggested by the results in Sedlácek (2016). Job finding rates are negatively correlated with the number of unemployment spells that are unmeasured. For the case when the job finding rate is lower than average and the number of hires is not mismeasured, then the measured job finding rate would be biased upward.

The total flow out of inactivity grows roughly 12% despite the fall in NtE flows because of the increase of roughly 33% in NtU flows. This may suggest that the total number of inactive people competing for jobs stayed relatively flat or mildly increased during the recession.

2.2 Data

This chapter uses data from the Survey on Income and Program Participation (the SIPP) and the Job Openings and Labor Turnover Survey (the JOLTS). The JOLTS survey was started in 2001 and is conducted by the Bureau of Labor Statistics (Bureau of Labor Statistics, 2008 - 2013). The JOLTS is a monthly survey of around 21,000 businesses that measures changes in labor demand. The JOLTS covers questions dealing with total employment, hires, separations, quits, job openings, and more. The SIPP is conducted by the Census Bureau. The 2008 edition of the SIPP is a panel covering January 2008 until May 2013 (U.S. Census Bureau, 2008 - 2013). There are two big advantages to using the SIPP for the analysis in this chapter. The first is the rich employment data which covers weekly job status during each surveyed month. The second is the availability of asset data in the SIPP. The special topical modules of the 2008 SIPP collected wealth, assets, and other household financial information during the 4th, 7th, and 10th waves. The SIPP over-samples low-income households. Households are divided into quarters and then interviewed once every 4 months. The 2008 SIPP begins in the first quarter of 2008 with about 42,000 households in the sample. The survey population is tracked, and so new households enter the data set as household composition changes over time. There is also a fair bit of attrition, the sample ends with only 20,000 households.

Currently, all variables are measured using a monthly reference period. The population includes all who reported searching at some point during the month. A search is considered successful if an individual obtains employment after reporting searching within the month that lasts at least to the end of that month. Since vacancies are not measured in SIPP, they are obtained from JOLTS data. Under the assumption that they sample from the same population, the market tightness is the ratio of the job finding rate to the vacancy fill rate: $\Theta_t = \frac{F_t}{Q_t} = \frac{\frac{H_t}{S_t}}{\frac{H_t}{V_t}} = \frac{V_t}{S_t}$. The JOLTS does not survey all industries, but no one in the SIPP worked in any of the excluded industries. Only about half or so of the hires from non-employment are observed to search in the month. This raises questions about which if any of these no-search hires either searched in a previous month or was a short duration search that went unrecorded. Job-to-job transitions are ignored. The SIPP does not ask about search behavior of anyone currently with a job. So the approach in this chapter is focused on transitions from unemployment.

2.3 Estimation Design

The Beveridge curve can be modeled as an equilibrium of a simple Diamond, Mortensen, and Pissarides matching function. In its most basic form, the relevant equation is $s(1-U) = A(V/U)^{\alpha}U$, which forms a curve in the vacancy - unemployment space. In this model, the shocks that cause a shift in the Beveridge curve are either a change in the exogenous separation rate given by s, or by a change in the matching efficiency, a catch-all residual. This chapter is focused on estimating α consistently and then using that to impute the residual for the unobserved matching efficiency.

The estimating equation is the basic log-log form of the matching function.

$$f_t = \mu + \alpha\theta_t + a_t + e_t$$

Here a_t is the log mismatch shock and e_t is an endogenous variable standing in for measurement error.

The approach in Borowczyk-Martins et al. (2013) assumes that the mismatch innovations in a_t are a covariance stationary process. For the analysis below this variable is assumed to follow an AR(1)[6] process. Defined in terms of the white noise ϵ_t, the AR process for the mismatch shock is defined by equation 2.2.

$$\epsilon_t \equiv a_t - \rho a_{t-1} - \nu_t \tag{2.2}$$

Where ν_t is a variable that accounts for a deterministic trend and seasonality components. Estimation requires the assumption: $E[\epsilon_t \epsilon_{t-1}] = 0$. However, the more convenient and slightly stronger assumption in equation 2.3 will be used.

$$E[\epsilon_t \theta_{t-j}] = 0 \text{ and } E[\epsilon_t f_{t-j}] = 0 \ \forall j > 1 \tag{2.3}$$

This assumes that past measures of the job finding rate and market tightness only effect the current job finding rate through their effects on current market tightness.

With those assumptions, the approach to estimation is straightforward. Taking the quasi-difference and thing substitute in for $a_t - \rho a_{t-1}$ yields equation 2.4.

$$f_t = (1-\rho)\mu + \alpha\theta_t - \alpha\rho\theta_{t-1} + \rho f_{t-1} + \nu_t + \epsilon_t + e_t - \rho e_{t-1} \tag{2.4}$$

[6]Using an AR(1) finds decent support using SIPP data discussed briefly in the next footnote. Borowczyk-Martins et al. (2013) used an ARMA(3,3) process.

Then an instrumental variable approach is used since the market tightness, θ, and the job finding rate, f, are likely to be correlated with e and ϵ of present and past time periods. Under the assumptions in equation 2.3 , the past values of θ and f available as instruments for f_t, θ_t, and θ_{t-1}. Unfortunately using more than one set of lagged variables as instruments quickly encounters multicollinearity issues. For example after using θ_{t-2}, and f_{t-2} additional lags contain very little extra information. With an additional assumption that measurement error can be ignored, then two instruments would be enough since there would only be a need to instrument for θ_t.

For these estimations, ν_t will be modeled as $\nu_t = 1_t^M + 1_t^{2010} + \gamma t$. The unobserved mismatch variable ν will include a monthly effect to account for seasonality, a term to estimate a possible discontinuity in mismatch before and after 2010, and a time trend. Altogether, this means the equation that will be estimated using the SIPP data will be equation 2.5.

$$f_t = \alpha\theta_t + \alpha\rho\theta_{t-1} + \rho f_{t-1} + 1_t^M + 1_t^{\text{post 2010}} + \tilde{\gamma}t + \epsilon_t \tag{2.5}$$

Given the structure, there is an option to use a restricted estimator that imposes the coefficient on θ_{t-1} to be $-\alpha\rho$. An example of how to estimate given that restriction is to fix $\alpha \in (0, 1)$ and then use a Hildreth et al. (1960) like approach [7] to search over $\rho \in (0, 1)$ using .01 increments. Using an unrestricted estimator yields similar results. The following estimation uses an unrestricted and straightforward GMM estimator. The results below specifically use an iterative GMM with f_{t-2} and θ_{t-2} as instruments for θ_t with the variance matrix estimated by using a Bartlett kernel truncated at 20 lags. The results also pass the overidentification test with an arbitrary selection of which lags are used as instruments.

[7] The non-linearity in parameters causes the model to have many local optima.

Table 2.1: Results (2nd Stage) - Lagged Variables

Coeff.	Estimate	Std.Error
θ_t	0.982	0.009**
f_{t-1}	0.414	0.0455**
θ_{t-1}	-0.465	0.0458**
1_t^{2010}	-0.020	0.006**

To test the validity of the instruments a first stage regression is done with Newey West standard errors with 20 lags. Only the instruments are reported below in table 2.2. The results here are higher than previous estimates from Yashiv (2007). Despite

Table 2.2: Results (1st Stage) - Lagged Variables

Coeff.	Estimate	Std.Error
θ_{t-2}	5.080	0.414**
f_{t-2}	-5.263	0.432**
F-Stat:		79.11

not restricting the coefficient of θ_{t-1}, it is approximately equal to what the model implies – namely $-\hat{\rho}\hat{\alpha}$. The indicator variable for 2010 and later periods is significantly different from zero, with a p-value less than 5%. The point estimate implies that the job finding rate was 2% less than what would've been expected given the same values for market tightness and other variables in the regression. These results indicate that there was an unexplained shift starting around 2010 as figure 2.1 seemed to indicate. These results give indirect evidence in support of the skills mismatch hypothesis. Matching in the labor market slowed around 2010.

This estimation can not convincingly account for all the possible measurement error sources described in the introduction. So these results ignore the possibility of measurement error causing bias and use the two instruments to account for only simultaneity issues. One way to check the impact of measurement error is instead of using the weekly job status data in the SIPP to count the number of job seekers and hires, is to use the typical U3 definition of unemployment and only count people as looking for work if they are currently without work and report looking for a job during the last month. This monthly U3 definition of unemployment will not account for depletion caused by hiring and it will understate the number of people looking for work during the month. Using the same estimation procedure but with these altered job finding probabilities yield similar results despite the intentional measurement error.

Table 2.3: Results (2nd Stage) - U3

Coeff. on	Estimate	Std.Error
θ^u	0.983	0.009**
f^u_{t-1}	0.414	0.045**
θ^u_{t-1}	-0.462	0.046**
$1^{2010,u}_t$	-0.020	0.006**

An additional concern is the closeness of the estimate for α to one, for example the baseline estimate's 95% confidence interval includes 1. This is not only different from most estimates in the literature, but this estimate also casts some doubts on the constant returns to scale functional form assumed for the matching function. This result is possibly caused by the way θ_t is being imputed as the natural logarithm of the ratio between the job finding and vacancy filling rate. Using that process to get θ means an equivalent way to write the initial estimation problem is

$$\log F_t = \alpha \log F_t - \alpha \log Q_t + \log A_t$$

So the estimation is relying on variation in Q_t to keep α away from one. This suggests a different way to impute the market tightness may yield better estimates. The alternative regression based on

$$\log F_t = \frac{-\alpha}{1-\alpha} \log Q_t + \log \tilde{A}_t$$

yields a slightly lower point estimate for α but is extremely imprecise and the lagged instruments perform poorly.

2.3.1 Asset Holdings as an Instrument for Search Intensity

To handle the additional endogeneity from the measurement error components in equation 2.4 another instrument is needed. A natural choice is the level of assets. As the level of assets decrease, search intensity increases Lentz and Tranaes (2005). For example, Chetty (2008) estimates that about 60% of the disemployment effect from unemployment insurance is from liquidity effects. Due to the design of the SIPP, this severely reduces the sample size since assets are only surveyed in the 4th, 7th, and 10th waves. So the sample is additionally split across the 9 census regions of the United States. With that structure, the estimation covers equation 2.6 where i indicates the region in the data.

$$f_{i,t} = \alpha\theta_{i,t} + \alpha\rho\theta_{i,t-1} + \rho f_{i,t-1} + 1_t^M + 1_t^{\text{post 2010}} + \tilde{\gamma}t + \epsilon_{i,t} + e_{i,t} - \rho e_{i,t-1} \tag{2.6}$$

Under the assumption that the measurement error is contemporaneously correlated with the job finding rate and the market tightness, additional instruments for θ_{t-1} and f_{t-1} are needed. Possible additional instruments could include average total household equity in interest-bearing assets, average total household wealth, and the average total household debt level. Of those, the average total debt is the best. Average total debt is strongly correlated with both the job finding rate and the market tightness.

The additional assumptions used to estimate equation 2.4 with the contemporaneous measurement are equation 2.7 and equation 2.8. Equation 2.7 is the assumption that the measurement error is only contemporaneous. Equation 2.8 is the assumption that the level of household debt, D_t, is uncorrelated with present-day measurement error in the market tightness and job finding rate and is also uncorrelated with future shocks in the unobserved mismatch variable.

$$E[e_{i,t}\theta_{i,t-j}] = 0 \text{ and } E[e_{i,t}f_{i,t-j}] = 0 \ \forall j > 1 \tag{2.7}$$

$$E[e_{i,t}D_{i,t}] = 0 \text{ and } E[\epsilon_{i,t}D_{i,t-j}] = 0 \ \forall j > 1 \tag{2.8}$$

The reported estimates in table 2.4 are from a 2 stage least squares regression with $\theta_{i,t}$, $\theta_{i,t-1}$, $f_{i,t-1}$ instrumented by $\theta_{i,t-2}$, $f_{i,t-2}$, $D_{i,t-1}$. The variable $D_{i,t-1}$ is the average household debt in region i at time $t-1$. The 95% confidence intervals are

Table 2.4: Results (2nd Stage) - Debt

Coeff.	Estimate	Std.Error
θ_t	0.986	0.110^{**}
f_{t-1}	1.283	0.387^{**}
θ_{t-1}	-1.296	0.453^{**}
1_t^{2010}	-0.021	0.027

quite large: While the point estimates for α and the 2010 indicator variable are similar

Table 2.5: Results - 95% Confidence Intervals - Debt

Coeff.	Lower Bound	Upper Bound
θ_t	0.770	1.201
f_{t-1}	0.524	2.04
θ_{t-1}	-2.184	$-.408$
1_t^{2010}	-0.073	0.031

to the results in the previous section, the imprecision of the estimates are high and economic conclusions should be done cautiously. The confidence intervals for α and ρ include points above one, which would run contrary to the assumptions of constant returns to scale in matching and stationarity of the mismatch variable made in the estimating equations.

The lagged instruments perform much worse with the shorter time horizon. Both the lagged job finding rate and the lagged market tightness are not strongly correlated in this smaller sample. This raises concerns about weak instruments causing bias in the point estimates.

2.4 Conclusion

This chapter addressed the presence of measurement error and simultaneity in estimating the aggregate matching function of Diamond, Mortensen, and Pissarides. The approach from Borowczyk-Martins et al. (2013) is used with data from the SIPP and the JOLTS to account for simultaneity issues in the estimating equation. This approach involves modeling the unobserved matching efficiency variable as an ARMA process, then taking the quasi-difference to set up an instrumental variables approach. To account for measurement error an instrumental variables approach is again used with the average total household debt from the SIPP as the necessary additional instrument.

The point estimates in this chapter are fairly consistent and suggest an α just below one and a shift in the Beveridge curve around 2010. This shift caused a drop in the job finding rate of roughly 2% relative to what would have been expected given similar congestion in the labor market. These estimates of the Beveridge curve shift following the Great Recession are similar to ones found in other papers in the literature, although slightly larger, many of which use different estimation approaches. This indirect evidence supports the theory that there was a mismatch between the types of workers firms were looking for and the population seeking work following the Great Recession.

There are many possible avenues for future research. The estimation strategy used in this chapter is simple but powerful and could be used with a richer data set to yield more precise results. The data for job openings required using an external data set and then matching the scale to compute the market tightness variable. The approach used in the estimates in this chapter use hires to make sure job seekers and job openings have the same scale. This was done because the sparsity was attractive, but alternate approaches could be used.

Chapter 3

Taylor Determinacy and Labor Supply

3.1 Introduction

Understanding unemployment and inflation are central topics in economics. The Federal Reserve has a dual mandate of ensuring price stability and near full employment. The Philips curve, the idea unemployment and inflation are inversely related over short time horizons, has historically been a key concern for central banks. Monetary authorities around the world are given a mission to prevent large changes in the overall price level of the economy. Concerns about a Philips curve cause central banks to face a dilemma balancing price stability goals with concerns about short-term labor market impacts. Most central banks accomplish this goal by picking a target for average price growth. The Phillips curve suggests that if a central bank takes action to contain inflation from rising above its target, then it should expect those actions to cause a temporary increase in unemployment. To accomplish a reduction in inflation the central bank reduces the supply of money, it does this by selling government debt and calibrates this sale by trying to hit a target interest rate for that debt on the market. The Taylor rule Taylor (1993) can quantify empirically how central banks have historically balanced the apparent trade-off embodied in the Phillips curve in choosing these interest rate targets.

In many New Keynesian macroeconomic models[1], a Taylor rule is used to model how a monetary authority will respond to changes in underlying macroeconomic variables. A common approach is to model the central bank as directly setting the interest rate based on how large deviations of inflation and output are from a target inflation level and steady state output. A key component in these New Keynesian models is that prices do not adjust freely to clear markets. Instead, most use Calvo pricing Calvo (1983). Calvo pricing has firms with market power that face a constant probability of being unable to adjust prices every quarter. A Phillips curve relation in these models arises from how changes in the decisions of agents in the model impact the setting of prices in those firms. The Taylor rule then closes the model by setting interest rates to influence the price equilibrium in the economy.[2] In many of these models the main channels from interest rate changes to price changes are a demand channel and an investment channel. In the demand channel, an increase in interest rates causes increased savings demand and the resulting reduced aggregate demand causes downward pressure on prices. In the investment channel, rising interest rates increase borrowing costs and therefore lower firm investment.

An important question for central banks is how responsive they need to be to deviations in inflation from their target rate to ensure they are able to get the economy to stay on the path of stable price growth. Stability around the steady state of the

[1]The cashless New Keynesian model used in this chapter is fairly typical. A good introduction to models of this type is Galí (2015).

[2]New Keynesian models generally have multiple equilibria and the Taylor rule is used as an equilibrium selection criterion. See Cochrane (2011).

model based on choices of the Taylor rule parameters depends on Taylor determinacy. A model is Taylor determined if, for a particular choice of parameters in the Taylor rule, the solution to the model both exists and is unique. In the baseline New Keynesian model, the model is generally determined if the central bank responds to deviations in inflation by increasing the interest rate more than one to one.

Kurozumi and Van Zandweghe (2010) adds a frictional labor market to the standard new Keynesian model. The labor market in Kurozumi and Van Zandweghe (2010) uses a Diamond, Mortensen, Pissarides matching function.[3] This matching function rations the number of new employment relationships that can be formed each period based on labor supply and labor demand. The matching function itself is an ad-hoc Cobb-Douglas function that takes the number of job postings and the number of job seekers as inputs to determine how many new employment relationships are formed each period. The idea behind these models is that in the labor market it takes time to find a match and there are transaction costs involved that make labor market adjustments sluggish. The matching function conveniently generates a Beveridge curve, the ratio of unemployment to job vacancies, and captures intuitive notions of search costs in a labor market.[4] Because of the search cost caused by matching in the labor market, firms face adjustment costs. These adjustment costs cause instability around the steady state for various choices of parameters in a Taylor rule. If monetary policy causes a decrease in employment today, next period there is more costly hiring for firms since they have to hire more to recover to their long-run employment level. As the economy recovers, firms anticipate these large hiring costs. This increase in future firm costs causes cost-push inflation as firms raise prices today to cover those

[3]See Pissarides (2000), Pissarides (2011), Mortensen, Dale T. (2011), or Diamond (2011) for an introduction.

[4]There is a large literature about the labor market with matching frictions. A good introduction is Pissarides (2000), Petrongolo and Pissarides (2001) is a good overview of the general literature, and Yashiv (2007) is a good overview of the empirical literature.

anticipated hiring costs in the future. Kurozumi and Van Zandweghe (2010) call this novel channel the "Vacancy channel". This can cause Taylor indeterminacy if labor adjustment is slow relative to changes in consumption or if the central bank is very aggressive to inflation rate deviations relative to unemployment.

Is labor supply important for business cycles and monetary policy? Since the 2008 recession, a new focus on labor supply shows that it can be important. Erceg and Levin (2014) finds that in the 2009 recession, fifty percent of the decline in the employment to population ratio was due to the fall in the participation rate. Their model has an adjustment cost for labor supply and households that do not have matching frictions in the labor market. This allows their model to match.Elsby et al. (2009) show that accounting for changes in participation is important to understanding unemployment dynamics. The literature on participation decisions in macro-models with matching has been growing in recent years including Furlanetto and Groshenny (2016) and Campolmi and Gnocchi (2016).

The key innovation in this chapter is to consider how labor supply responses affect Taylor determinacy. In Kurozumi and Van Zandweghe (2010), labor is supplied inelastically. If participation changes as a result of changing labor market conditions, then the hiring costs of firms could be different than predicted in Kurozumi and Van Zandweghe (2010). Additionally, Kurozumi and Van Zandweghe (2010) find that as consumption is more variable relative to employment changes the effect is strengthened. To address this a model similar to Galí (2010) is used in this chapter. The model has Calvo price setting, labor market matching with Nash bargaining, households which allocate members between employment and out of the labor force, and a central bank that operates according to a Taylor rule. Because of the matching in the labor market, there is unemployment in the model from unmatched workers looking for work.

The findings in this chapter show that relative to a setting with inelastic labor supply, the inflationary response from an increase in interest rates from the vacancy channel is reduced. As the disutility function becomes less convex and participation more elastic, wages are less volatile since the participation absorbs some of the impact from changes in labor demand. With the option to leave the labor force, temporarily low wages create a discouraged worker effect like in Lucas and Rapping (1969).

Since wages do not move as much with participation rate changes, there is relatively less hiring cost pressure on firms adjusting back to the full employment level. Despite the reduction in labor supply, job finding rates still fall lowering the bargaining position of households. Real wages fall. Taken together, this causes the choices of parameters that ensure determinacy to increase. In particular, high responsiveness to inflation deviations with lower responsiveness to changes in employment is less likely to cause Taylor indeterminacy. Only responding to expected deviations in inflation almost guarantees Taylor indeterminacy.

3.2 Model

The model is inspired by the representative household design from Merz (1995) and Andolfatto (1996). The model is inhabited by three kinds of decision makers, each a unit mass of infinitely lived agents. They consist of households, wholesale firms, and Calvo firms. There is also a government that conducts monetary policy specified by a Taylor rule. The model has discrete timing with each period indexed by $t = 0, 1, 2, ..., \infty$.

Households make decisions about how their unit mass of members are allocated between looking for work, working, or in leisure. After the labor market clears, households purchase consumption goods from each of the unique Calvo firms and trade one-period bonds with other households.

Wholesale firms produce wholesale goods depending on the number of workers they employ. New workers are hired based on responses to job postings.

There are two kinds of firms in the model, Calvo firms and wholesale firms. Calvo firms have a competitive monopoly buying wholesale goods and then reselling them as a differentiated good indexed by j. Calvo firms, as their name implies, face Calvo (1983) style price frictions. Calvo firms do not hire labor, their only input in production is the generic wholesale good produced by wholesale firms.

Wholesale firms produce their generic good using labor as the sole input. The labor market has Diamond, Mortensen, and Pissarides style matching frictions. The number of matches are determined using a Cobb-Douglas function that takes the number of vacancies posted by wholesale firms and the number of searching members from households to give the number of new hires each period. The wage for all workers is determined by Nash bargaining between firms and households on the new hires. There are no capital goods in the model.

The timing of the model is as follows: At the beginning of the period a δ share of all employment relationships end. Then agents make their decisions. Households decide how to allocate their time between search and leisure. Households decide how many bonds to purchase. Wholesale firms determine how many vacancies are posted. The labor market resolves and wages are settled by Nash bargaining between the matched households and wholesale firms. Calvo firms that are able, change their price, the other Calvo firms keep the price they had last period. The Calvo firms then repackage wholesale goods to meet the demand for their differentiated products from households.

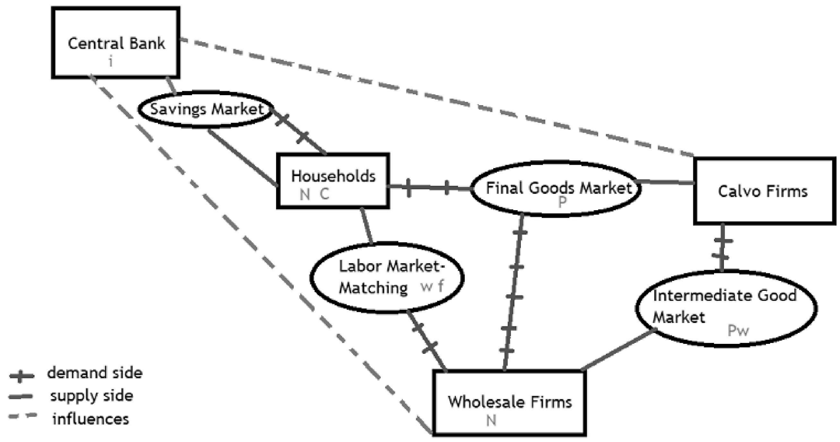


Figure 3.1: The Agents in the Model and the Associated Markets

3.2.1 Households

Each household contains a unit mass of members and consumption is shared between members. Each household is atomistic and take as given the current nominal interest rate i_t, real wage w_t, the dividend payment D_t, and the job finding rate f_t

Each household buys goods from each Calvo firm, with a constant elasticity of substitution of ϵ. The number goods demanded from firm j is $c_t(j)$ at price $P_t(j)$ is given by $c_t(j) = [\frac{P_t(j)}{P_t}]^{\epsilon} C_t$ with $C_t = (\int_0^1 c_t(j)^{\frac{1+\epsilon}{\epsilon}} dj)^{\frac{\epsilon}{1+\epsilon}}$ and $P_t = [\int_0^1 P_t(j)^{1+\epsilon} dj]^{\frac{1}{1+\epsilon}}$.

The household uses labor income from N_t workers with the negotiated wage w_t to buy single-period bonds from other households which pay a return of $(1 + i_t)$ in the next period and to pay for their consumption of final goods C_t. The inflation rate π_t is defined as $1 + \pi_t \equiv P_t/P_{t-1}$ and the real rate of interest is defined using the Fischer rule as $R_t \equiv \frac{1+i_t}{1+\pi_{t+1}}$. The budget constraint in each period written in real terms is therefore given by $C_t = R_{t-1}B_{t-1} - B_t + w_t N_t + D_t$.

Taking the job finding rate as given, the household sends S_t members to look for work in order to reach the target employment level for this period N_t. Since households are large and contain an infinite number of members, a law of large numbers applies and there is no uncertainty about the resulting level of employment for households. In order to achieve that employment level the household must send $S_t = (1/f_t)(N_t - (1-\delta)N_{t-1})$ members to look for work. The members who search and fail to find work become unemployed, so total unemployment for the household is equal to $U_t = (1 - f_t)S_t$. Since the total number of new hires is $N_t - (1-\delta)N_{t-1}$, total unemployment for household written in terms of employment is $U_t = (1 - f_t)/f_t(N_t - (1-\delta)N_{t-1})$.The term $\frac{1-f_t}{f_t}$ is the average number of unemployed per new hire[5].

The effort variable, L_t, is equal to the household's contribution to the labor force: the total number of members in the household working plus the number of household members looking for work, $L_t = N_t + U_t$. Written in terms of the employment level, the total effort is equal to the number employed plus the number of unemployed out of new hires $L_t = N_t + (1-f_t)/f_t)[N_t - (1-\delta)N_{t-1}]$ or equivalently the number employed plus the number of unemployed per hire reduced by the search cost savings of retaining some employment from the previous period $L_t = (1 + \frac{1-f_t}{f_t})N_t - \frac{1-f_t}{f_t}(1-\delta)N_{t-1}$.

The household has a forward-looking, additively separable utility function that is a sum of the individual period consumption utility $u(C_t)$ reduced by disutility from the total time spent in unemployment and employment given by the disutility function $\Phi(L_t)$. Households have a discount rate of β. Each individual period utility is monotonic, strictly concave, and each satisfies an Inada condition. Specifically, I assume $u'(x) > 0$, $\Phi'(x) > 0$ $u''(x) < 0$, $\Phi''(x) < 0$, and $\lim_{x \to 0} u'(x) = \infty$.

Writing the problem recursively and letting Z_t be a vector of prices, households solve equation 3.1.

[5]As a result of following a geometric distribution.

$$W(N_{t-1}, B_{t-1}, Z_t) = \max_{N_t \in [0,1], B_t, C_t \geq 0} \frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{L_t^{1+\phi}}{1+\phi} + \beta E_t[W(N_t, B_t, Z_{t+1})] \quad (3.1)$$

Subject to

$$C_t = R_{t-1}B_{t-1} - B_t + w_t N_t + D_t \quad (3.2)$$

3.2.1.1 Household First-Order Conditions

$$C_t^{-\sigma} = \beta E_t[\frac{1+i_t}{1+\pi_{t+1}} C_{t+1}^{-\sigma}]]$$

$$w_t = \chi(1 + \frac{1-f_t}{f_t})\frac{L_t^{\phi}}{C_t^{-\sigma}} - \chi(1-\delta)E_t[\beta \frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} \frac{1-f_{t+1}}{f_{t+1}} \frac{L_{t+1}^{\phi}}{C_{t+1}^{-\sigma}}]$$

Since it follows a geometric distribution, the fraction $\frac{1-f}{f}$ is the average number of unemployed people per new hire. The marginal disutility of effort for newly employed people is $\chi \frac{L_t^{\phi}}{C_t^{-\sigma}}$ and $\chi \frac{1-f}{f} \frac{L_t^{\phi}}{C_t^{-\sigma}}$ is the marginal disutility for unemployed times the number of unemployed required per new hire. In terms of current consumption, $\chi(1-\delta)E_t\left[\beta \frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} \frac{1-f_{t+1}}{f_{t+1}} \frac{L_{t+1}^{\phi}}{C_{t+1}^{-\sigma}}\right]$ accounts for the effort savings of having on the margin $(1-\delta)$ less people next period working. As another shorthand, the modified stochastic discount factor $\hat{\beta}_{t+1}$ is defined as the normal stochastic discount factor using the intertemporal rate of substitution times the probability of remaining employed in the next period, namely: $\hat{\beta}_{t+1} = (1-\delta)\beta \frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}}$.

3.2.2 Wholesale Firms

There is a unit mass of wholesale firms in the model. They produce wholesale goods which are sold to the Calvo firms at the relative price P_t^w. Each firm is large and employs a unit mass of workers. Of the N_{t-1} workers employed at the firm each period, the firm only retains $(1-\delta)N_{t-1}$ next period. To employ more workers, wholesale firms must post vacancies to match with prospective employees. For each vacancy that firms decide to post, they must pay a real cost γ per vacancy posted. As discussed in the matching function section, this can be rewritten as the cost $\Gamma f_t^{\frac{1-\omega}{\omega}} H_t$ where $\Gamma = \gamma M^{(-1-\omega)/\omega}$ is the adjusted real cost, $f_t^{\frac{1-\omega}{\omega}}$ is proportional to the number of vacancies posted, and $H_t = N_t - (1-\delta)N_{t-1}$ is the number of new hires. Firms are each large enough that a law of large numbers in hires applies and each must post vacancies of $V_t = H_t/q_t$ to reach a target employment level N_t. The number of hires firms need each period is $H_t = N_t - (1-\delta)N_{t-1}$. The prevailing wage rate is set through Nash bargaining between households and wholesale firms. Firms take wages and prices as given when making vacancy posting decisions. Firms have decreasing returns to scale.

Wholesale firms pay dividends to households and have a discount rate $\tilde{\beta}_{t+1} = \beta \frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}}$.

$$\Pi_t(N_{t-1}, Z_t) = \max_{N_t} P_t^w A_t N_t^{1-\alpha} - w_t N_t - \Gamma f_t^{\frac{1-\omega}{\omega}} H_t + E_t[\tilde{\beta}_{t+1}\Pi_{t+1}(N_t, Z_{t+1})] \quad (3.3)$$

Labor demand is given by the following first-order condition for Wholesale Firms in equation 3.8.

$$w_t = (1-\alpha)P_t^w A_t N_t^{-\alpha} - \Gamma f_t^{\frac{1-\omega}{\omega}} + E_t[\tilde{\beta}_{t+1}(1-\delta)\Gamma f_{t+1}^{\frac{1-\omega}{\omega}}] \quad (3.4)$$

Relative to the standard labor demand functions in simple macroeconomic models, the new terms here are the hiring cost smoothing terms related to the job finding rate. The firm is forward-looking and may push hiring into the future if hiring is relatively costly today and vice versa.

3.2.3 Matching

The number of hires in the labor market is rationed by a Cobb-Douglas function that takes the number of vacancies V_t posted by wholesale firms and the number of people S_t looking for work as inputs. The matching function has an exponent of ω on vacancies and $1-\omega$ exponent on the number of people searching for work.

$$H_t = MV_t^{\omega} S_t^{1-\omega}$$

The job finding rate, f_t, is defined as the number of hires per searching worker and the market tightness Θ_t is the number of vacancies per searcher.

$$f_t \equiv \frac{H_t}{S_t} = M(\frac{V_t}{S_t})^{\omega} = M\Theta_t^{\omega}$$

Likewise the vacancy filling rate is defined as hires per vacancy posted.

$$q_t = \frac{H_t}{V_t} = \frac{f_t}{\Theta_t} = M\Theta_t^{\omega-1}$$

Wholesale firms pay a real cost γ for each vacancy posted, for the rest of this chapter this cost function will be given in terms of the job finding rate as follows.

$$\gamma V_t = \frac{\gamma H_t}{q_t} = \gamma M^{-1}\Theta_t^{1-\omega} H_t$$

Then using $\Theta = M^{-1/\omega} f_t^{1/\omega}$ and defining $\Gamma = \gamma M^{(-1-\omega)/\omega}$.

$$\gamma V_t = \Gamma f_t^{\frac{1-\omega}{\omega}} H_t$$

3.2.4 Nash Bargaining

Wages are set every period through Nash bargaining over the net surplus of a potential employment relation between households and firms labeled S_t^H and S_t^W respectively. If a match is found effort cost is sunk – matched individuals incur the effort cost of employed individuals regardless of the result of negotiation. The benefit of keeping a match is the additional labor income less the employed disutility and labor search savings next period. Altogether that implies that the net surplus generated from a match to households is given by $S_t^H = w_t C_t^{-\sigma} + \chi\beta(1-\delta)E_t[\frac{1-f_{t+1}}{f_{t+1}} L_{t+1}^{\phi}]$.

At equilibrium the surplus to the household is equal to the marginal cost of employing one more member, $S_t^H = \chi(1 + \frac{1-f_t}{f_t})L_t^{\phi}$.

The benefit of employing an additional matched worker for wholesale firms is the marginal productivity increase minus the wage payment and search cost saving for the next period. The first-order condition of the firm implies this is equal to the sunk search cost paid in the current period.

$$S_t^W \equiv (1-\alpha)P_t^w N_t^{-\alpha} - w_t + E_t[\frac{1+\pi_{t+1}}{1+i_t}(1-\delta)\Gamma f_{t+1}^{\frac{1-\omega}{\omega}}] = \Gamma f_t^{\frac{1-\omega}{\omega}}$$

The Nash bargaining problem with bargaining power η is :

$$\max_w [S_t^H]^{\eta}[S_t^w]^{1-\eta}$$

3.2.4.1 Nash Bargaining Solution

$$\eta[S_t^H]^{-1}C_t^{-\sigma} = (1-\eta)[S_t^w]^{-1}$$

$$\Gamma f_t^{\frac{1-\omega}{\omega}} C_t^{-\sigma} = \frac{(1-\eta)}{\eta}(w_t C_t^{-\sigma} - \beta(1-\delta)\chi E_t[\frac{1-f_{t+1}}{f_{t+1}} L_{t+1}^{\phi}])$$

$$\frac{\eta}{1-\eta}\Gamma f_t^{\frac{1-\omega}{\omega}} = \chi(1+\frac{1-f_t}{f_t})\frac{L_t^{\phi}}{C_t^{\sigma}} \tag{3.5}$$

3.2.5 Calvo Firms

Calvo firms are monopolistically competitive, and buy wholesale goods at P_t^w and then resell it as a differentiated product. The Calvo firms pay their profits as dividends to the household. Calvo firms discount the future at $\tilde{\beta}_{t+1} = \beta C_{t+1}^{-\sigma}/C_t^{-\sigma}$

These firms face Calvo-style price frictions. Each period Calvo firms are allowed to reoptimize on price with probability $1-\theta_P$, otherwise each firm remains at their price from the last period.

To solve this the decision problem is written recursively with two value functions. J in the following equation is the expected profit to the firm when the firm can pick a price during this period. $F(P_{t-1})$ is the expected profit when the firm remains at the price from the previous period.

$$J = \max_{P_t(j)}(\frac{P_t(j)}{P_t} - P_t^w)(\frac{P_t(j)}{P_t})^{\epsilon}C_t + E_t[\tilde{\beta}_{t+1}((1-\theta_p)J + \theta_p F(P_t(j))]$$

$$F(P_{t-1}(j)) = (\frac{P_{t-1}(j)}{P_t} - P_t^w)(\frac{P_{t-1}(j)}{P_t})^{\epsilon}C_t + E_t[\tilde{\beta}_{t+1}((1-\theta_p)J + \theta_p F(P_{t-1}(j)))]$$

$$P_t(j) = \frac{\epsilon}{1+\epsilon}\frac{\sum_{s=0}^{\infty}(\tilde{\beta}_{t+s}\theta_p)^s P_{t+s}^w P_{t+s}^{-(1+\epsilon)}C_{t+s}}{\sum_{s=0}^{\infty}(\tilde{\beta}_{t+s}\theta_p)^s P_{t+s}^{-(1+\epsilon)}C_{t+s}}$$

Focusing on the symmetric equilibrium where all firms that choose new prices, pick the same re-optimization price P_t^* yields the aggregate inflation rate given by equation 3.11.

$$P_t = [(1-\theta_p)(P_t^*)^{1+\epsilon} + \theta_p P_{t-1}^{1+\epsilon}]^{\frac{1}{1+\epsilon}}$$

$$1 + \pi_t = [(1 - \theta_p)(\frac{P_t^*}{P_{t-1}})^{1+\epsilon} + \theta_p]^{\frac{1}{1+\epsilon}} \tag{3.6}$$

The reset price inflation in equation 3.11 P_t^*/P_{t-1} can be written as the following set of recursive equations in equilibrium.

$$\frac{P_t^*}{P_{t-1}} = \frac{\epsilon}{1+\epsilon}\frac{g_t}{h_t}$$

where

$$g_t = (1 + \pi_t)[\frac{P_t^w}{P_t}C_t + \theta_p E_t[\frac{P_{t+1}}{P_t(1+i_t)}(1 + \pi_{t+1})^{-(1+\epsilon)} g_{t+1}]$$

$$h_t = C_t + \theta_p E_t[\frac{P_{t+1}}{P_t(1+i_t)}(1 + \pi_{t+1})^{-(1+\epsilon)} h_{t+1}]$$

This inherently assumes $\theta_p \frac{1}{1+r} < 1$. In economic terms this implies that firms set price level according to a weighted time average of real marginal cost where the weights correspond to time discounting, the probability of maintaining that price for that period, quantity sold, and aggregate price level.

3.2.6 Taylor Rule

The government sets a nominal interest rate target to achieve its policy objectives given by a Taylor rule. Following Kurozumi and Van Zandweghe (2010) and evidence from Orphanides and Wieland (2008), the baseline Taylor rule in the model depends on expected inflation instead of the more common rules that use actual inflation. The Taylor rule also depends on past interest rates to smooth policy responses. Altogether, the Taylor rule weights are given by ϕ_R on the previous interest rate, a weight on expected inflation deviations of Φ_Π, and a weight on the employment level deviations of ϕ_U. There is also a stochastic monetary shock z_t that shifts the interest rate. The shock follows an AR(1) process, $z_t = \rho z_{t-1} + \zeta_t$ where ζ_t is an iid mean zero random variable.

$$1 + i_t = (1 + i_{t-1})^{\phi_R}[(1 + i)(\frac{E_t[\pi_{t+1}]}{\pi})^{\phi_\pi}(\frac{N_t}{N})^{\phi_U}]^{1-\phi_R}]e^{z_t} \tag{3.7}$$

3.2.7 Steady State

There exists a zero inflation, no growth steady state where every variable is constant. This implies that the steady state interest rate is $\beta(1+i) = 1$ from the household's first order condition in equation 3.6. Solving for the steady state markup of Calvo firms implies that the relative wholesale price is the inverse of that markup and depends on the elasticity of substitution in the households demand function. $P^w = \frac{1+\epsilon}{\epsilon}$.

To hit reasonable steady state values for the job finding rate f and the employment level N, the steady state is solved by fixing those variables to reasonably steady state values and then adjusting the choices for the parameters on the bargaining power, η, the steady state consumption level C, and the relative weight given to labor disutility, χ to hit those targets. This has added benefit of making the solution to the steady state a linear system.

1. $C = N^{1-\alpha} - \delta N \Gamma f^{\frac{1-\omega}{\omega}}$

2. $w = (1-\alpha)\frac{1+\epsilon}{\epsilon}N^{-\alpha} - (1-(1-\delta)\beta)\Gamma f^{\frac{1-\omega}{\omega}}$

3. $\chi = \frac{\frac{\eta}{1-\eta}\Gamma f^{\frac{1-\omega}{\omega}}}{(1+\frac{1-f}{f})\frac{L^\phi}{C^{-\sigma}}}$

4. $\eta = \frac{\frac{\chi}{f}L^\phi C^\sigma}{\frac{\chi}{f}L^\phi C^\sigma + \Gamma f^{\frac{1-\omega}{\omega}}}$

The first equation is from the good market clearing condition. The second equation combines the first order condition for wholesale firms with the Nash bargaining solution and the last equation combines the Nash equilibrium with the participation first order condition of households. In the steady state $L = (f + \delta(1-f))/fN$, the steady state wage is found using the participation first order condition of households given in equation 3.7.

3.3 Linear Approximation around the Steady State

This chapter is focused on the existence and uniqueness of a solution to a linear approximation of the model around the steady state given different choices of the policy parameters in the Taylor rule. The model is log linearized around the steady state and then the policy rules are solved using an updated version of Gomez et al. (2016)'s implementation of the algorithm from Sims (2002). The full system is listed below. The lower case notation denotes log deviations from the steady state; for example $\tilde{y}_t \equiv (Y_t - Y)/Y$.

1. $(1-\lambda_f)\tilde{w}_t - \sigma(1-\lambda_f)\tilde{c}_t = \phi\tilde{L}_t - \tilde{f}_t - (\phi\lambda_f E_t[\tilde{L}_{t+1}] - \beta(1-\delta)E_t[\tilde{f}_{t+1}])$
   $\lambda_f = \beta(1-\delta)(1-f)$

2. $\tilde{P}_t^w = \alpha\tilde{n}_t + \frac{w}{\tau}\tilde{w}_t + \frac{\Gamma_f}{\tau}\tilde{f}_t - \beta(1-\delta)\frac{\Gamma_f}{\tau}E_t[\tilde{f}_{t+1}] - \frac{\beta}{\tau}E_t[r_{t+1}]$
   $\tau = w + (1-\beta(1-\delta)\Gamma f^{\frac{1-\omega}{\omega}}$
   $\Gamma_f = \frac{1-\omega}{\omega}\Gamma f^{\frac{1-\omega}{\omega}}$

3. $\frac{1}{\omega}\tilde{f}_t = \phi\tilde{l}_t + \sigma\tilde{c}_t$

4. $\tilde{L}_t = \frac{N}{L}\tilde{N}_t + \frac{U}{L}\tilde{U}_t$

5. $\tilde{U}_t = \frac{1}{\delta}\tilde{N}_t - \frac{1-\delta}{\delta}\tilde{N}_{t-1} - \frac{1}{1-f}\tilde{f}_t$

6. $E_t[\tilde{C}_{t+1}] = \tilde{C}_t + \frac{1}{\sigma}E_t[r_{t+1}]$

7. $E_t[r_{t+1}] = i_t - E_t[\pi_{t+1}]$

8. $\pi_t = \beta E_t[\pi_{t+1}] + \lambda_p P_t^w$

9. $(1-\alpha-\Theta)\tilde{N}_t = (1-\Theta)\tilde{C}_t + \delta\Theta\tilde{f}_t - (1-\delta)\Theta\tilde{N}_{t-1}$ $\Theta = \frac{\Gamma f^{\frac{1-\omega}{\omega}}}{N^{1-\alpha}}$

10. $i_t = \phi_\pi E_t[\pi_{t+1}] + \phi_U\tilde{N}_t + z_t$

3.4 Calibration

The parameters of the model are calibrated to match empirical evidence from other papers or to hit certain steady state values. The Calvo price probability is set to the standard $\theta_p = 0.7$ which corresponds to a price change every three quarters. The elasticity of substitution between the differentiated Calvo goods is set to $\epsilon = -10$, which yields a steady state price markup of of about 1.11 for the Calvo firms. For the wholesale firms, the exponent in the productivity function $Y = N^{1-\alpha}$ is set to the common assumption of $\alpha = 1/3$ which in a normal constant return to scale Cobb-Douglas production function would give a wage share of income of about a third. However, in this model there is no capital.

Households discount future periods with a rate of $\beta = .98$ yielding a steady state real interest rate of about 1%. The household's coefficient of relative risk aversion is set at $\sigma = 1$ for convenience but it also matches the choice in the closely related Galí (2010) and Kurozumi and Van Zandweghe (2010) papers and serves to make comparisons easier. The choice of the curvature parameter for the disutility of effort can be controversial since the parameter chosen in most macro-models diverges significantly from results given in quasi-experimental microeconemetric studies. The baseline in this chapter of $\phi = 4/3$ is motivated in part from the discussions in Keane and Rogerson (2012) and Chetty et al. (2011). This parameter determines the response of participation to changes in the path of wages, so it is both central to the analysis and the results are sensitive to the parameter choice. Alternative calibration choices for the disutility function are discussed in the results section.

Following evidence in Orphanides and Wieland (2008), the Taylor rule estimates are set to 2.4 for the expected inflation response and 1.5 for the labor market (employment) response. The total hiring cost $\delta\Gamma f^{\frac{1-\omega}{\omega}}$ is set to be 2.3% of steady state output to match evidence from Yashiv (2000). This implies that $\Gamma = .0274$. The matching function exponent ω is set to 0.72 to match with the results from the literature described in Yashiv (2000).

Most of the remaining parameters are set to hit steady state values for the employment to population ratio, the job finding rate, and the unemployment rate. The employment to population ratio is set to 0.62, the job finding rate is set to 0.70, and the unemployment rate is set to 4.5%. This yields a separation rate of 0.17, a bargaining power of 0.998 for firms, and the weight given to disutility in the combined household utility function $\chi = 20.75$. Hagedorn and Manovskii (2008) supports a calibration that puts high weight on firm bargaining power, but a strong outside option for workers.

3.5 Results

3.5.1 Baseline Model Impulse Response

To understand the dynamics in the model we look at the impulse response to a one-time positive interest rate shock of $z_0 = e_0 = .25$.

A positive interest rate shock sends the economy into contraction. On impact employment, wages, participation, and inflation all fall. Interestingly, unemployment also falls on impact. Since wages contract sharply, leisure becomes relatively cheap and the number of people that leave the labor force is larger than the number

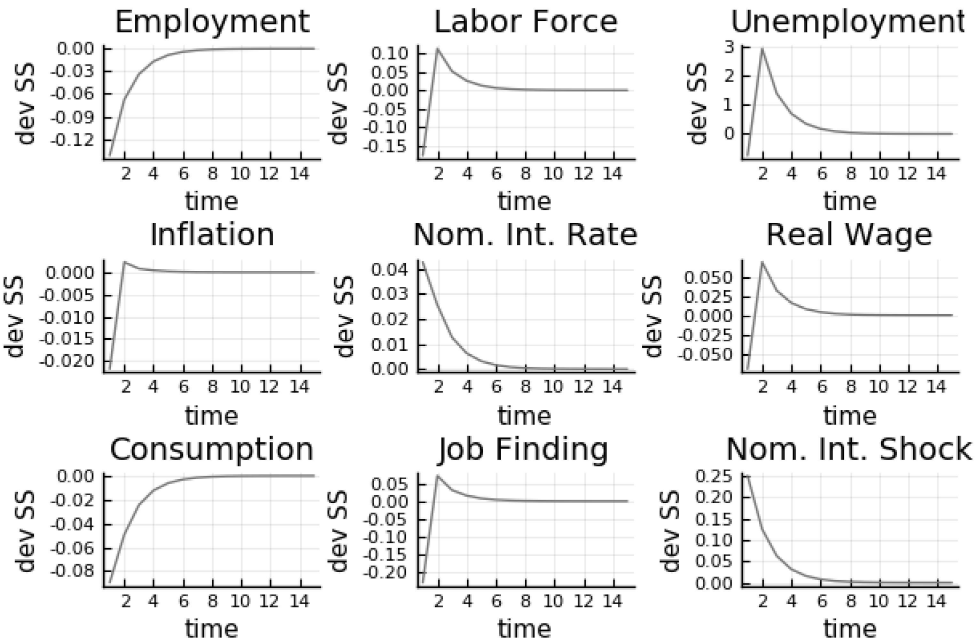


Figure 3.2: Impulse Response of Baseline Model
The impulse function of the baseline model with a positive unexpected shock to the nominal interest rate setting rule of the central bank. These impulse response functions show the path over time resulting from that decaying 25 basis point increase in the nominal interest shock in the Taylor rule. The numbers on the vertical axis for the inflation rate, the interest rate, and the shock correspond to direct changes in the rate from the steady state, for example a 0.25 reading would be 25 basis points. The remainder of the variables are given in terms of the percentage deviation from the steady state where a 1.5 reading would correspond to a deviation of 1.5%.

of people that leave employment. As interest rates, wages, and prices begin to recover labor supply increases faster than employment. Unemployment rises drastically. Unemployment stays above its steady state value as the recovery continues, slowly decaying towards the steady state as wages, employment, and prices return to trend.

In this model wages, which are bargained every period, are likely to be too flexible and are the likely cause of the poor performance of models that use this matching function structure as emphasized in Shimer (2005) and Galí (2010). However, employment is downwardly rigid in this model. Firms and households can not elect to end employment relationships they can only choose not to enter new employment relationships. Together this should have the effect of forcing more variability in wages than should be expected in the short run. Previous literature such as Galí (2010) and Erceg et al. (2000) use the ambiguity in wage setting created by the ex-post economic surplus in firm-worker matches to motivate a staggered wage setting model similar to the Calvo pricing model used to generate price rigidity. Other papers such as Hall (2005) look at bounds in wage setting including fixed real wages. A more recent paper Christiano et al. (2016) is able to generate more stable wages in the bargaining environment using a slightly different parameterization and model matching the results from Hagedorn and Manovskii (2008).

3.5.2 Taylor Determinacy

For this baseline model under which sets of the Taylor rule policy parameters does the solution to the linearized system is both unique and exists?

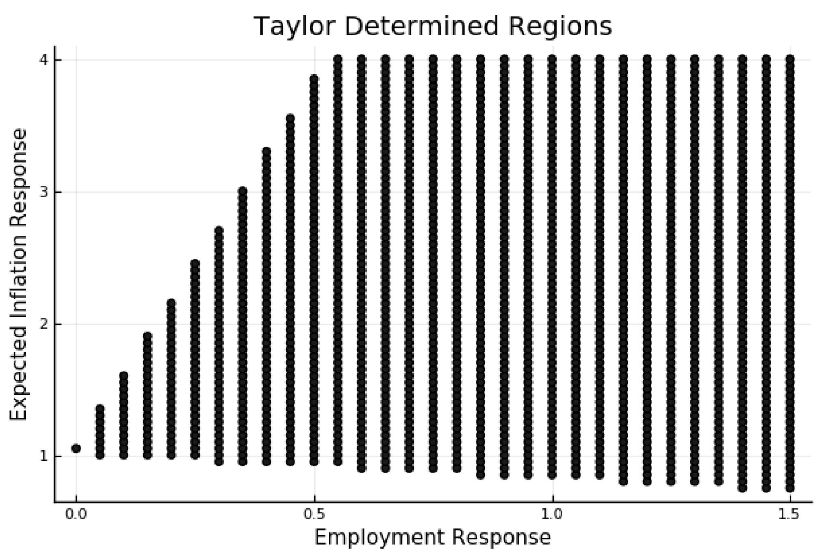


Figure 3.3: Taylor Determinacy in the Baseline Model
The marked areas on this graph are Taylor determined in the baseline model. This graph walks through the grid of possible parameter choices for the weights in the Taylor rule, marking with a circle if the resulting solution to the linear system both exists and is unique.

A rule of thumb for models to have Taylor determinacy is the Taylor rule should respond to inflation changes by more than 1:1. For example if the inflation rate is 10% percent above target then the nominal interest rate needs to be set by more than 10% above target to insure the inflation rate returns to the target level. However, if monetary policy is insufficiently responsive to unemployment, then even strong responses to inflation do not guarantee determinacy. In fact, as the response to inflation is more vigorous, the required minimum response to unemployment for Taylor determinacy increases as well. The results in this chapter echo some of the findings from other papers on models in this class. Blanchard and Galí (2010) show that strict unemployment targeting from the central bank performs better in welfare terms than strict inflation targeting. Kurozumi and Van Zandweghe (2010) show that Taylor indeterminacy is caused when the response to unemployment is insufficiently strong. This is caused by hiring costs and the relative sluggish adjustment of labor market variables.

3.6 Labor Supply Elasticity

A drastic increase in the curvature of the disutility function, for example when $\phi = 500.0$, then labor supply becomes almost completely inelastic around the kink. Therefore the model is able to replicate the results in Kurozumi and Van Zandweghe (2010).

How important are labor participation dynamics for the response to unexpected monetary policy interest rate adjustments and Taylor determinacy? An increase in the curvature of the disutility of effort implies smaller changes in the participation rate[6]. As the results in figure 3.4 show, increasing the curvature of the disutility

[6]This version of the model with less elastic labor supply also serves as a good comparison to

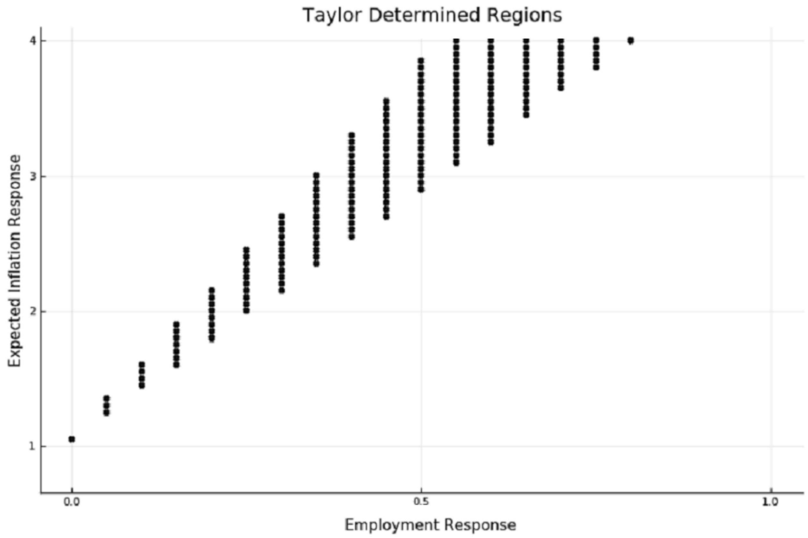


Figure 3.4: Elastic and Inelastic Labor Supply, Taylor Determinacy
The baseline model with more elastic labor supply has a larger determinacy region. The region that is determined in the elastic labor supply model but not in the inelastic labor supply model is highlighted in this graph. Each circle represents a pair of parameter choices that results in the solution to the linear system both exists and is unique.

function increases the sets of parameters for which the model does not have Taylor determinacy.

Additionally, the choice of the curvature parameter for the disutility of effort is controversial since the parameter chosen in most macro-models diverges significantly from results given in quasi-experimental microeconometric studies. The baseline in this chapter of $\phi = 1$ is motivated in part from the discussions in Keane and Rogerson (2012) and Chetty et al. (2011). This parameter determines the response of participation to changes in the path of wages, so it is both central to the analysis and the results are sensitive to the parameter choice. The results given in figure 3.5 show that as the disutility function becomes less convex and therefore Frisch elasticity, the

Kurozumi and Van Zandweghe (2010) which has inelastic labor supply. As their results predict, since this chapter shows that the addition of labor supply makes the adjustment of employment less sluggish relative to consumption the range of parameters that induce stability is larger as labor elasticity increases.

marginal utility constant wage elasticity of labor supply, increases then on impact wages and participation fall by more and there is less disinflation. Additionally, the indeterminate Taylor rule parameter region when the monetary authority has low interest rate responsiveness to changes in employment and high interest rate responsiveness to changes in inflation is reduced. This implies the effect found in Kurozumi and Van Zandweghe (2010) is strengthened when using a more convex labor supply disutility function that is more in line with the quasi-experimental microeconomic studies. As the ϕ decreases and the discouraged worker effect increases and the region for which the linearization around the steady state is stable increases. When $\phi = 0.5$ you get the following results keeping the response to employment changes to $\phi_y = 0.045$.

Comparing the impulse response functions from both indicate that the differing path of wages and their direct impact on supply side costs are strongly impacted by the change in participation. In part, this mitigation of the effect in Kurozumi and Van Zandweghe (2010) is from the increased fall in wages decreasing the hiring costs in the future.

3.7 The Role of Matching Frictions

As the probability of finding a job approaches one, the number of unemployed declines. When the job finding rate is one, the first order condition for labor supply of households becomes similar to what is seen in standard economic models without matching frictions. The wage rate is such that it equates the marginal utility of additional consumption of working more with the disutility that the work would entail. When the steady is very high then the impulse response function responds differently.

Comparing the results to a modified model with wages that are set to clear labor

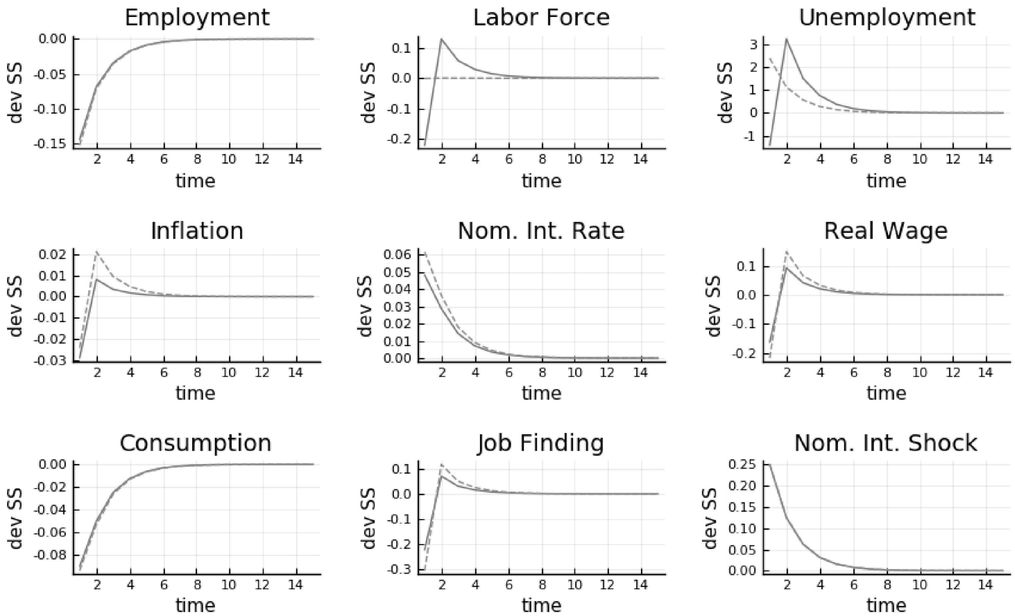


Figure 3.5: Elastic and Inelastic Labor Supply, Impulse Response
The dashed lines are the impulse response functions for the inelastic labor supply model. The solid lines are the impulse response functions for the baseline model, also displayed alone in figure 3.2. The impulse response functions show the path over time resulting from a 25 basis point increase in the nominal interest shock in the Taylor rule. The numbers on the vertical axis for the inflation rate, the interest rate, and the shock correspond to direct changes in the rate from the steady state, for example a 0.25 reading would be 25 basis points. The remainder of the variables are given in terms of the percentage deviation from the steady state where a 1.5 reading would correspond to a deviation of 1.5%.

demand with supply instead of matching frictions is useful. This comparison New Keynesian model uses the following equations: Households labor supply

$$w_t = \chi \frac{L_t^{\phi}}{C_t^{-\sigma}} \tag{3.8}$$

Firms' labor demand, which is a bit different from the standard since it includes the hiring cost

$$\Gamma = (1-\alpha) P_t^w A_t N_t^{-\alpha} - w_t + E_t[\tilde{\beta}_{t+1}(1-\delta)\Gamma] \tag{3.9}$$

Then the new equations for the models are

$$\tilde{w}_t = \phi \tilde{L}_t - \sigma \tilde{C}_t \tag{3.10}$$

$$\tilde{P}^w_t = \frac{w}{\tau}\tilde{w}_t + \alpha \tilde{N}_t - \frac{\beta}{\tau} E[r_{t+1}] \tag{3.11}$$

where again $\tau = w + (1 - \beta(1 - \delta))\Gamma$

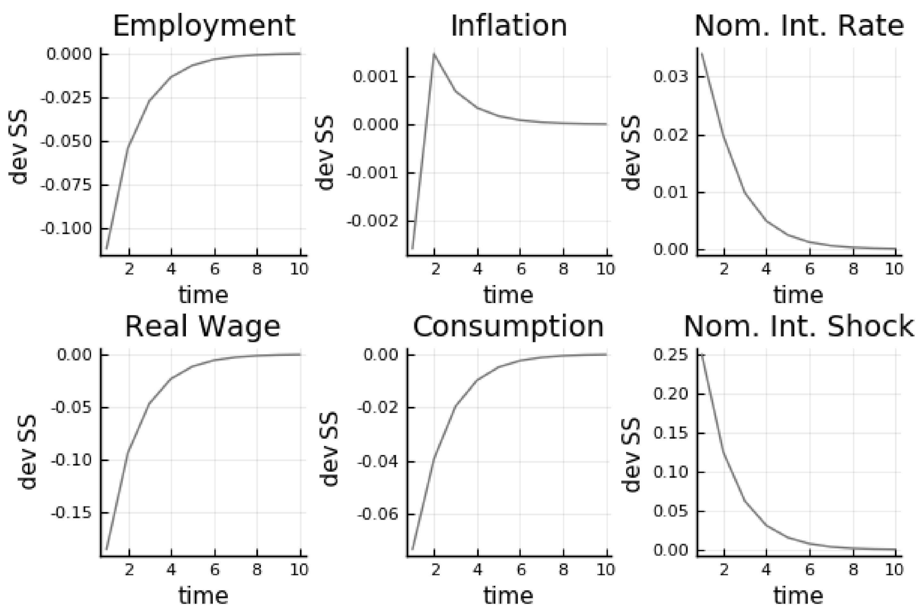


Figure 3.6: New Keynesian Impulse Response
Impulse response functions to a nominal interest rate shock in the baseline model without matching frictions. The impulse response functions show the path over time resulting from a 25 basis point increase in the nominal interest shock in the Taylor rule. The numbers on the vertical axis for the inflation rate, the interest rate, and the shock correspond to direct changes in the rate from the steady state, for example a 0.25 reading would be 25 basis points. The remainder of the variables are given in terms of the percentage deviation from the steady state where a 1.5 reading would correspond to a deviation of 1.5%.

While in general the response remains the same, the magnitude of the recession is smaller than in the model with matching frictions. Additionally, the pattern of wages is very different when the wages are being set to clear the labor market instead of by

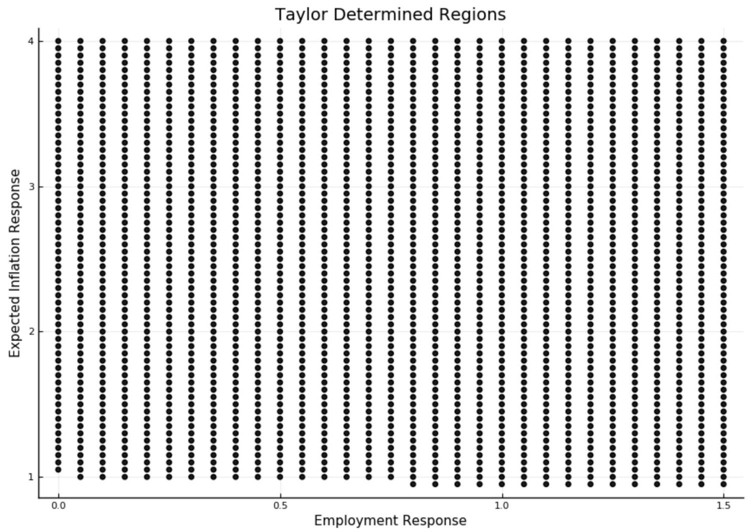


Figure 3.7: Taylor Determinacy in the New Keynesian Model
This graph walks through the grid of possible parameter choices for the weights in the Taylor rule, marking with a circle if the resulting solution to the linear system both exists and is unique. For the New Keynesian model, the majority of the parameter space results in a determinant solution.

Nash bargaining. The Taylor determinacy is the same as the textbook model case, as long as the response to inflation is strong enough, more than 1:1, then the model is determined. It is clear that the determinacy results depend on the movement of labor supply. The results here conform to what was anticipated in the Kurozumi and Van Zandweghe (2010), the additional flexibility from a labor supply decision help the adjustment in employment be less sluggish and closer to the adjustment in consumption.

Figure 3.8 shows the comparison between the three models. The lower region is similar between all three and corresponds to the greater than 1:1 rule of thumb for monetary policy. Even though the hiring cost and slow depreciation of employment are present in all models, the upper region of indeterminacy is only present in models with matching frictions. In the models with matching frictions, more elastic labor supply leads to a decrease in the size of the upper region of indeterminacy. Coun-

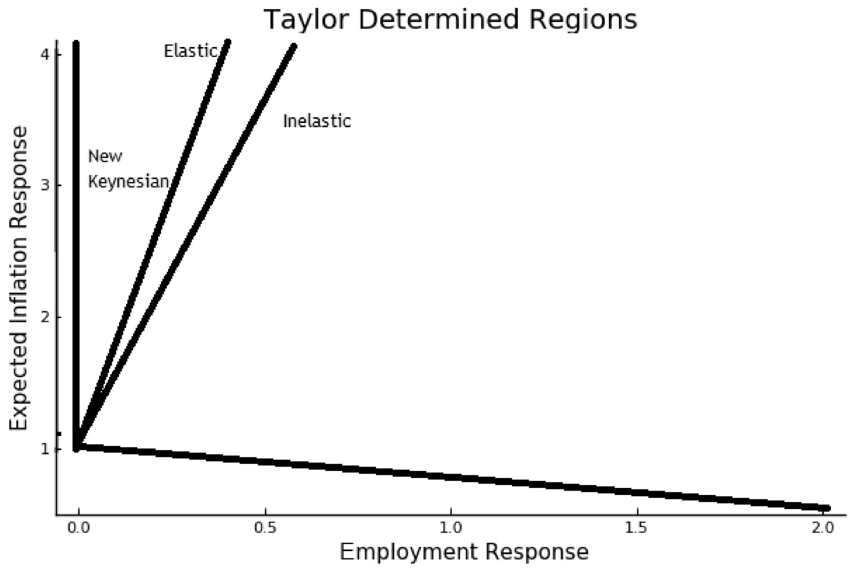


Figure 3.8: Taylor Determinacy Boundaries
All three models have the same lower boundary between indeterminacy below the one-to-one weight on inflation. The upper boundary where to the left there is insufficient weight on inflation depends on the particular model used. The New Keynesian model without search frictions doesn't have an indeterminant region at all. The model with inelastic labor supply has the largest indeterminant region. The model with both active labor supply and matching frictions lies in between these two extremes.

tercyclical movements in labor supply occur because participation follows household employment targets that follow demand. The participation margin soaks up some of the volatility in wages similar to a simple supply and demand model of the labor market. The more elastic the supply curve, the more quantity changes relative to price changes are induced from shifts in labor demand.

3.8 Conclusion

This chapter showed that hiring costs can cause monetary policy to become unpredictable and lead to instability in the economy. This is not caused only by monetary policy not responding strongly enough to inflation deviating from the target, but also by not responding enough to disruptions in the labor market. When the central bank is aggressive in pinning inflation to its long-run target it is important to account for the disruptions this policy causes in the labor market. Holding the response to cyclical unemployment fixed, the response to inflation that guarantees stability is bounded. The policy response can be too strong as well as being too weak. The likelihood that a particular response to price instability is effective increases as the policy is more sensitive to labor market disruptions. Estimates of Taylor rule parameters that match historical Federal Reserve behavior imply these bounds are unlikely to be violated for the United States. Still, the results in this chapter show that responding aggressively to employment deviations is crucial in meeting the price stability goals of a central bank regardless of its other goals.

Responding to measures of unemployment is more effective for monetary policy than measures of employment or output. Because of the addition of labor supply; employment and output do not correlate strongly with unemployment or labor market costs. This is partly because of the greater volatility in unemployment compared against output or employment itself. Unemployment is the measure directly connected to adjustment costs in the labor market and therefore the important measure to target to counteract inflation caused by those adjustment costs.

In this model labor supply has a mitigating effect on adjustment costs and inflation. The greater elasticity of labor supply reduces the variability in wages which reduces the resulting response in inflation. The dynamics in this model match the inflow from non-participation into the labor force, which is countercyclical. However, the outflow from unemployment into participation is strongly procyclical. As noted in Elsby et al. (2015) this outflow is mainly compositional. During recessions the population of unemployed mostly contains individuals with high labor attachment.

This concurs with results in Kurozumi and Van Zandweghe (2010) which showed that labor hiring costs can put upward pressure on inflation as the result of unexpected interest rate increases. With a Taylor rule based on expectations or as adjustment of labor variables are slow relative to consumption then the economy may no longer be stable around the steady state. The addition of labor supply mitigates this effect, but stability still depends crucially on the relative strength of the responses to inflation relative to labor market variables. When the discouraged worker effect dominates and labor supply falls in response to an increase in interest rates, the model is more likely to be stable around the steady state. This is due to a variety of mechanisms, the strongest of which is the greater reactivity of wages as labor participation falls, similar to labor supply dynamics in Lucas and Rapping (1969). For policy this implies that it is important to consider hiring cost and it is possible to create a situation where interest rate increases raise the path of future inflation growth.

Several avenues could be fruitful for further research. One of which is a precautionary motive arising out of income risk for individuals in the households. Precautionary savings implies more consumption volatility relative to a permanent income benchmark as unemployment induces greater savings demand for individuals to self-insure themselves against long unemployment spells. The same motive exists for labor supply as noted in Acemoglu and Shimer (1999). This would create an additional added worker effect and the results here would imply less wage variability and a stronger vacancy channel than implied in this chapter. Another is accounting for labor market skill growth and decay based on employment history. Finally, this chapter does not impose a zero lower bound on nominal interest rates. In fact in the example impulse response function with a high curvature, using the Taylor rule prescribed the central bank sets negative nominal interest rates on impact. Presumably, accounting for a zero lower pound would increase the regions of indeterminacy since it would mitigate the amount the central bank could respond to changes, in effect reducing the policy weights on inflation and employment when near the zero lower bound. Finally a richer set of heterogeneity of workers within families could help participation match outflow characteristics from the labor force. Erceg and Levin (2014) has a model that accomplishes part of this.

These results also imply that like in many papers before such as Galí (2010) and Shimer (2005) that in macro-labor models with matching frictions, labor dynamics in themselves do not seem to have large effects on inflation. In part, this seems to rest on the flexibility on wages given by period by period Nash bargaining. These results also imply however that ignoring labor supply often leads to misleading results. A message that finds support with the findings of Elsby et al. (2009) and Krusell et al. (2012).

REFERENCES

REFERENCES

Aaronson, Daniel, Jonathan Davis, Luojia Hu, et al. (2012), "Explaining the Decline in the US Labor Force Participation Rate." *Chicago Fed Letter*.

Aaronson, Stephanie, Bruce Fallick, Andrew Figura, Jonathan F Pingle, and William L Wascher (2006), "The recent decline in the labor force participation rate and its implications for potential labor supply." *Brookings Papers on Economic Activity*, 2006, 69–154.

Acemoglu, Daron and Robert Shimer (1999), "Efficient Unemployment Insurance." *Journal of Political Economy*, 107, 893–928.

Andolfatto, David (1996), "Business Cycles and Labor-Market Search." *American Economic Review*, 112–132.

Barnichon, Regis and Andrew Figura (2015), "Labor Market Heterogeneity and the Aggregate Matching Function." *American Economic Journal: Macroeconomics*, 7, 222–249.

Berman, Eli (1997), "Help Wanted, Job Needed: Estimates of a Matching Function from Employment Service Data." *Journal of Labor Economics*, 15, S251–S292.

Bernanke, Ben and Alan S Blinder (1992), "The Federal Funds Rate and the Transmission of Monetary Policy." *American Economic Review*, 82, 901–921.

Blanchard, Olivier and Jordi Galí (2010), "Labor Markets and Monetary Policy: A New Keynesian Model with Unemployment." *American Economic Journal: Macroeconomics*, 2, 1–30.

Blanchard, Olivier Jean, Peter Diamond, Robert E Hall, and Janet Yellen (1989), "The Beveridge Curve." *Brookings Papers on Economic Activity*, 1989, 1–76.

Board of Governors of the Federal Reserve System (2003 - 2022), "Total Assets (Less Eliminations from Consolidation): Wednesday Level [WALCL]." *retrieved from FRED, Federal Reserve Bank of St. Louis*, URL https://fred.stlouisfed.org/series/WALCL(accessedJuly,2022).

Borowczyk-Martins, Daniel, Grégory Jolivet, and Fabien Postel-Vinay (2013), "Accounting for Endogeneity in Matching Function Estimation." *Review of Economic Dynamics*, 16, 440–451.

Bullard, James et al. (2014), "The Rise and Fall of Labor Force Participation in the United States." *Federal Reserve Bank of St. Louis Review, First Quarter*, 96, 1–12.

Bureau of Labor Statistics (1948 - 2022), "Current Population Survey." *retrieved from FRED, Federal Reserve Bank of St. Louis*, URL https://www.fred.stlouisfed.org/categories/12(accessedJune,2022).

Bureau of Labor Statistics (2001 - 2021), "Job Openings and Labor Turnover Survey." *retrieved from FRED, Federal Reserve Bank of St. Louis*, URL https://www.fred.stlouisfed.org/categories/32241(accessedMarch,2021).

Bureau of Labor Statistics (2008 - 2013), "Job Openings and Labor Turnover Survey." URL https://www.bls.gov/jlt/(accessedJune,2022).

Calvo, Guillermo A (1983), "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics*, 12, 383–398.

Campolmi, Alessia and Stefano Gnocchi (2016), "Labor Market Participation, Unemployment and Monetary Policy." *Journal of Monetary Economics*, 79, 17–29.

Case, Anne and Angus Deaton (2015), "Rising Morbidity and Mortality in Midlife among White Non-Hispanic Americans in the 21st Century." *Proceedings of the National Academy of Sciences*, 112, 15078–15083.

Chetty, Raj (2008), "Moral Hazard versus Liquidity and Optimal Unemployment Insurance." *Journal of Political Economy*, 116, 173–234.

Chetty, Raj, Adam Guren, Day Manoli, and Andrea Weber (2011), "Are Micro and Macro Labor Supply Elasticities Consistent? A Review of Evidence on the Intensive and Extensive Margins." *American Economic Review*, 101, 471–75.

Christiano, Lawrence, Martin Eichenbaum, and Mathias Trabandt (2016), "Unemployment and Business Cycles." *Econometrica*, 84, 1523–1569.

Christiano, Lawrence J, Martin Eichenbaum, and Charles L Evans (2005), "Nominal Rigidities and The Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy*, 113, 1–45.

Cochrane, John H (2011), "Determinacy and Identification with Taylor Rules." *Journal of Political Economy*, 119, 565–615.

David, H and Mark G Duggan (2006), "The Growth in the Social Security Disability Rolls: A Fiscal Crisis Unfolding." *Journal of Economic Perspectives*, 20, 71–96.

Davis, Steven J and John Haltiwanger (2014), "Labor Market Fluidity and Economic Performance." Technical report, National Bureau of Economic Research.

Diamond, Peter (2011), "Unemployment, Vacancies, Wages." *American Economic Review*, 101, 1045–72.

Elsby, Michael WL, Bart Hobijn, and Ayşegül Şahin (2015), "On the Importance of the Participation Margin for Labor Market Fluctuations." *Journal of Monetary Economics*, 72, 64–82.

Elsby, Michael WL, Bart Hobijn, Ayşegül Şahin, Robert G Valletta, Betsey Stevenson, and Andrew Langan (2011), "The Labor Market in the Great Recession—An Update to September 2011." *Brookings Papers on Economic Activity*, 2011, 353–384.

Elsby, Michael WL, Ryan Michaels, and Gary Solon (2009), "The Ins and Outs of Cyclical Unemployment." *American Economic Journal: Macroeconomics*, 1, 84–110.

Erceg, Christopher, Dale Henderson, and Andrew Levin (2000), "Optimal Monetary Policy with Staggered Wage and Price Contracts." *Journal of Monetary Economics*, 46, 281–313.

Erceg, Christopher J and Andrew T Levin (2014), "Labor Force Participation and Monetary Policy in the Wake of the Great Recession." *Journal of Money, Credit and Banking*, 46, 3–49.

Fujita, Shigeru et al. (2014), "On the Causes of Declines in the Labor Force Participation Rate." *Research Rap Special Report, Federal Reserve Bank of Philadelphia*, 6.

Furlanetto, Francesco and Nicolas Groshenny (2016), "Mismatch Shocks and Unemployment during the Great Recession." *Journal of Applied Econometrics*, 31, 1197–1214.

Galí, Jordi (2010), "Monetary Policy and Unemployment." In *Handbook of Monetary Economics*, volume 3, 487–546, Elsevier.

Galí, Jordi (2015), *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework and its Applications*. Princeton University Press.

Goldin, Claudia and Joshua Mitchell (2017), "The New Life Cycle of Women's Wmployment: Disappearing Humps, Sagging Middles, Expanding Tops." *Journal of Economic Perspectives*, 31, 161–82.

Gomez, Matthieu, Victoria Gregory, and Spencer Lyon (2016), "Gensys.jl." URL https://github.com/QuantEcon/Gensys.jl(accessedMarch,2019.

Hagedorn, Marcus and Iourii Manovskii (2008), "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited." *American Economic Review*, 98, 1692–1706.

Hall, Robert (2005), "Employment Fluctuations with Equilibrium Wage Stickiness." *American Economic Review*, 95, 50–65.

Hildreth, Clifford, Y Lu John, et al. (1960), "Demand relations with autocorrelated disturbances." *Technical Bulletin. Michigan State University Agricultural Experiment Station.*

Hipple, Steven F (2016), "Labor Force Participation: What Has Happened Since The Peak?" *Monthly Lab. Rev.*, 139, 1.

Hotchkiss, Julie L and Fernando Rios-Avila (2013), "Identifying Factors Behind the Decline in the US Labor Force Participation Rate." *Business and Economic Research*, 3, 257.

Jarociński, Marek and Peter Karadi (2020), "Deconstructing Monetary Policy Surprises — The Role of Information Shocks." *American Economic Journal: Macroeconomics*, 12, 1–43.

Keane, Michael and Richard Rogerson (2012), "Micro and Macro Labor Supply Elasticities: A Reassessment of Conventional Wisdom." *Journal of Economic Literature*, 50, 464–76.

Krusell, Per, Toshihiko Mukoyama, Richard Rogerson, and Ayşegül Şahin (2012), "Is Labor Supply Important for Business Cycles?" Technical report, National Bureau of Economic Research.

Kudlyak, Marianna (2013), "A Cohort Model of Labor Force Participation." *Economic Quarterly*, 99, 25–43.

Kurozumi, Takushi and Willem Van Zandweghe (2010), "Labor Market Search, the Taylor Principle, and Indeterminacy." *Journal of Monetary Economics*, 57, 851–858.

Lentz, Rasmus and Torben Tranaes (2005), "Job Search and Savings: Wealth Effects and Duration Dependence." *Journal of Labor Economics*, 23, 467–489.

Lucas, Robert and Leonard Rapping (1969), "Real Wages, Employment, and Inflation." *Journal of Political Economy*, 77, 721–754.

Merz, Monika (1995), "Search in the Labor Market and the Real Business Cycle." *Journal of Monetary Economics*, 36, 269–300.

Mortensen, Dale T. (2011), "Markets with Search Friction and the DMP Model." *American Economic Review*, 101, 1073–91.

Orphanides, Athanasios and Volker Wieland (2008), "Economic Projections and Rules of Thumb for Monetary Policy." *Federal Reserve Bank of St. Louis Review*, 90, 307–24.

Petrongolo, Barbara and Christopher A Pissarides (2001), "Looking into the Black Box: A Survey of the Matching Function." *Journal of Economic Literature*, 39, 390–431.

Pissarides, Christopher A (2000), *Equilibrium Unemployment Theory*. MIT press.

Pissarides, Christopher A (2011), "Equilibrium in the Labor Market with Search Frictions." *American Economic Review*, 101, 1092–1105.

Romer, Christina D and David H Romer (2000), "Federal Reserve Information and the Behavior of Interest Rates." *American Economic Review*, 90, 429–457.

Ruggles, Steven, Sarah Flood, Ronald Goeken, Megan Schouweiler, and Matthew Sobek (2022), "IPUMS USA: Version 12.0 [American Community Survey 2000 - 2020]." *Minneapolis, MN: IPUMS*, URL https://doi.org/10.18128/D010.V12.0(accessedJune,2022).

Şahin, Ayşegül, Joseph Song, Giorgio Topa, and Giovanni L Violante (2014), "Mismatch Unemployment." *The American Economic Review*, 104, 3529–3564.

Schulhofer-Wohl, Sam, Robert Hall, et al. (2014), "Measuring Matching Efficiency with Heterogeneous Jobseekers." In *2014 Meeting Papers*, 368, Society for Economic Dynamics.

Sedlácek, Petr (2016), "The Aggregate Matching Function and Job Search from Employment and Out of the Labor Force." *Review of Economic Dynamics*.

Shimer, Robert (2005), "The Cyclical Behavior of Equilibrium Unemployment and Vacancies." *American Economic Review*, 95, 25–49.

Shimer, Robert (2012), "Reassessing the Ins and Outs of Unemployment." *Review of Economic Dynamics*, 15, 127–148.

Sims, Christopher A (2002), "Solving Linear Rational Expectations Models." *Computational Economics*, 20, 1.

Taylor, John B (1993), "Discretion versus policy rules in practice." In *Carnegie-Rochester Conference Series on Public Policy*, volume 39, 195–214, Elsevier.

U.S. Census Bureau (2008 - 2013), "Survey of Income and Program Participation." *NBER*, URL https://www.nber.org/research/data/(accessedJune,2022).

Van Zandweghe, Willem (2012), "Interpreting the Recent Decline in Labor Force Participation." *Economic Review - Federal Reserve Bank of Kansas City*, 5.

Yashiv, Eran (2000), "The Determinants of Equilibrium Unemployment." *American Economic Review*, 90, 1297–1322.

Yashiv, Eran (2007), "Labor Search and Matching in Macroeconomics." *European Economic Review*, 51, 1859–1895.