HOUSEHOLD SAVING AND INCOME UNCERTAINTY: EMPIRICAL EVIDENCE AND
IMPLICATIONS FOR MONETARY POLICY

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Abstract

Most households in the US do not own interest bearing assets, a direct contradiction of the common representative agent assumption of New Keynesian models. Using the Survey of Consumer Finances, I document precautionary saving in the economy with a new measure, *checking account balance to income* ratio. I find that (a) an augmented medium-scale NK model with a precautionary saving motive can match this ratio well; (b) precautionary saving lowers the relative importance of the direct effect of monetary policy; (c) a NK model with precautionary saving relies less on nominal and real frictions; (d) the precautionary saving mechanism leads to lower inflation during economic recoveries; and (e) an extension with downward rigid wages is able to produce an asymmetric response of the economy to monetary policy in line with the recent literature. Given the central role of the mechanism linking saving to income risk for these results and the lack of clear empirical evidence for this relationship, using data on consumption, income and employment growth across 28 MSA from the Consumer Expenditure Survey, I document with an instrumental variable strategy that the consumption-income ratio is positively correlated with employment growth and increases by 0.4 percentage points in response to a one percentage point increase in employment growth. Based on this estimate, a sizable fraction of 42% of the increase in saving between 2006 and 2010 can be attributed to negative employment growth.

INDEX WORDS: Monetary Policy, Household Saving, Income Risk

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CHAPTER 1

PRECAUTIONARY SAVING AND THE TRANSMISSION OF MONETARY POLICY[1]

This paper explores the importance of two empirical facts for monetary policy. First, only a minority of households own interest bearing, liquid investments such as bonds, stocks or money market mutual funds. Second, for these same income groups, saving is counter-cyclical and the checking account serves as their main savings vehicle. Together, these two facts contradict the dominant transmission channel of monetary policy in standard macro models.

Typically, in a representative agent New Keynesian model, monetary policy works through the direct intertemporal substitution channel: Kaplan, Moll and Violante (2018) find that this channel is responsible for up to 95% of the total effect of policy changes. Furthermore, economists have long known that representative agent models are inconsistent with both aggregate data and household behavior. For example, Campbell and Mankiw (1990) show that a model in which half of all agents are hand-to-mouth consumers aligns best with aggregate data on consumption, income and interest rates. Vissing-Jørgensen (2002) provides evidence that households who do not own bonds or stocks do not react to interest rate changes. These results have not gone unnoticed and most major models used by central banks and the OECD feature some version of hand-to-mouth or borrowing-constrained agents.[2]

[2]Lindé, Smets and Wouters (2016) provide an overview of commonly used NK models by institutions and lessons learned from the fit of these models during and after the Great Recession.

Yet, the clear counter-cyclical saving behavior of a large subset of households who also do not own financial wealth suggests that simply adding hand-to-mouth consumers is not the answer. Intuitively, a given monetary policy intervention is less effective in an economy in which a subset of agents does not react to interest rate changes but at the same time, adjusts consumption and saving in response to the state of the economy. For example, precautionary saving amplifies recessions when households cut back consumption in response to higher labor market risk. A monetary policy intervention that lowers interest rates will then not change this response directly if households are not exposed to short-term interest rates.

Therefore, I ask four questions: Empirically, how prevalent is precautionary saving among households in the US? How well does a New Keynesian model augmented with households that save in response to labor market conditions match this data? To what degree does the inclusion of these households change the transmission of monetary policy? And, in an application, can a model with precautionary saving address the recent issues of a persistently low inflation rate despite a near zero target interest rate and thus the seemingly low effectiveness of monetary policy?

Measuring saving is not straightforward. Kaplan and Violante (2014), Kaplan, Moll and Violante (2018) and many others solve nonlinear models to match the wealth distribution with different asset categories. One drawback is that these models have a limited state space and the contribution of portfolio reallocation, asset prices and precautionary saving over the business cycle is hard to disentangle (as discussed in Kaplan, Moll and Violante (2018)).[3] Generally, these models also focus on the stationary equilibrium or short time frames, such as the Great Recession.

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[3]Kaplan and Violante (2014) fix the inflation rate, for example, though their goal is to estimate the MPC in response to tax refunds and not monetary policy.

I propose as a measure of precautionary saving that closely tracks voluntary saving over the business cycle, the *checking account balance to income* ratio. Disaggregated data from the Survey of Consumer Finances from 1989 to 2013 shows that most households do not own financial assets such as bonds or stocks, but primarily have access to a checking account. For these households, movements in this ratio over time will likely reflect a true saving motive. Sorting households by income quintile, I find that this ratio divides the US population into three groups: The top 20% who own most of the financial wealth and do not display any business cycle pattern; the middle 30% whose ratio moves strongly counter-cyclically; and hand-to-mouth households with a fairly stable, slightly pro-cyclical ratio, the bottom 40%.[4]

Another recent study that aims to quantify precautionary saving is Krueger, Mitman and Perri (2016). They use the change in consumption over the change in income between 2006 and 2010 as an indicator for saving by income quintile. A negative change in this ratio, however, is not the same as precautionary saving and can reflect involuntary saving, such as forced deleveraging or debt with variable interest rates, two common occurrences over that period.

How well estimated general equilibrium models track precautionary saving is an open question. Bufferstock or precautionary saving amplifies business cycle movements (Challe and Ragot (2016), Ravn and Sterk (2017), Krueger, Mitman and Perri (2016)), is able to solve the forward guidance puzzle in NK models (Mckay, Nakamura and Steinsson (2016)) and has strong implications for the transmission of monetary policy (Werning (2015), Auclert (2017), Kaplan, Moll and Violante (2018)).[5] Yet, the two models that are closest to this paper do not track saving explicitly. Challe and

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[4]The lowest 10% have very volatile income and account balances and were excluded from the sample, discussed further in the data section.

[5]For the purpose of this paper these terms are interchangeable though technically they represent two separate types of saving. The focus of this paper are models linearized around the steady state and therefore saving is of the bufferstock type. The key determinant of

Ragot (2016) use the ratio of consumption of the bottom 60% to the top 40% as an estimation target and assume that agents save just enough to cover one period of consumption, whereas Ravn and Sterk (2017) compare the vacancy rate in their model to the data.

To test how well models of precautionary saving match the data, as my benchmark case, I augment a standard medium scale New Keynesian model in the mold of Smets and Wouters (2007) and Christiano, Eichenbaum and Evans (2005) with the precautionary saving mechanism developed by Carroll and Toche (2009). Wages are sticky and follow an exogenous wage rule that creates involuntary unemployment. Agents are of two types: traders who invest into capital and are insured against income loss through unemployment, as well as limited agents who face absolute income loss upon permanent unemployment and only save in their checking account. This income risk gives rise to the precautionary saving motive for limited agents.

The setup of this link between saving and the labor market follows Carroll, Sommer and Slacalek (2012). They estimate a partial equilibrium model of buffer-stock saving to match the time series of the aggregate saving rate in the US economy, separate the contribution of unemployment risk, wealth shocks and credit accessibility and find that unemployment risk is the most important determinant of business cycle variation of the saving rate.

I find that saving in the benchmark model qualitatively tracks the data well, and provides a quantitative match until about the mid 2000s. In the run up to and aftermath of the Great Recession the implied saving ratio is too high by several percentage points. This gap between observed and implied saving shows (as many have before) how unique the last decade has been from the perspective of the business

saving, however, is income / labor market uncertainty and intuitively saving can be called precautionary.

cycle literature when debt constraints and the housing market played an important role.

Next, I turn to the transmission mechanism of monetary policy in the benchmark model. As a general result for models with incomplete markets, Werning (2015) derives conditions that determine how the total effect of monetary policy varies in comparison to a representative agent model.[6] Yet, the focus of this paper is not the total effect but the relative importance of channels other than intertemporal substitution for the transmission of monetary policy. A recent contribution to this literature is Auclert (2017) who evaluates the amplification of monetary policy through three redistribution channels if agents have heterogeneous marginal propensities to consume.[7]

The estimated benchmark model showcases a strong labor market channel of monetary policy and the contribution of the direct effect of monetary policy is reduced compared to an estimated representative agent version of the model. Furthermore, the benchmark model relies less on nominal and real frictions. In particular, capital adjustment cost and habit persistence, two parameters that are necessary to prohibit excessive consumption smoothing in a standard NK model are much lower. When the the labor market is kept fixed at its steady state values, I find that the response of uninsured agents to a monetary policy shock is several times smaller than in the benchmark model with time varying unemployment risk. For insured agents, I find no significant change in their response, in line with criticism of Kaplan, Moll and Violante (2018). The shift in the monetary policy transmission mechanism to the

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[6]For example, if income, liquidity and borrowing constraints of heterogeneous agents are proportional to output, the total effect of monetary policy will be the same, a result that is true in my model.

[7]Another paper, Mckay, Nakamura and Steinsson (2016), shows that models of buffer-stock saving can resolve the forward guidance puzzle, the excessive response of representative agent models to forward guidance over long time horizons.

labor market therefore is an opportunity to further study different aspects of the labor market and how these interact with monetary policy, as I do at the end of this paper in an extension with downward nominally rigid wages.

The benchmark model with precautionary saving is also able to solve the empirical issue raised by Canzoneri, Cumby and Diba (2007), namely that representative agent model implied real interest rates are negatively correlated with observed real interest rates. Because in the model with precautionary saving, the real interest rate is not determined by the Euler Equation of one representative agent alone, the aggregate real interest rate is different from the real interest rate on capital. The resulting graph looks remarkably similar to the figure in Canzoneri, Cumby and Diba (2007).[8]

Last, as an application, I investigate to what degree the benchmark model can explain the occurrence of persistently low inflation since the Great Recession despite a near zero Federal Funds Rate and good economic growth (see King and Watson (2012)). This topic has been looked at from man different angles. For example, Del Negro, Giannoni and Schorfheide (2015) show that the inflation response to the Great Recession can be replicated in a NK model with financial frictions. Gilchrist et al. (2016) analyze empirically the price setting behavior of financially constrained and unconstrained firms, and Stock and Watson (2010) approach this problem from a forecasting view, explaining how inflation forecasting dynamics have changed since the Great Recession.

Compared to a representative agent version of my model, a negative aggregate demand shock that both lowers output and inflation implies a lower interest rate and longer transition of inflation back to the steady state in the benchmark model with precautionary saving. The precautionary saving channel is thus a promising

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[8]In a related literature, Alvarez, Atkenson and Edmond (2009) and Khan and Thomas (2014) show how this result can also be achieved in Baumol-Tobin style models with monetary policy.

candidate to explain the consistently low inflation rate since the Great Recession. I further show that this result is strengthened in an extension of the benchmark model with downward rigid nominal wages.[9]

The chapter proceeds as follows: Section 1.1 discusses precautionary saving in the data. The model is described in Section 1.2. The estimation results and answers to the questions posed in the introduction are in Section 1.3. Section 1.5 concludes.

1.1 HOUSEHOLD DATA

Designing New Keynesian models with heterogeneous agents raises two empirical questions: What fraction of households displays a precautionary savings motive? And, what metric can be used to evaluate whether such a model captures the precautionary saving behavior of these consumers?

I use disaggregated data of the Survey of Consumer finances from 1989 to 2013 to answer these questions. Three facts emerge: First, few households own assets or liabilities with interest rates that are closely linked to the Federal Funds Rate. Second, the checking account is their main vehicle for liquid saving, and third, the savings behavior of a large fraction of households, about 30% of the population, is strongly counter-cyclical, especially during the Great Recession.

The triennial *Survey of Consumer Finances* (SCF) is a representative survey of the financial position of all households in the United States. I use data from the years 1989 to 2013, discard the top 5% of households by net worth to remove outliers and restrict the sample to households age 22 to 79[10]. There are two benefits to exploring

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[9]I choose this extension because the literature has mostly focused on hiring frictions and downward rigid nominal wages are one of the defining features of the last decade, see Schmitt-Grohé and Uribe (2013).

[10]I follow Kaplan and Violante (2014) in deciding on how to restrict the data

the question of precautionary saving using SCF data. First, survey questions are consistent going back to 1989 and therefore yield a longer time series than other data sets. Second, the SCF is very comprehensive and splits assets and liabilities into many different categories such as checking account balance, bonds, stocks, car loans and credit card debt. This disaggregation is not available in the Consumer Expenditure Survey of the BLS nor the PSID.

In my analysis, I propose the *average checking account balance to income* ratio as a measure of saving as it is more likely to track actual saving. Changes in the often used consumption to income ratio, for example, do not necessarily imply precautionary saving but can also reflect other forms of saving such as involuntary deleveraging. Intuitively, households are less likely to increase their checking account balance relative to income when they are forced to pay down debt or have to fulfill other financial obligations that vary counter-cyclically with the business cycle. On the contrary, one would expect households to decrease their checking account balance under those circumstances. I therefore assume that an increase in the *average checking account balance to income* ratio reflects voluntary saving out of current income. Nevertheless, my findings are consistent with Krueger, Mitman and Perri (2016) who use PSID and Consumption Expenditure Survey data to measure household saving between the two years of 2006 and 2010 as changes in the ratio of consumption over income.

1.1.1 Ownership of Financial Assets

Table 1.1 shows the percentage of households in the SCF that own either bonds, stocks or invest into money market mutual funds by income quintile in the year 2001[11], the year with the highest fraction of asset ownership for the top four quintiles, see figure 1.1. Column two lists the medium income in each quintile, and column three

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[11]Most of this data was collected in the year 2000

Table 1.1: Asset Holding by Income Quintile in 2001

Quint	Med Inc	Perct Owning	Mean Asset	Med Asset	90th Ptile
1	8741.14	6	1696.86	0	0
2	20858.90	14.1	4470.19	0	3400
3	34852.51	21.6	8252.77	0	12000
4	53451.36	31	12911.43	0	25000
5	94567.78	47	29704.99	0	90000

The percetage of households that hold investments in bonds, stocks or money market mutual funds increases with income quintile, but is very low. Mean total investments in these three categories never exceeds the median income in each category. Data is taken from the SCF 2001 and in 2001US$.

the number of households that hold any of these investments in percent. The next two columns show the average investment size for each quintile as well as the median investment. The last column shows the amount invested by the 90th percentile within each quintile.

Two facts stand out: First, investment into bonds, stocks or money market mutual funds increases with income, but even in the highest income quintile, only about 50% of households hold these investments. Second, for all but the highest income group, the amount invested even at the top within each quintile is not very large. For example, in the lowest income quintile, the average investment is $1697; but even a household at the 90th percentile within the lowest quintile has an investment of $0. Looking further up the income distribution, in the fourth quintile, of which 31% of households hold investments, the amount invested by the highest ranked households in that quintile is relatively modest and just roughly half of the quintile median income. Only for the highest income quintile do financial investments represent a meaningful fraction of median income.
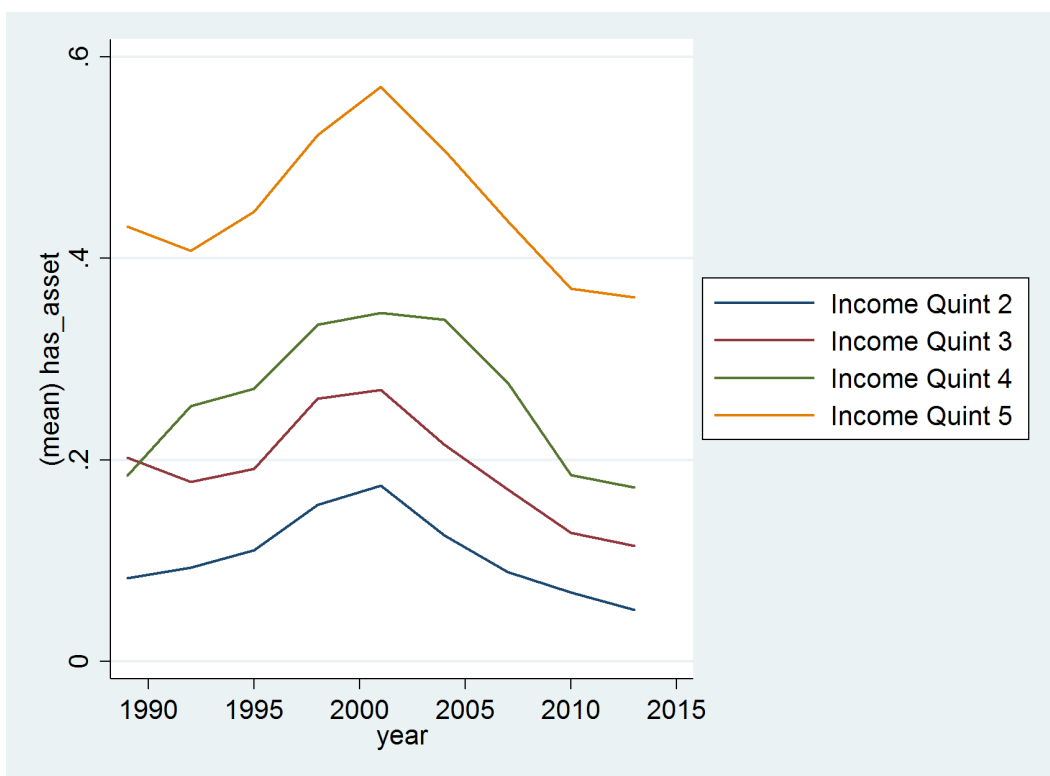
Figure 1.1: Financial Asset Ownership in Percent by Income Quintile

Financial asset ownership in percent by income quintile 1989 - 2013, SCF data

The data does not suggest that households who do not own financial investments are not exposed to any interest rate at all. They have mortgages, car loans, credit card debt and retirement accounts. The interest rates on these common liabilities, however, move slowly and do not adjust quickly. For example, it took several years at the zero lower bound for the average credit card or mortgage interest rate to decrease by just one percentage point, as shown in figures A.3 to A.5 in the Appendix. Secondly, retirement accounts are often subject to penalties and households rarely use these for

consumption smoothing.[12] These results are supported by Vissing-Jørgensen (2002) who shows that households that do not own bonds or stocks do not react to changes in the Federal Funds Rate.

1.1.2 Checking Account Balance

Virtually all households in the SCF own a checking account. Absent financial investments, this account is the main savings vehicle. For the years 1989 to 2013, I compute the ratio of checking account balance to income for all income groups except the bottom 10% who hold very little money in their checking account and have volatile income.

I expect the movement of this ratio by income group over time to capture whether or not households voluntarily save or dissave. For hand-to-mouth households, this ratio should stay roughly constant. Income groups that engage in precautionary saving should see counter-cyclical movements in this ratio, higher ratios around recessions and lower ratios during expansions. For the highest income groups that hold financial investments, the movement in this ratio is ambiguous since these households are more likely to reallocate their portfolio regularly.

The SCF does not disclose payment frequency and I use total quarterly income (reported total yearly income divided by 4), the usual time period in NK models as denominator. Checking account balance is the average monthly balance of the month prior to the survey response date and includes all checking accounts held by a household.

Using the *average checking account balance to quarterly income* ratio, all remaining households in the SCF can be divided into three groups by income: the bottom 40%

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[12]Kaplan and Violante (2014) discuss why retirement accounts are not an important vehicles of short-term saving.
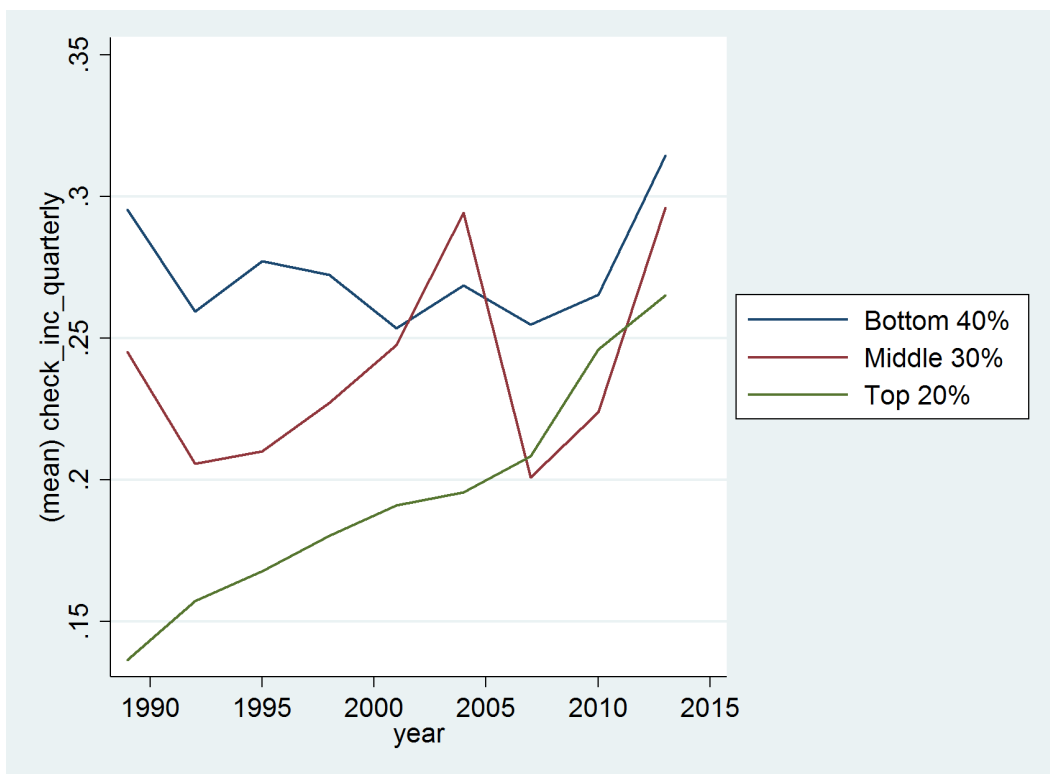
Figure 1.2: Checking Account to Income Ratio

Checking account to quarterly income ratio by income group, 1989 - 2013, SCF data

households, the middle 30% and the top 20%. These are shown in figure 1.2. The only movement in the checking account balance to quarterly income ratio that all the groups have in common is a strong upward movement since the Great Recession.

Apart from this common movement, these three groups behave very differently. The bottom 40% have a fairly stable ratio, essentially hand-to-mouth behavior. In contrast, the middle 30% of households display a ratio that moves counter-cyclically. It is low in the 1990s and increases towards and after the recession and jobless recovery of the early 2000s. Then, during the economic and housing boom of the mid 2000s, their ratio drops sharply, only to increase again in the year 2010 and 2013, following

the Great Recession. Lastly, for the top 20% of the income distribution this ratio is continuously increasing, albeit at a faster pace since the financial crisis. This result is robust to the exclusion of households that own financial investments, see figure A.2 in the Appendix. The main focus of the rest of this paper will be on the middle 30% of households since the observed counter-cyclical saving behavior has not been described by the literature on New Keynesian models before.

The advantage of using disaggregated SCF data becomes clear when liquid assets are added to checking account balances, the only category of liquid investment in the PSID, for example. Figure A.1 in the Appendix shows how the few households that own these investments dominate the ratio after aggregation by income group. The variation in the stock market, especially around the year 2000, and thus asset value to income ratio for those households who own stocks at that time dwarfs the movement of savings in checking accounts of all other households. The information on the saving behavior of all other households is therefore lost after averaging across households by income quintile.

Together, the observation that most households do not own liquid financial assets, that interest rates on common liabilities adjust slowly to Federal Funds Rate changes and the clear division of households into three groups by the *average checking account balance to income* ratio motivates the extension of the canonical New Keynesian model with limited participation in asset markets and labor market risk for a subset of agents.

1.2   The Model

I extend a standard medium scale New Keynesian model similar to Smets and Wouters (2007) and Christiano, Eichenbaum and Evans (2005) in two ways to capture the low ownership of liquid investments and strong counter-cyclical savings behavior in the

data. First, I add an exogenously sticky wage equation that sets the wage above the market clearing level and creates involuntary unemployment. Second, on the demand side, there are two types of households, traders, fraction n^p of all households, and non-traders, $1 - n^p$.

The setup for traders is similar to the standard representative agent in NK models. They invest into bonds and capital, are subject to investment adjustment cost and choose capital utilization. All traders belong to a large family and are insured against the loss of income in case of unemployment. Non-traders, on the other hand, only participate in the bond market and are subject to irreversible unemployment risk. Unemployment implies zero income until death. These agents' only option is to consume their savings when unemployed. The risk of unemployment thus creates a precautionary saving motive. These limited agents are modeled following Carroll and Toche (2009). Given the discussion on the exposure of households to the interest rate in the data above, the assumption that non-traders save in bonds is counter-intuitive. As I show in the results section, however, the precautionary saving motive strictly dominates the intertemporal substitution mechanism for these agents and the results of this cashless model are virtually the same as in a model in which non-traders save in cash.[13]

On the supply side, a competitive final goods firms aggregates intermediate goods into one final good. Intermediate goods are produced by a continuum of monopolistic firms that employ labor and capital services. Prices are set according to Calvo (1983) and indexed to inflation in periods in which an intermediate firm cannot adjust its prices. A monetary policy rule and passive government expenditure equation close the model.

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[13]The cashless model also has the advantage that it can be easily estimated at the zero lower bound.

All derivations are detailed in Appendix A.2.1.

1.2.1 Final Goods Firm

The final goods firm aggregates the intermediate products into one final good. Each intermediate good is sold at price $P_t(j)$ and the final good has price P_t. The production function is

$$y_t = \left(\int y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}$$

Cost minimization gives the demand function for intermediate good $y_t(j)$ and an expression for the aggregate price level P_t, where ϵ is price elasticity of demand for good j:

$$y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon} y_t \tag{1.1}$$

$$P_t = \left(\int P_t(j)^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}} \tag{1.2}$$

1.2.2 Intermediate Good Firms

A continuum of identical intermediate good firms use utilized capital $\hat{K}_t(j)$ and effective labor $\hat{N}_t(j)$ (both defined further below) as well as technology A_t to produce output $y_t(j)$. They minimize cost and maximize profit by choosing the optimal inputs and price $P_t(j)$ given the demand function (1.1) and factor prices. Price setting follows Calvo (1983). Firms can reset their prices with probability $1 - \phi$ every period. Prices that are not reset are indexed to the inflation rate. The production function is:

$$y_t(j) = A_t \hat{K}_t(j)^\alpha \hat{N}_t(j)^{1-\alpha}$$

where α is the share of capital in production.

Cost minimization given factor prices and subject to the demand function of the final goods producer leads to the following first order conditions:

$$
\begin{aligned}
w_t &= mc_t(j)(1-\alpha)y_t(j)\hat{N}_t^{-1}(j) \\
R_t &= mc_t(j)\alpha y_t(j)\hat{K}_t^{-1}(j)
\end{aligned}
\tag{1.3}
$$

w_t and R_t are the real factor prices and mc_t is the real marginal cost of producing one extra unit of output.

Under Calvo pricing, firms can reset their price $P_t(j)$ with probability $(1-\phi)$ every period. Conversely, with probability ϕ, prices are indexed to lagged inflation $(\pi_{t-1}^{\xi_p})$ where $\xi_p \in [0,1]$ is the inflation indexation parameter. Intermediate firms are owned by traders and future profit is discounted by their stochastic discount factor $\beta^s \frac{\lambda_{t+s}}{\lambda_t}$, defined in equation 1.14 below. Intermediate firms maximize expected future profit given the demand function by choosing the optimal price $P_t(j)$:

$$
\max_{P_t(j)} \quad \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \frac{\lambda_{t+s}}{\lambda_t} \left(\frac{\pi_{t-1,t+s-1}^{\xi_p} P_t(j)}{P_{t+s}} y_{t+s}(j) - mc_{t+s}(j)y_{t+s}(j) \right)
$$

$$
\text{s.t.} \quad y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon} y_t
$$

The optimal price, written in terms of optimal price inflation is:

$$\pi_t^{\#} = \frac{\epsilon}{\epsilon-1} \frac{\hat{B}_t}{\hat{A}_t} \pi_t \tag{1.4}$$

where

$$\hat{A}_t = \lambda_t y_t + \beta\phi\pi_{t+1}^{(\epsilon-1)}\pi_t^{\xi_p(\epsilon-1)}\mathbb{E}_t\hat{A}_{t+1}$$

$$\hat{B}_t = \lambda_t mc_t y_t + \beta\phi\pi_{t+1}^{\epsilon}\pi_t^{-\epsilon\xi_p}\mathbb{E}_t\hat{B}_{t+1}$$

Since all intermediate firms are homogeneous, we can integrate across all intermediaries to get aggregate output y_t

$$y_t = \frac{A_t\hat{K}_t^{\alpha}\hat{N}_t^{1-\alpha}}{v_t^p} \tag{1.5}$$

where v_t is a measure of price dispersion:

$$v_t^p = \pi_t^{\epsilon}\left((1-\phi)(\pi_t^{\#})^{-\epsilon} + \pi_{t-1}^{-\xi_p\epsilon}\phi v_{t-1}^p\right)$$

1.2.3 LABOR MARKET

The link between precautionary saving and the labor market is created via an exogenous sticky wage equation and involuntary unemployment. There is no leisure-labor decision. Both types of households work full time when employed, and do not work any hours when unemployed. Traders, however, are more efficient than non-traders and provide $\eta > 1$ labor per agent. η both reflects the fact that traders earn higher income in the data and hold more wealth. Firms cannot discriminate between workers and, by the law of large numbers, employ both types in the same proportion. Traders earn a wage of ηw_t, and limited agents w_t.[14]

The exogenous wage rule is adaptive, as proposed by Hall (2005), and an average between last period's wage and a fixed wage parameter $\bar{w}$. The latter is multiplied by an adjustment factor which varies with the tightness of the labor market and is subject to a wage shock $e^{z_t^w}$. In the literature, this wage parameter is usually taken as

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[14]The setup of the labor market is very close to Challe and Ragot (2016) but I abstract from hiring frictions.

a short-cut around wage bargaining and equal to the outcome of a bargaining process (see for example Blanchard and Galí (2010)). Here, absent a labor-leisure decision, this wage parameter is calibrated to yield the targeted unemployment rate in steady state by setting the wage above the marginal cost. In real terms, the wage rule is as follows:

$$w_t = \left(\frac{w_{t-1}}{\pi_t}\right)^{\gamma_w} \left(\bar{w} e^{z_t^w} \left[\frac{n_t}{n_{ss}}\right]^{\phi_w}\right)^{(1-\gamma_w)} \tag{1.6}$$

where the parameter $\phi_w \geq 0$ determines by how much the wage adjusts to labor market conditions, and $\gamma_w \in [0,1]$ the inertia in nominal wages. If $\gamma_w = 1$, nominal wages are perfectly sticky.[15] The larger ϕ_w, the more does the wage react to labor market tightness.

The wage shock follows:

$$z_t^w = \rho_w z_{t-1}^w + \epsilon_t^w \tag{1.7}$$

Given the assumption of non-discriminatory hiring by firms above, unemployment is equally split between both traders and limited households. The fraction of limited, unemployed households is $n_t^u = urate_t(1-n^p)$ and given recursively by

$$n_t^u = (1-\sigma^d)n_{t-1}^u + \sigma_t^u n_{t-1}^e \tag{1.8}$$

where σ^d is the fixed rehiring probability of unemployed agents, σ_t^u the probability of unemployment at the beginning of period t and n_{t-1}^e the share of limited, employed workers at the end of period $t-1$.[16] The firm FOCs yield labor demand and thus unemployment. Given unemployment, equation (1.8) determines σ_t^u. This

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[15]I explore the importance of rigid nominal wages in an extension at the end of the paper.

[16]σ^d can be thought of as the hiring probability.

unemployment probability, σ_t^u, is the key variable that determines saving for non-traders. Traders are insured against unemployment in large families and the share of unemployed traders is given by: $urate_t n_p$. Together, limited, employed households and traders provide aggregate, effective labor $\hat{N}_t$:

$$\hat{N}_t = n_t^e + n_p \eta (1 - urate_t) \tag{1.9}$$

and the total labor supply is

$$N_t = n_t^e + n_p (1 - urate_t) \tag{1.10}$$

1.2.4 TRADERS

Traders are similar to the standard representative agent setup in NK models. I assume that these agents belong to one large family, fraction n_p of all agents, and within that family are fully insured against unemployment. The family head maximizes utility by choosing consumption, investment, capital utilization, next period's capital stock and saving in real bonds. When employed, an agent provides labor of 1, and 0 otherwise.

Investment is subject to quadratic investment cost $S_t(I_t, I_{t-1})$ when $\tau > 0$ which is paid in consumption units for changes in the level of investment per unit of investment, and includes an investment adjustment cost shock $e^{z_t^I}$. These cost are modeled as in Christiano, Eichenbaum and Evans (2005). Existing capital depreciates at rate δ^K. Investment per period is thus given by:

$$K_{t+1} - (1 - \delta^K)K_t = e^{z_t^I} \left(1 - \frac{\tau}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right) I_t \tag{1.11}$$

Cost shock z_t^I evolves according to the following process:

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$$z_t^I = \rho_I z_{t-1}^I + \epsilon_t^I \tag{1.12}$$

Investment cost play a key role in representative agent NK models and as I will discuss later, one implication of adding households with a precautionary saving motive is that the importance of these costs decreases substantially.

Capital K_t is utilized at rate u_t to yield effective capital $\hat{K}_t = u_t K_t$. Utilization cost $\eta^K(u_t)$ are paid in consumption units and are calibrated such that in steady state the utilization rate is $u_{ss} = 1$ and cost are $\eta^K(u_{ss}) = 0$. In addition, $\eta^{K'}(u_{ss}) > 0$ and $\eta^{K''}(u_{ss}) > 0$. The functional form follows Christiano, Trabandt and Walentin (2010), chapter 7:

$$\eta^K(u_t) = \chi_1(1 - u_t) + \frac{\chi_2}{2}(u_t - 1)^2 \tag{1.13}$$

Traders maximize utility given prices, bond holding from last period, the capital stock, the previous level of investment, the previous level of consumption as well as the level of employment (in real terms):

$$V_t = \max_{c_t, I_t, u_t, b_{t+1}, K_{t+1}} ln(c_t - bc_{t-1}) + \beta \mathbb{E}_t V_{t+1}$$

subject to

$$c_t + I_t + b_{t+1} \le R_t u_t K_t + w_t \omega N_t - \eta(u_t) K_t + (1 + r_t^i)\frac{1}{\pi_t} b_t + \frac{1}{n_p} \frac{\Pi_t}{P_t} + T_t^G$$

$$K_{t+1} - (1 - \delta^K)K_t = e^{z_t^I}\left(1 - \frac{\tau}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right) I_t$$

$$N_t = (1 - urate_t)$$

where, b is the consumption habit parameter, Π_t is the profit of the intermediaries, $(1 + r_t^i)$ is the nominal interest rate, T_t^G are real lump sum taxes and b_t are real bonds.

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Let λ_t and μ_t be the multipliers on the budget constraint and capital accumulation equation. The optimality conditions are:

$$\lambda_t = \frac{1}{c_t - bc_{t_1}} - \beta\mathbb{E}_t\left[\frac{1}{c_{t+1} - bc_t}\right] \tag{1.14}$$

$$R_t = \chi_1 + \chi_2(u_t - 1) \tag{1.15}$$

$$\lambda_t = (1 + r_t^i)\beta\mathbb{E}_t\left[\lambda_{t+1}\frac{1}{\pi_{t+1}}\right] \tag{1.16}$$

$$\lambda_t = \mu_t e^{z_t^I}\left(\left(1 - \frac{\tau}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right) - \tau\frac{I_t}{I_{t-1}}\left(\frac{I_t}{I_{t-1}} - 1\right)\right)$$
$$- \beta\mathbb{E}_t\left[\mu_{t+1}z_{t+1}^I\tau\left(\frac{I_{t+1}}{I_t} - 1\right)\frac{I_{t+1}^2}{I_t^2}\right] \tag{1.17}$$

$$\mu_t = \beta\mathbb{E}_t\left[\lambda_{t+1}\left(R_{t+1}u_{t+1} - \eta(u_{t+1})\right) + \mu_{t+1}(1 - \delta^K)\right] \tag{1.18}$$

Equation 1.14 is the stochastic discount factor. Since traders are also firm owners, this SDF was used in the optimization problem of intermediaries. Equation 1.15 shows the role of capital utilization. Utilization rate adjustments alleviate the effect of interest rate shocks on the return on capital services. Equation 1.16 is the Euler Equation. And the last two equations are the optimality conditions for investment and capital utilization.

1.2.5 EMPLOYED, LIMITED AGENTS

Limited households are a fraction $(1 - n_p)$ of all households and split into employed and unemployed agents. These households represent the counter-cyclically saving households in the data. Their two defining features are that they can only save in riskless bonds and face uninsurable unemployment risk. Employed agents are assigned to

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large families when they are born and share income and assets.[17] A family head maximizes the utility of all agents and assigns each member a level of consumption and saving. If an agent becomes unemployed, however, it must take its savings and leave the family. Once unemployed, labor income is zero and agents consume their savings until they die with probability σ^d. In the context of this model, this death probability is equivalent to a rehiring probability. This risk of unemployment and zero income gives rise to the precautionary saving motive.

The employed agent problem has a family level wealth state variable X_t^e, after the labor market transitions have occurred. Since there are infinitely many employed and newborn agents, the rates of loss of agents to unemployment and the allocation of newborn workers to families are the same across all families by the law of large numbers. While n_t^u and n_t^e can vary over time, the total fraction of limited agents is constant at $1 - n^p$.

The choice variables for the family head are per-member (lowercase) wealth, x_t^e, and consumption, c_t^e. Employed workers supply one unit of labor inelastically. The law of motion for real pooled resources takes into account the wealth inflows and outflows in the labor market transition stage at the beginning of the period:

$$X_t^e = (1 - \sigma_t^u)n_{t-1}^e \frac{1}{\pi_t}(1 + r_{t-1}^i)x_{t-1}^e + D_t^u \tag{1.19}$$

where the first term on the right determines the outflow of resources that unemployed workers take with them, and D_t^u is the transfer of wealth from newly deceased unemployed agents to newborn, employed workers.

The family head then solves the following problem (in real terms):

_____

[17]This assumption solves the aggregation problem with different cohorts of limited, employed households.

$$V_t^e = \max_{c_t^e, x_t^e} n_t^e ln(c_t^e) + \beta_e \mathbb{E}\left[V_{t+1}^e + \sigma_{t+1}^u n_t^e V_{t+1}^u\right]$$

subject to

$$n_t^e(c_t^e + x_t^e - T_t^G) \le X_t^e + n_t^e w_t \tag{1.20}$$

$$X_{t+1}^e = (1 - \sigma_{t+1}^u)n_t^e \frac{1}{\pi_{t+1}}(1 + r_t^i)x_t^e + D_{t+1}^u$$

$$x_t^e \ge 0$$

where T_t^G is a lumpsum tax. Assuming that the BC constraint holds with equality, that $x_t^e > 0$ (implied by otherwise consumption of zero when unemployed) and substituting for X_t^e, the first order conditions and envelope conditions are:

$$\frac{\partial V_t^e}{\partial c_t^e} = n_t^e \frac{1}{c_t^e} - n_t^e \lambda_t = 0$$

$$\frac{\partial V_t^e}{\partial x_t^e} = -n_t^e \lambda_t + \beta_e \mathbb{E}_t\left[\frac{\partial V_{t+1}^e}{\partial x_t^e} + \sigma_{t+1}^u n_t^e \frac{\partial V_{t+1}^u}{\partial x_t^e}\right] = 0$$

$$\frac{\partial V_t^e}{x_{t-1}^e} = \lambda_t(1 - \sigma_t^u)n_{t-1}^e \frac{1}{\pi_t}(1 + r_{t-1}^i)$$

$$\frac{\partial V_t^u}{\partial x_t^e} = \frac{1}{c_t^u}\frac{1}{\pi_t}(1 + r_{t-1}^i)$$

Where the last envelope condition is given by equation (A.24) in the appendix of the problem for unemployed agents. Iterating forward the envelope conditions and substituting we get:

$$\lambda_t = \frac{1}{c_t^e}$$

$$n_t^e \lambda_t = \beta_e(1 + r_t^i)\mathbb{E}_t\left[\lambda_{t+1}(1 - \sigma_{t+1}^u)n_t^e \frac{1}{\pi_{t+1}} + \sigma_{t+1}^u n_t^e \frac{1}{c_{t+1}^u}\frac{1}{\pi_{t+1}}\right]$$

which together give the Euler Equation for employed, limited households:

$$\frac{1}{c_t^e} = \beta_e(1 + r_t^i)\mathbb{E}_t\left[(1 - \sigma_{t+1}^u)\frac{1}{c_{t+1}^e}\frac{1}{\pi_{t+1}} + \sigma_{t+1}^u \frac{1}{c_{t+1}^u}\frac{1}{\pi_{t+1}}\right] \tag{1.21}$$

As long as $\mathbb{E}_t\beta_e\frac{1}{\pi_{t+1}} < 1$, absent the unemployment probability, impatience implies consumption up to the borrowing limit of $x_t^e = 0$. The probability of unemployment next period, however, creates a savings motive to avoid a potential consumption level of zero. This target savings level depends on the unemployment probability, expected length of unemployment, as well as income, the discount factor and expected inflation.

1.2.6 Unemployed, Limited Agents

Unemployed households face fixed death probability σ^d, do not receive any income and only consume their savings. These unemployed households solve the following problem:

$$V_t^u = \max_{c_t^u, x_t^u} ln(c_t^u) + \beta_e(1 - \sigma^d)\mathbb{E}V_{t+1}^u$$

subject to

$$c_t^u + x_t^u \leq \frac{1}{\pi_t}(1 + r_{t-1}^i)x_{t-1}^u$$

$$x_t^u \geq 0$$

(1.22)

where x_t^u are real savings in bonds in period t and there is a no-borrowing limit. In the initial period of unemployment $x_{t-1}^u = x_{t-1}^e$. Taking FOCs yields the Euler Equation:[18]

$$\frac{1}{c_t^u} = \beta_e(1 - \sigma^d)(1 + i_t)\mathbb{E}_t\left[\frac{1}{c_{t+1}^u}\frac{1}{\pi_{t+1}}\right]$$

(1.23)

From the Euler Equation and the lifetime budget constraint, the perfect foresight solution becomes:

$$c_t^u = (1 - \beta_e(1 - \sigma^d))\frac{1}{\pi_t}(1 + r_{t-1}^i)x_{t-1}^u = k_u\frac{1}{\pi_t}(1 + r_{t-1}^i)x_{t-1}^u$$

(1.24)

---

[18]A binding no-borrowing constraint implies zero consumption.

Thus, unemployed households consume a constant fraction of their income.

1.2.7 Aggregate Unemployment Variables

Aggregate dynamics are described by three variables: consumption, $\bar{C}_t^u$, saving, $\bar{S}_t^u$, and transfers from the deceased households, $\bar{D}_t^u$.

Consumption consists of the newly unemployed agents' consumption (no death probability in first period) and consumption of the surviving, previously unemployed agents.

$$\bar{C}_t^u = \sigma_t^u n_{t-1}^e c_t^u + (1 - \sigma^d) k^u \frac{1}{\pi_t} (1 + r_{t-1}^i) \bar{S}_{t-1}^u \tag{1.25}$$

Aggregate saving combines the saving of the newly unemployed with the saving of the surviving unemployed:

$$\bar{S}_t^u = \frac{1}{\pi_t} (1 + r_{t-1}^i)(1 - k^u) \left(x_{t-1}^e n_{t-1}^e \sigma_t^u + (1 - \sigma^d) \bar{S}_{t-1}^u \right) \tag{1.26}$$

And, lastly, transfers are the real savings of the deceased agents, out of the group of previously unemployed households:

$$\bar{D}_t^u = \sigma^d \frac{1}{\pi_t} (1 + r_{t-1}^i) \bar{S}_{t-1}^u \tag{1.27}$$

1.2.8 Monetary Policy and Government

Monetary policy follows a Taylor rule that reacts to deviations of inflation from the target of steady state inflation and to output growth (see e.g. Guerrieri and Iacoviello (2017)).

$$(1 + r_t^i) = (1 + r_{t-1}^i)^{r_R} \left(\frac{\pi_t}{\pi_{SS}} \right)^{(1-r_R)r_\pi} \left(\frac{y_t}{y_{t-1}} \right)^{(1-r_R)r_y} (1 + r_{SS}^i)^{1-r_R} \epsilon_{r,t} \tag{1.28}$$

where $\epsilon_{r,t}$ is the monetary policy shock.

Government spending is an exogenous fraction of output:

$$G_t = \omega_t y_t$$

where ω_t is follows an AR(1) process:

$$\omega_t = \rho_g \omega_{t-1} + (1 - \rho_g)\bar{\omega} + \epsilon_t^G$$

The government levies lumpsum taxes on traders and employed, limited households according to a balanced budget rule:

$$G_t = n_t^e T_t^G + n_p T_t^g \tag{1.29}$$

1.2.9 Aggregation and Equilibrium

In equilibrium, effective labor and capital markets clear:

$$\hat{N}_t = n_t^e + (1 - urate_t)\eta n_p$$

$$\hat{K}_t = n_p u_t K_t$$

The bond market clears:

$$n_t^e x_t^e + S_t^u = n_p b_{t+1}$$

The aggregate resource constraint is:

$$y_t = G_t + n_t^e c_t^e + C_t^u + n_p(c_t + I_t + \eta^K(u_t)K_t)$$

The law of motion for capital is

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$$K_{t+1} - (1 - \delta^K)K_t = e^{z_t^I}\left(1 - \frac{\tau}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right)I_t$$

The law of motion for the fraction of limited, unemployed agents is:

$$n_t^u = (1 - \sigma^d)n_{t-1}^u + \sigma_t^u n_{t-1}^e$$

Inflation is given by

$$\pi_t^{1-\epsilon} = (1 - \phi)\pi_t^{\#(1-\epsilon)} + \phi\pi_{t-1}^{\xi_p(1-\epsilon)}$$

where $\pi_t^{\#}$ is defined in equation (1.4).

The real wage is determined by the wage equation:

$$w_t = \left(\frac{w_{t-1}}{\pi_t}\right)^{\gamma_w}\left(\bar{w}e^{z_t^w}\left[\frac{n_t}{n_{ss}}\right]^{\phi_w}\right)^{(1-\gamma_w)} \tag{1.30}$$

The shock processes are:

$$
\begin{aligned}
z_t^I &= \rho_I z_{t-1}^I + \epsilon_t^I \\
z_t^w &= \rho_w z_{t-1}^w + \epsilon_t^w \\
\omega_t &= \rho_G \omega_{t-1} + (1 - \rho_G)\bar{\omega} + \epsilon_t^G \\
A_t &= \rho_A A_{t-1} + (1 - \rho_A)\bar{A} + \epsilon_t^A
\end{aligned}
\tag{1.31}
$$

Therefore, an equilibrium in this economy is a set of value and policy functions, a set of prices and a set government policies, such that given prices and state variables, (1) the policy functions solve the household problems of traders; limited, employed; limited, unemployed households, (2) firms maximize profits, (3) the bond, labor and capital markets clear, (4) wages are set according to the wage rule, and (5) government policy is given by the balanced budget equation and monetary policy rule.

Table 1.2: Calibrated Parameters

parameter	description	value	target
π_{ss}	steady state inflation	0	
σ^d	death probability	0.6011	mean unemployment duration
β	discount factor traders	0.9904	quarterly interest rate
β_e	discount factor limited	0.96	close match of SCF chkg-inc ratio
α	share of capital in production	1/3	
χ_1	capital utilization parameter	0.0297	$u_{ss} = 1$
χ_2	capital utilization parameter	0.01	Christiano et.al. 2005
δ^K	capital depreciation rate	0.02	
ϵ_p	price elasticity of demand	10	
n_p	share of traders	0.4	SCF data, see section 1.1
$\bar{w}$	log wage parameter	0.6456	average unemployment
ω	share of government	0.2	Christiano et.al. 2005
η	wage premium	1.5	Challe and Ragot (2016)

1.3 Estimation and Results

In this section, I estimate the benchmark model and answer the questions listed in the introduction: How well does a precautionary saving model match the observed saving pattern in the data? How does the inclusion of households that engage in precautionary saving change the transmission of monetary policy? What are the implications for monetary policy? And, can a model of precautionary saving explain the sluggish inflation rate and seemingly low effectiveness of monetary policy since the financial crisis?

1.3.1 Calibration and Estimation

The model is estimated using five quarterly time series from the end of the Volker period in 1982Q2 until 2017Q1. To examine how well this model with uninsurable labor market risk and precautinary saving matches the data I will compare the model

implied *checking account to quarterly income* ratio of limited, employed households to the data points in the SCF for the middle 30% of households by income, as outlined in the data section.

The five time series used in the estimation are the change in real investment per capita, the change in real output per capita, the inflation rate, the secondary market 3-month T-Bill rate and the unemployment rate.[19] The time series are described in detail in the appendix in section A.2.6.

The parameters of this model are grouped into two categories: calibrated parameters and estimated parameters. Table 1.2 lists the calibrated parameters and the targets used. The model is linearized around a zero inflation steady state. The share of capital α is set to $1/3$, the quarterly depreciation rate is 2% and the price elasticity of demand equal to 10. These four values are commonly used in the NK literature. The death probability of unemployed agents, σ^d is chosen to match the average unemployment duration in quarters. The real interest rate pins down the discount factor of traders, β. The capital utilization parameters are chosen to set capital utilization to 1 in steady state. This calibration implies $\chi_1 = 0.0297$. Since χ_2 is problematic to estimate and not the focus of this paper, I take the value of 0.01 from Christiano, Eichenbaum and Evans (2005). The wage parameter $\bar{w}$ is implied by the steady state unemployment rate. Given the steady state unemployment rate and death probability, the law of motion for limited, unemployed agents, equation (1.8), implies an unemployment probability around 4%. Both the calibrated death probability and implied unemployment probability are in line with Shimer (2005).

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[19]A drawback of this estimation method is that the ZLB is matched by a series of unexpected shocks to the Taylor Rule and households do not expect the interest rate to stay at that level. This approach has been used by other papers as well, see Challe and Ragot (2016).

Table 1.3: Estimated Parameters

Model	Parameters Description	Prior [bound]	Mode	Posterior 10%	Posterior Median	Posterior 90%
γ_w	wage inertia	beta [0.5,0.1]	0.7708	0.7339	0.7712	0.8040
ϕ_w	wage adjustment	gamma [1,0.2]	1.2614	1.1053	1.2930	1.5191
b	habit persistence	beta [0.7,0.1]	0.5389	0.3973	0.5144	0.6389
τ	investment cost	normal [1,0.5]	1.0047	0.7909	1.0996	1.4462
ϕ_p	calvo probability	beta [0.5,0.1]	0.6746	0.6365	0.6659	0.6924
ζ_p	inflation index	beta [0.5,0.2]	0.1386	0.0804	0.1739	0.2957
ϕ_y	output Taylor	normal [0.125 0.05]	0.2094	0.1558	0.2133	0.2694
ϕ_π	inflation Taylor	normal [1.5,0.1]	1.8635	1.7821	1.8746	1.9843
ρ_i	inertia Taylor	beta [0.9,0.05]	0.7803	0.7531	0.7786	0.8016
ρ_w	AR(1) wage shock	beta [0.9,0.05]	0.9242	0.8455	0.9158	0.9606
ρ_a	AR(1) TFP shock	beta [0.9,0.05]	0.9535	0.9291	0.9532	0.9698
ρ_g	AR(1) gov shock	beta [0.9,0.05]	0.9744	0.9637	0.9731	0.9806
ρ_z	AR(1) invest cost shock	beta [0.9,0.05]	0.9129	0.8856	0.9086	0.9309
σ_w	sd wage shock	inv gamma [0.01,0.002]	0.0520	0.0460	0.0529	0.0602
σ_i	sd Taylor shock	inv gamma [0.002,0.002]	0.0015	0.0014	0.0015	0.0017
σ_a	sd TFP shock	inv gamma [0.01,0.002]	0.0052	0.0048	0.0052	0.0056
σ_g	sd gov shock	inv gamma [0.01,0.002]	0.0071	0.0065	0.0072	0.0079
σ_z	sd invest cost shock	inv gamma [0.01,0.002]	0.0137	0.0124	0.0143	0.0166

The fraction of limited agents is 60% given the relative proportions of the middle and high income groups in the data. The wage premium is set to 1.5 following Challe and Ragot (2016). Lastly, the discount factor of limited, employed agents, β_e, is difficult to pin down since SCF data on saving is only available every three years, starting in 1989. Matching the average checking account balance to income ratio for that period leads to a discount factor of 0.945. Following the estimation, however, the model implied path of this ratio is quantitatively too low. I thus choose a discount factor of 0.96 which leads to a close match between the model ratio and SCF data. This adjustment does not alter the qualitative result but increases the amount of saving at every point in time by roughly the same amount, as shown in figure A.6 in the Appendix.

The estimated parameters are shown in table 1.3. The third column details the prior distribution and parameters, while the last four columns show the estimation results. The estimated parameters align well with the literature. There are two prominent exceptions, however, which are the key difference between the benchmark model and canonical NK models: the capital adjustment cost parameter and the habit parameter. Both are markedly lower in the benchmark model. Furthermore, the benchmark model allows for more price and wage flexibility. These results already indicate that the transmission mechanism of monetary policy does not solely work through the intertemporal substitution channel of traders. I will return to the transmission mechanism of monetary policy after first evaluating how well the benchmark model can match the observed data on precautionary saving.

1.3.2 Model Implied Saving

The benchmark model fits the data on precautionary saving quantitatively well until the mid 2000s but overestimates the savings ratio in the run up to and time since the Great Recession. Across all available years, however, the same trend in savings is clearly visible in the model implied savings ratio and the SCF data.

Following the discussion in part 1.1, I compare the model implied *average checking account balance to quarterly income* ratio of the limited, employed households to the values derived from the Survey of Consumer Finances for the middle income group of households. For the model outcome, I use end-of-period savings per agent x_t^e divided by 2 over wage income w_t as target variable:

$$chkinc_t = \frac{\frac{x_t^e}{2}}{w_t}$$

I retrieve the time series for this savings ratio by feeding the shocks that were extracted at the estimation stage back into the model. From the SCF, I take the
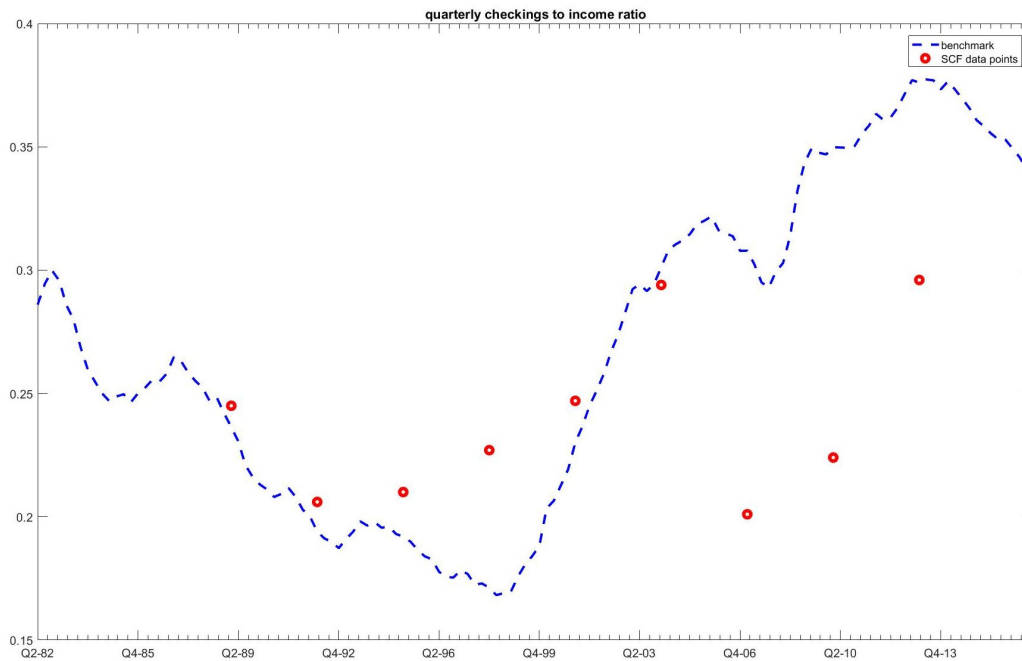
Figure 1.3: Model Implied Saving Ratio

Comparison of model implied checking account balance to income ratio vs. SCF data, period 1982Q2 to 2017Q1.

values calculated in the data section which are available every three years for the period 1989 - 2013.

The resulting comparison is shown in figure 1.3. The model matches the long-run business cycle variation of savings quite well. The drop in savings during the 1990s and eventual increase around the dotcom bust and following short recession as well as the decrease during the housing boom and sharp increase during and after the Great Recession are clearly visible.

In addition, during the nineties and up until around 2004, the implied savings ratio is very close to the SCF data points. For the last 10 years of the sample, however,

the model implies a much larger magnitude of precautionary saving, starting just before the Great Recession. Since the benchmark model does not capture the housing boom before the financial crisis nor debt constraints after 2008, this deviation is not surprising.

Further evidence that this model captures the data better than a standard representative agent model is the movement of the real interest rate. In Appendix A.3 I show that this model is able to reproduce the result of Canzoneri, Cumby and Diba (2007). The estimated real interest rate in this model does not coincide with the implied aggregate interest rate and moves in the opposite direction at the beginning and end of recessions, a fact that a representative agent model cannot reproduce.

Lastly, the model is also externally validated by the empirical results of Stamm (2018) (chapter 2 of this dissertation) who shows that the correlation between the consumption-income ratio and employment growth is positive in the data, with a value of 0.096. In the representative agent version of this model, this correlation is negative at -0.055 and the response of the representative agent to a one percentage point increase in employment growth is a negative -0.16. As Stamm (2018) shows, this coefficient is positive in the data and positive for the benchmark model as well.

1.4   Transmission of Monetary Policy

The precautionary saving motive links consumption of limited, employed agents to the labor market. This link breaks the dominance of the direct effect of monetary policy via the intertemporal substitution channel of traders.

A strong indication of the strength of the indirect effect can be seen in the estimated parameters of the benchmark model compared to a representative agent ver-
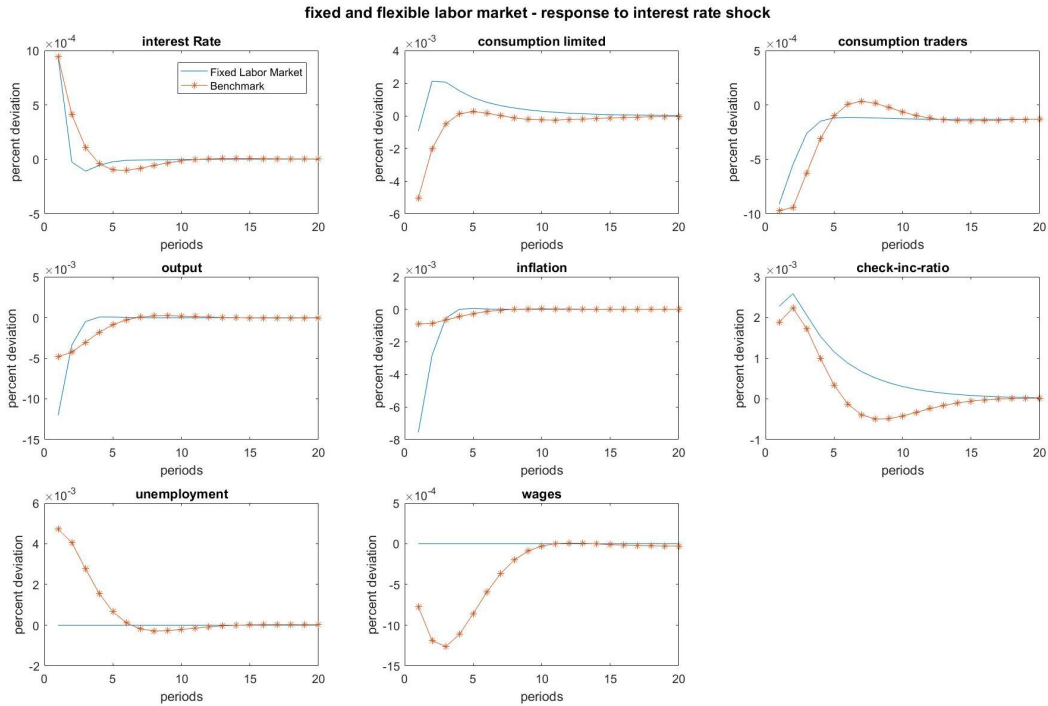
Figure 1.4: Montary Policy IRF with Fixed Labor Market

Comparison of IRF after monetary policy shock in the benchmark model compared with a fixed labor market. When labor income, unemployment and taxes are fixed, only the interest rate channel remains. The response of limited, employed agents is very different in this scenario while traders respond similarly in both models.

sion in which the share of limited agents is set to 0.[20] Standard NK models rely on strong real and nominal frictions to inhibit the consumption smoothing motive of the representative agent. For example, capital adjustment costs and consumption habits increase the cost of using capital to save and dissave.[21] Furthermore, sticky prices and wages prohibit the immediate response of prices to changes of consumption.

[20]See Appendix A.2.3 for a description of the model and the estimation results of the representative agent version of the benchmark model.

[21]See Rupert and Sustek (2016) for a detailed discussion.

All of these frictions are lower and therefore less important in the estimated bench-mark model.[22] The capital adjustment cost and habit parameters are 1 and 0.54, respectively, compared to 1.6 and 0.78 in the representative agent economy. Prices are also more flexible in the benchmark model. The estimated calvo and inflation indexation parameters are 0.67 and 0.14, more flexible than the estimated values of 0.7 and 0.07 in the representative agent model. The same is true for wages. Nominal wage inertia is estimated at 0.77 and the labor market tightness adjustment param-eter is 1.26 in the benchmark economy, whereas these are estimated at 0.8 and 1 in the representative agent model. Since both models were estimated with the same data these results show that the benchmark model relies less on frictions and more on an indirect transmission mechanism for monetary policy.

I highlight the relative importance of the indirect effect in two steps: First, the direct effect of monetary policy on limited, employed households is given in figure 1.4. The IRFs depict the response to a monetary policy shock for the benchmark model and an augmented benchmark economy in which the non-interest income for limited, employed households is held constant. Second, in figure 1.5, I compare the IRFs for a monetary policy shock in the benchmark model and a cash version of the benchmark model in which limited, employed households do not earn interest income.

The separation of the direct from the total effect of monetary policy for limited, employed agents is clearly visible when all real non-interest income is held constant. Specifically, government expenses and taxes, the unemployment rate and real wages are fixed at their respective steady state values. Figure 1.4 shows that the response of traders is very similar in both models, despite different paths of output and inflation, highlighting the strengths of the direct effect of monetary policy on these agents.

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[22]One common criticism of current NK models is their reliance on frictions that are much stronger than indicated by micro evidence. My results indicate that lowering the importance of the intertemporal substitution mechanism can potentially resolve this issue.
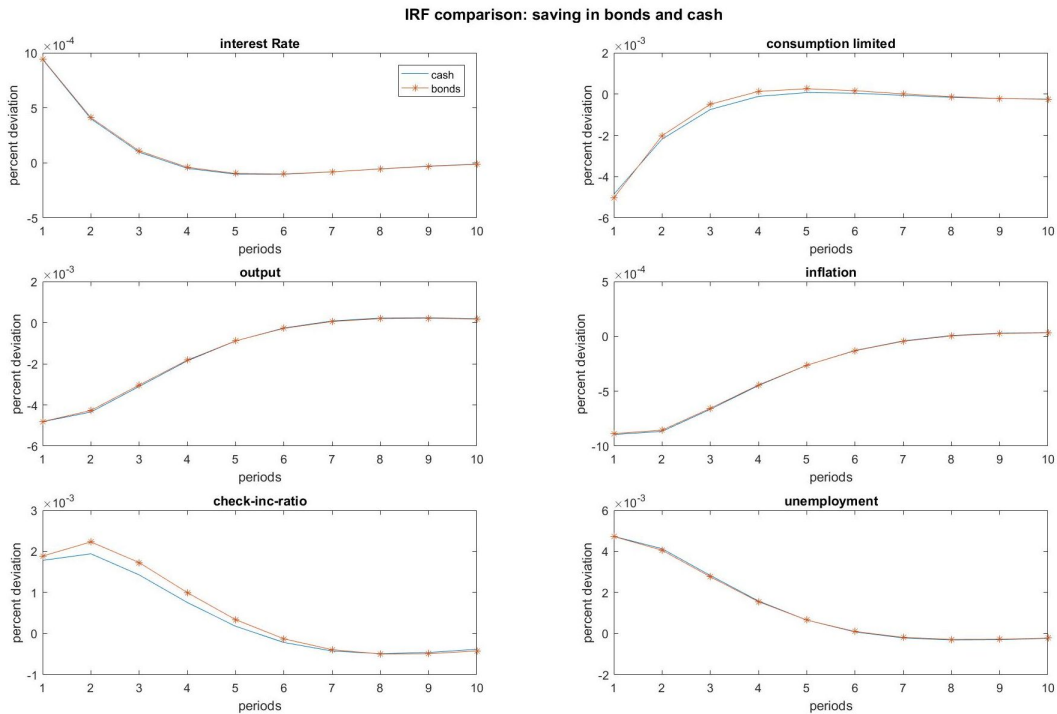
Figure 1.5: Monetary Policy IRF: Benchmark and Cash Model

Comparison of IRF after monetary policy shock in the benchmark model compared to the cash model in which limited, employed households do not earn interest on their saving. The IRF to a monetary policy shock are virtually identical and show that the labor market channel dominates the interest rate channel for limited, employed households. Traders do not hold cash but invest into bonds instead, a condition that is verified ex post.

The reaction of limited, employed agents, on the other hand, is very different in these two scenarios. Absent a change in labor market risk, they barely react initially and then, following strong deflation, dissave their additional real savings. In contrast, in the benchmark model that includes labor market risk, limited agents immediately decrease consumption and increase saving as the unemployment probability goes up. The labor market, thus, plays a strong role in the transmission of monetary policy in

the model with precautionary saving. Also note that the impact of monetary policy is lower and the economy takes longer to return to the steady state.

To investigate how strongly the precautionary saving channel dominates the intertemporal substitution channel for limited, employed agents I compare the benchmark model in which all agents earn interest on their savings to a "cash" model in which limited, employed agents save in cash which does not earn interest.[23] [24] Importantly, the interest rate is not part of the Euler Equation for limited agents in the cash economy and they only react to the path of inflation and the labor market. Figure 1.5 shows the IRFs following a positive shock to the interest rate for both models. These paths are virtually the same and therefore intertemporal substitution does not play a role for non-traders.[25]

The implication for monetary policy in a model with a strong indirect transmission channel is that, following aggregate shocks, interest rate changes need to overcome movements of demand into the opposite direction. For example, if the economy is pushed into a recession through a aggregate demand shock, an application I will look at in the next section, the response of monetary policy has to be more forceful. The initial shock is amplified when households increase savings in response to greater labor market uncertainty. At first, only traders who directly react to the interest rate will adjust consumption and this adjustment has to be strong enough to cancel the drop in demand from non-traders.
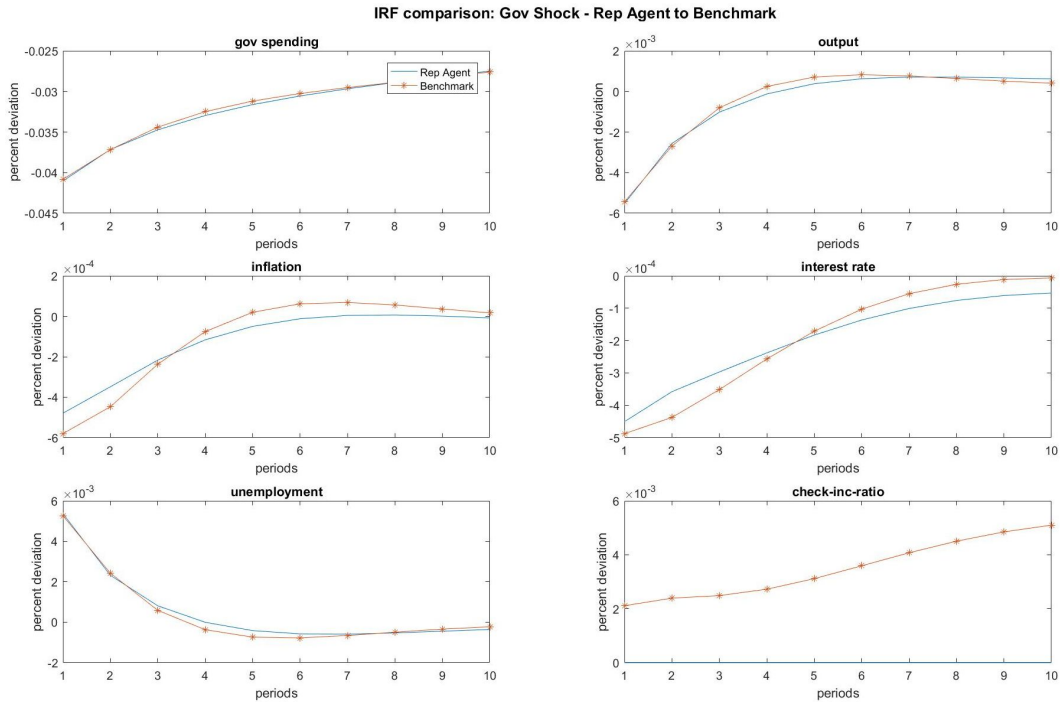
Figure 1.6: Missing Inflation IRF Comparison

Comparison of IRFs in benchmark and representative agent model after a government spending shock which is both deflationary and reduces output. Both models use the same process for government spending and Taylor Rule. The reduction in output causes a rise in unemployment and in turn increases savings. Despite similar paths for output and unemployment, in the benchmark economy inflation drops more despite a lower interest rate. The benchmark interest rate stays below the representative agent model rate until after output and unemployment return to the steady state.

1.4.1 Missing Inflation Since the Great Recession

Inflation since the Great Recession has been persistently below the 2% target of the Federal Reserve Bank despite a near 0% interest rate, strong output growth

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[23]Described in Appendix A.2.2.

[24]Since cash is dominated by bonds, traders do not invest into cash, a condition I verify ex-post using the multiplier on the non-negativity constraint for cash savings. This constraint is binding for traders but not binding for limited, employed households.

[25]Saving in the benchmark economy is higher in the steady state.

and decreasing unemployment. Evidence that the saving mechanism might play an important role in answering this question can be seen in the data. Both middle and low income households strongly increased their savings during and after the Great Recession. Especially the data of the 2013 Survey of Consumer Finances shows that even several years after the recession, household savings were at a record high.

I simulate the Great Recession through a shock to government demand. This shock both lowers output and inflation, and, intuitively, is a shift of the aggregate demand curve to the left. The initial reaction of the economy mimics the impact of the recession.

The optimal response of monetary policy is to lower interest rates to stimulate household consumption and increase demand. The dominating indirect effect of monetary policy on limited households' saving behavior implies, however, that traders have to adjust consumption even more than in a representative agent NK model to overcome the additional drop in aggregate demand due to the precautionary savings motive. The lower the fraction of traders in the economy, the more the target rate has to be adjusted. Figure 1.6 illustrates this effect. I compare IRFs of the estimated benchmark economy to the estimated representative agent model.[26]

Following the same shock to government spending, the initial impact is the same in both models. Output and unemployment follow similar transition paths, but limited agents increase their savings in the benchmark economy. The initial impact on inflation is therefore stronger in the benchmark model, despite a lower interest rate. The optimal policy rate in the benchmark economy stays below the representative agent model rate until after output and unemployment return to the steady state, in line with the intuition outlined above. The IRFs show that the precautionary saving

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[26]The parameters governing the AR process for government spending and the Taylor Rule are the same and as estimated in the benchmark model to ensure that the comparison is valid.

channel is a promising candidate to explain the consistently low inflation rate since the Great Recession as it aligns well with observed household saving behavior in the data and implies both a lower inflation rate and lower interest rates.

1.4.2 Downward Rigid Nominal Wages

The benchmark model abstracted from any mechanism that would intensify or weaken the precautionary saving channel. This abstraction allowed me to analyze how the saving channel itself changes the workings of standard New Keynesian models. I now extend the model with downward rigid nominal wages, a defining feature of the data during the Great Recession in many countries.[27] This fact is important in the context of precautionary saving because the strength of saving motive increases with wage rigidity since more rigid nominal wages lead to a larger variation in unemployment. The previous discussion has shown that the effectiveness of a given monetary policy intervention weakens the more households respond to labor market movements and save. Downward rigid nominal wages therefore imply an asymmetric response of the labor market and thus higher saving in downturns compared to the benchmark model. In turn, one would expect monetary policy to be less effective during recessions. Empirical evidence in Tenreyro and Thwaites (2016) supports this hypothesis.

To capture this asymmetry, I augment the benchmark economy with a second wage equation that has a higher $\gamma_w^A = 0.95$ wage rigidity parameter, compared to the estimated $\gamma_w = 0.7708$. The higher this value, the more nominally rigid is the wage. The augmented wage equation takes effect when nominal wages are falling in the model, while the economy behaves as in the benchmark model when nominal wages are rising. Apart from this change in the wage parameter, the two economies are identical.

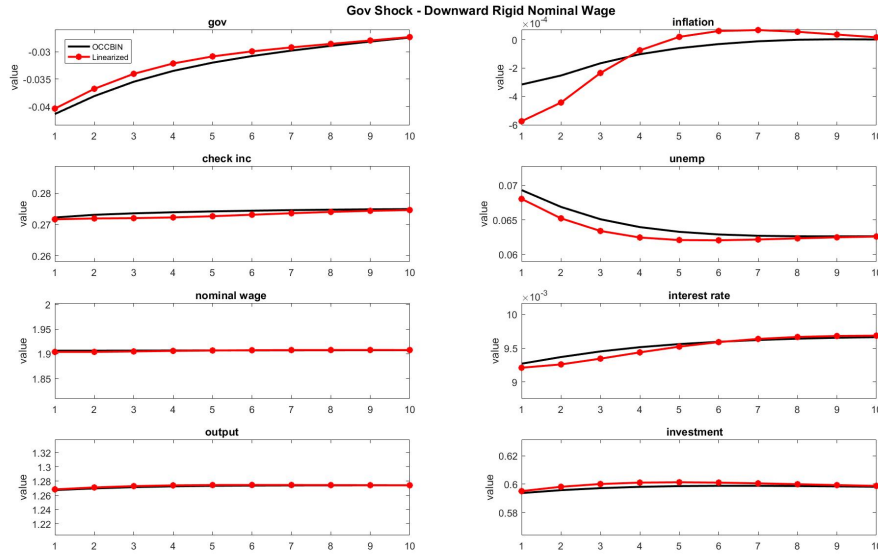[27]Schmitt-Grohé and Uribe (2013) provide a good overview.

Figure 1.7: Downward Rigid Wages

Comparison of IRFs in benchmark model and extended model with downward rigid wages. The red line is identical to the IRFs of the benchmark model shown in figure 1.6. Nominal wages fall for 6 periods, and the economy follows the augmented model. The black line, shows that the impact of the constraint continues even after the constraint does not bind anymore. While the initial impact on inflation is lower in the beginning, higher unemployment leads to more saving and a longer and lower transition path of inflation during the recovery.

To solve the model under two different wage setting regimes, I use the method of endogenously binding constraints, developed by Guerrieri and Iacoviello (2015). An advantage of the piecewise linear solution method is that it can accommodate a large state space. I exploit this feature to solve the medium scale NK model under varying wage equations. The algorithm switches between the two models based on whether the nominal wage is increasing or decreasing. As shown in their paper, the solution of this algorithm approximates closely the solution found using fully nonlinear models.[28]

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[28]One criticism of the piecewise linear solution method is that households do not expect the change between models. This drawback might be problematic in the case of binding

Figure 1.7 shows the response of the extended and benchmark models to the same government demand shock as in the previous section. The red, dotted line is the same as in figure 1.6 for the benchmark model. The black line depicts the response of the augmented model. Following a government demand shock, nominal wages fall for 6 periods and the rigid wage equation takes effect.[29] The slower wage adjustment leads to higher unemployment and saving, but the path of output is virtually identical.[30] While the time series of nominal wages is different, this difference is very small and shown in detail in figure A.10 in the appendix.

The largest difference between the benchmark model and the augmented model is the path of inflation. While the initial drop is not as large as in the benchmark economy, it now takes longer to return to the steady state and at a lower level during the transition.[31]

A second difference between the benchmark economy and the extended model is the path of investment. Even though interest rates are slightly higher, investment is actually lower. Monetary policy is less potent in stimulating investment during the simulated recession, in line with recent evidence of asymmetric effects of monetary policy by Tenreyro and Thwaites (2016).

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borrowing constraints that affect household decisions directly, but is unlikely to change the outcome in this model. Households never reach the borrowing constraint and households do not take the effect of their decision making on wages into account directly. In addition, Guerrieri and Iacoviello (2017) use this method to solve a model with an occasionally binding leverage constraint and show that the piecewise linear solution approximates the global solution well.

[29]See the bottom right graph in figure A.9.

[30]Since government spending is a share of output, the slightly different path of output explain why the response of government spending is not exactly the same in both models.

[31]Interestingly, this result might be a compromise between economists that argue inflation has not been low enough and economists who wonder why inflation is not higher, see Hall (2011).

1.5   Conclusion

Standard New Keynesian models rely almost exclusively on the intertemporal substitution channel which is responsible for 95% of the total effect of monetary policy. The fact that most households do not own financial assets or liabilities that are directly exposed to the policy interest rate and exhibit a counter-cyclical saving behavior indicate that models of precautionary saving and incomplete markets might resolve this issue.

Using data from the Survey of Consumer Finances from 1989 to 2013, I define as measure of precautionary saving the *average monthly checking account balance to income* ratio and find that an estimated medium scale New Keynesian model in which a large fraction of households are not insured against permanent income loss through unemployment matches this ratio well. I further show that in such a model the direct effect of monetary policy is dominated by the state of the labor market for these agents. In a simulation of the Great Recession, the benchmark model both implies a lower inflation rate and longer transition back to the steady state compared to an estimated representative agent version of the model. This result is strengthened when the model is extended with downward rigid nominal wages. The extension of the benchmark model with downward rigid nominal wages also fits the evidence on asymmetric effects of monetary policy found by Tenreyro and Thwaites (2016).

Precautionary saving, therefore, is a promising extension of the canonical NK model. The measure of precautionary saving presented in this paper can be a valuable guide to evaluate how well other extensions can improve the match between the model and data.

For example, one possible explanation of the low quantitative match between the model implied savings ratio and the data the last 10 years is unemployment

duration. In the data, average unemployment duration is quite volatile, but fixed in the benchmark model. The model both implies a lower savings ratio in the mid-90s when unemployment duration was above average and a higher savings ratio in the mid-2000s when unemployment duration was low. In addition, the benchmark model presented in this paper assumes that firms cannot discriminate between high and low productive workers. Unemployment, however, increases much more sharply for less productive workers and it takes longer for these jobs to reappear after a recession.

Furthermore, Carroll, Sommer and Slacalek (2012) find that fluctuations in net worth and access to credit are important determinants of the aggregate savings rate, in addition to labor market risk. Few households in the data hold liquid assets but house ownership and mortgage debt increased greatly before the Great Recession. The house price boom and expanded subprime mortgage sector in the mid 2000s would imply a much lower savings ratio in that period as households bought real estate, while binding borrowing constraints and leverage shocks can explain why this ratio did not increase to the degree that the model suggests.

Another factor is the role of automatic stabilizers and risk faced by households over the business cycle. During the Great Recession, the Obama administration extended unemployment benefits from 26 weeks (depending on the State) to 99 weeks, see Rothstein (2011). A combination of varying unemployment duration and unemployment benefits might well explain why despite an increase in average unemployment duration, savings did not increase as much as the benchmark model would indicate. As Galí, Vallés and López-Salido (2007) show, the presence of non-Ricardian households strongly increases the effect of government spending on consumption.

Lastly, models with precautionary saving can potentially answer the issue raised in King and Watson (2012), namely that traditional NK models have difficulty matching the inflation rate starting in the early 2000s and heavily rely on cost shocks to do so.

According to the Survey of Consumer Finances, saving behavior became very volatile around that time and will therefore have impacted the inflation rate in a way that cannot be captured with a representative agent New Keynesian model.

Household Consumption-Income Ratio and Employment Risk, an Empirical Analysis[1]

Looking at the the personal saving rate in the United States and its relationship with employment growth in particular, as shown in figure 2.1(a), three stylized facts become apparent: first, the aggregate saving rate has been decreasing until the Great Recession. Second, it increased sharply after the Great Recession and has remained at this higher level. Third, even before the Great Recession, the aggregate personal saving rate moves countercyclically with employment growth.

While a large literature has focused on the interaction of credit availability, income uncertainty, the level of saving and aggregate demand, for example Guerrieri and Lorenzoni (2017) and Hall (2011), the interaction between income risk and saving in particular has only recently become of more interest (Ravn and Sterk (2017), Challe and Ragot (2016), Mckay, Nakamura and Steinsson (2016), Krueger, Mitman and Perri (2016)). Stamm (2017) shows that if households are exposed to income uncertainty, the direct effect of monetary policy is less important and interest rate cuts imply lower inflation than in a standard New Keynesian model.
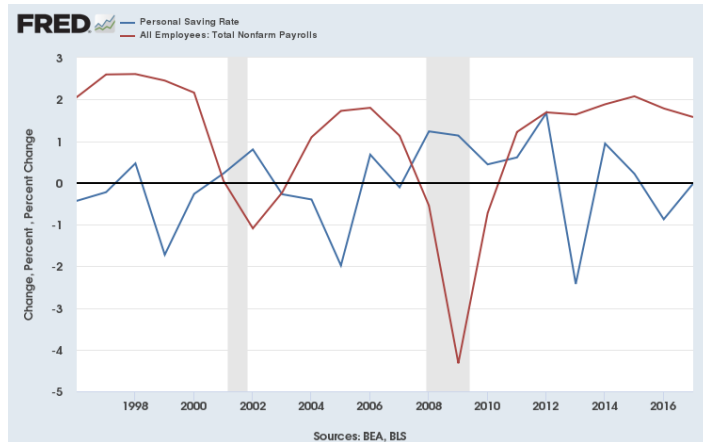
Yet, clear empirical evidence of the response of saving to employment risk does not exist, in contrast to the relationship between credit availability, debt and consumption which has been documented extensively (Mian and Sufi (2011), Mian, Rao and Sufi

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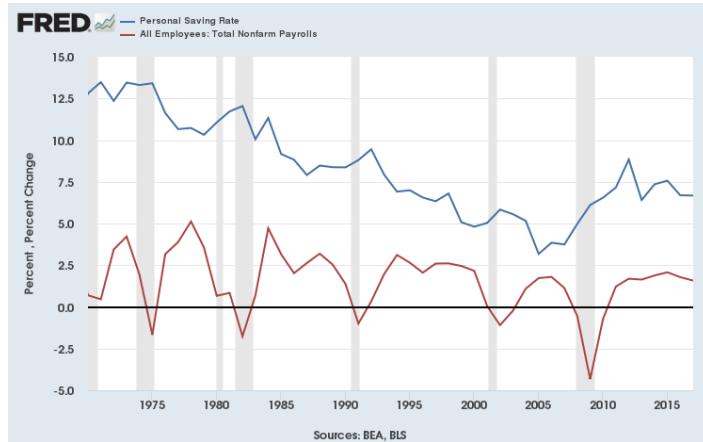
(a) US Personal Saving Rate and Employment Growth

(b) Percent Change of US Personal Saving Rate and Employment Growth

Figure 2.1: US Personal Saving Rate and Employment Growth

(2013)). This lag of evidence is driven by the fact that household saving data with variation in employment or income risk is not freely available[2].

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[2]The BEA publishes an aggregate saving rate for the United States but not for States or other geographic areas. Recent research has focused mainly on evidence from the PSID and the Federal Reserve Bank's Survey of Consumer Finances. Neither survey allows for a sub-national geographic aggregation of data to exploit variation in employment growth or income risk.

The central goal of this paper is to estimate the response of the saving rate to changes in employment explicitly. I examine this channel using data on household consumption and income aggregated into 28 MSAs across the United States from 1996 to 2016 published by the consumer expenditure survey (Consumer Expenditure Survey (2018)). I calculate employment growth for each MSA from IPUMS-CPS, matching the CEX MSA definition county-by-county as closely as possible. While the relationship between employment growth and the personal saving rate as shown in figure 2.1 suggests a negative correlation, both time series may be jointly determined by other channels. To account for this endogeneity problem, I use the Bartik instrument calculated on the 3-digit industry level for each geographic area.

Regressing the consumption-income ratio on employment growth at the MSA level, I find that employment growth is highly significant with a positive coefficent of 0.42. This coefficient implies that a one percentage point drop in employment growth decreases the consumption-income ratio by 0.42 percentage points and thus increases household saving. This coefficient is robust to controlling for MSA level attributes such as average age, percentage of homeowners and size of the MSA. To put this into perspective, the result implies that the saving response to employment growth during the Great Recession accounts for a large fraction of the increase in the saving rate. In addition, the first lag of the consumption-income ratio is weakly significant, indicating that employment growth has a persistent effect on savings.

These results are instructive for the design of models that aim to capture this mechanism. For example, the correlation between employment growth and the consumption-income ratio in the data is a positive 0.0962, whereas Stamm (2017) shows that a standard NK model with added employment growth has a negative correlation -0.0587.

Adding households with an explicit bufferstock saving mechanism introduces a group of agents whose consumption-income ratio is correlated positively with employment growth (0.0617) and whose consumption-income ratio to employment growth coefficient is 0.38. The overall response of aggregate saving to employment growth then depends on the relative shares of each group of agents.

A similar attempt to quantify the response of saving to employment risk is Carroll, Sommer and Slacalek (2012) who regress the aggregate saving rate on credit availability, wealth shocks and unemployment uncertainty and find that unemployment uncertainty accounts for the business cycle variation of the saving rate while the other two components determine the long-run downward trend of the saving rate. This paper, however, uses aggregate data with time-variation in (expected) employment risk.

The second chapter proceeds as follows: Section 2.1 discusses data set. MSA boundary definitions and related issues are explained in section 2.2. The instrument for employment growth, estimation strategy and results are presented in sections 2.3 to 2.5. Section 2.6 concludes.

2.1 Data

The data set used in my analysis is compiled form two sources and contains two-year averaged MSA level observations from 1996/1997 to 2015/2016 for MSAs of different size across the United States. Consumption (denoted expenditure in the CEX) and pretax income as well as control variables are taken from the Consumer Expenditure Survey which publishes two-year averages for a varying number of MSAs every year based on their household survey. I merge these variables with data on employment
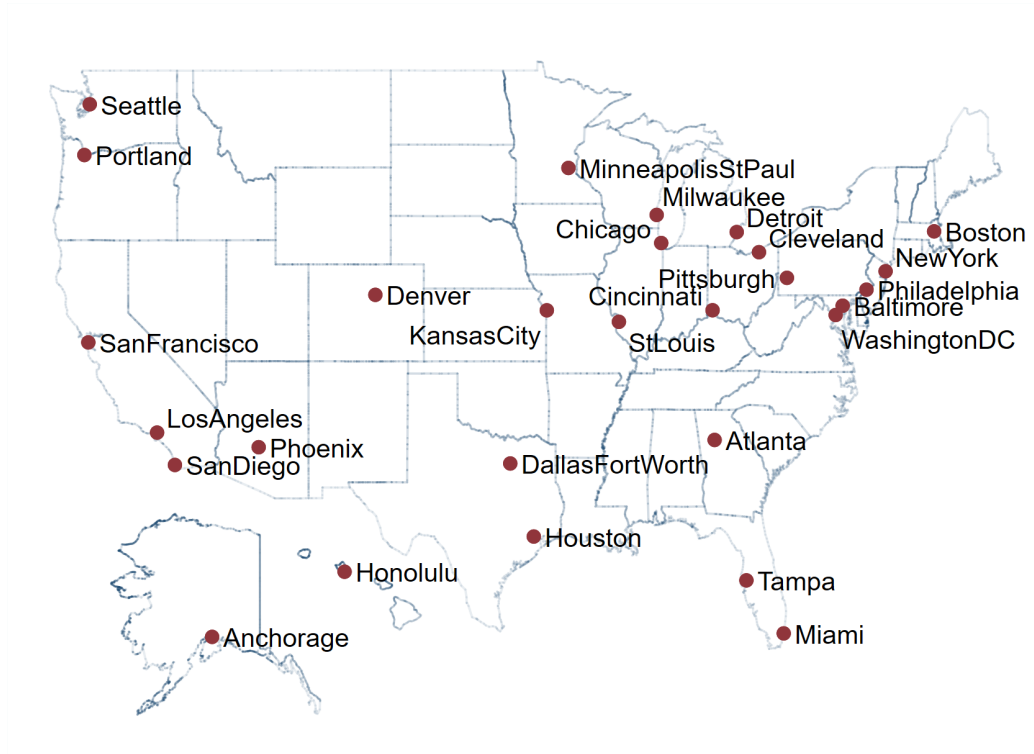
Figure 2.2: Map of MSAs in Sample

by industry within each geographic area from IPUMS-CPS for the years 1996-2016 (Sarah Flood, Miriam King, Renae Rodgers (2018)).

To account for the endogeneity problem, I construct the Bartik instrument for employment growth for each MSA based on the national leave-one-out employment growth rates of the 3-digit industry categories contained in IPUMS-CPS and the initial share of each industry in every MSA 1996/1997. The final data set contains 211 non-overlapping two-year observations across 28 MSAs with at most 10 observations per MSA and, depending on the size of the MSA, the Bartik instrument is calculated from 109 to 205 industries.

Summary statistics for the final sample are presented in table 2.1. These summary statistics are calculated as within-MSA averages over the period that the MSA is in the sample, except for the columns "Inc 96/97" and "# Ind 96/97". The latter two colums show the income in 1996-1997 and the number of 3-digit industries that the Bartik Instrument is based on in each MSA in 1996-1997. The average consumption-income ratio varies between 70% and 80% of pretax income and all but four MSA experienced positive employment growth on average across the sample period. The notable exceptions regarding employment growth are Pittsburgh, Detroit, Milwaukee and Cleveland.

Population size varies greatly. New York and Los Angeles are the largest MSA with average populations of 20 million and 15 million, respectively. These two MSA actually account for almost 30% of the entire population in the sample and I control for population size accordingly. The smallest two MSA are Anchorage with under 300,000 residents and Honolulu with about 850,000 residents. These differences in population size are also reflected in the CEX sample size. While New York and Los Angeles have an average sample size of several thousand consumer units, the average CEX sample size for Anchorage and Honolulu are only 94 and 279 consumer units, respectively. The regressions are robust to controlling for sample size instead of population.

The average age of the population as measured by the CEX is fairly evenly distributed across MSA. The percentage of homeowners, however, is not. In some MSA, notably the smaller ones like Tampa and Philadelphia, almost 70% of consumer units are homeowners whereas only around 50% of consumer units are homeowners in large MSA such as New York and Los Angeles. Both age and homeownership correlate with retirement status which somewhat shields the household from economic uncertainty. Furthermore, as Mian and Sufi (2011) have shown, homeownership is also highly correlated with household debt and thus changes in the consumption-income ratio might

Table 2.1: Summary Statistics for MSA in Final Sample

MSA	Exp-Inc Ratio	% ΔEmp	Inc 96/97	Age	% Homeowner	Population	CEX Sample	# Ind 96/97
Anchorage	0.881	0.01	58,133	42.7	60.00	272,551	94	109
Atlanta	0.711	0.03	46,693	46.0	67.60	4,798,055	1,998	152
Baltimore	0.696	0.01	44,622	50.5	69.10	2,564,934	1,005	123
Boston	0.744	0.02	51,616	48.6	62.56	5,223,356	2,703	175
Chicago	0.784	0.01	43,208	49.1	67.70	8,649,655	3,329	190
Cincinnati	0.806	0.01	44,279	47.3	61.50	1,909,474	880	147
Cleveland	0.777	-0.02	41,564	51.6	70.78	2,877,751	1,163	161
DallasFortWorth	0.822	0.04	44,530	45.5	61.60	6,125,626	2,246	171
Denver	0.816	0.05	52,591	44.4	65.25	2,781,473	1,136	158
Detroit	0.789	-0.02	41,732	49.4	72.89	4,943,191	2,086	179
Honolulu	0.793	0.03	49,255	52.0	56.20	855,897	279	127
Houston	0.809	0.04	42,529	45.7	62.30	5,048,332	1,849	159
KansasCity	0.767	0.04	41,272	47.3	68.25	1,952,043	782	134
LosAngeles	0.824	0.02	47,595	47.7	53.10	15,633,777	5,442	202
Miami	0.806	0.02	37,537	49.8	61.56	3,833,761	1,622	161
Milwaukee	0.833	-0.02	46,795	49.4	61.25	1,973,185	713	136
MinneapolisStPaul	0.800	0.02	49,452	47.4	70.50	3,430,563	1,383	150
NewYork	0.768	0.01	45,877	49.8	55.56	20,869,195	8,139	205
Philadelphia	0.758	0.01	45,470	50.0	70.44	5,828,021	2,388	188
Phoenix	0.843	0.04	46,832	46.3	62.80	3,498,544	1,410	159
Pittsburgh	0.849	-0.01	39,139	52.4	71.20	2,257,915	1,054	155
Portland	0.881	0.04	43,885	47.5	62.60	2,409,726	1,048	153
SanDiego	0.817	0.02	43,229	48.5	54.60	2,679,751	1,014	128
SanFrancisco	0.806	0.02	52,562	47.0	59.50	6,650,885	2,774	160
Seattle	0.840	0.02	45,276	47.6	63.89	3,773,952	1,686	142
StLouis	0.803	0.03	44,715	49.4	71.80	2,568,550	1,018	137
Tampa	0.806	0.04	35,972	50.3	72.00	2,255,186	1,044	146
WashingtonDC	0.700	0.04	58,210	47.3	67.90	5,663,864	2,075	140

This table presents summary statistics for the 28 MSA and 191 observations included in the final sample. The columns show within-MSA averages for the non-overlapping two-year periods except for the columns "Inc 96/97" and "# Ind 96/97". The latter two colums show the income and the number of 3-digit industries that the Bartik Instrument is based on in each MSA in 1996-1997.
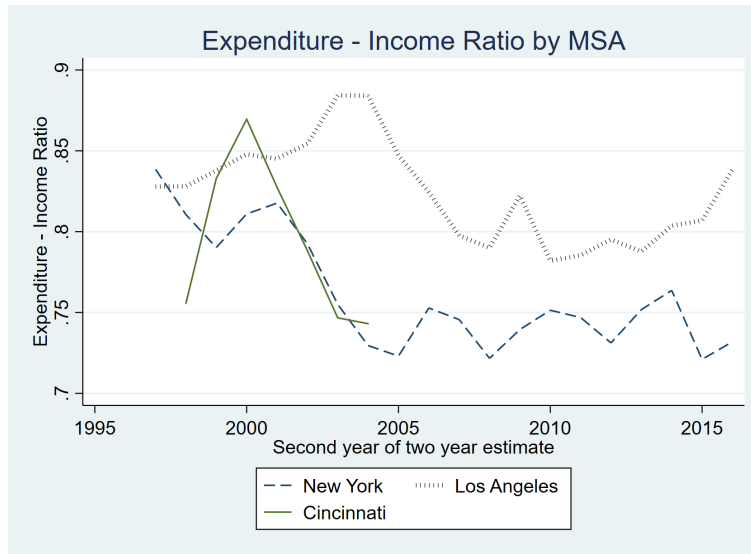
Figure 2.3: Example of Consumption-Income Ratio for Three MSA

not only reflect the savings channel of employment growth, despite the instrument. Age and homeownership are therefore two of my control variables.

2.1.1 CEX Data

The Consumer Expenditure Survey (CEX) is a representative survey of consumption and income of "consumer units" in the United States. Consumer units are defined as either a family household, a group of two or more persons who live together and jointly make significant expenditure decisions, or individuals who might live in a shared living arrangement but are financially independent. From the CEX, I take consumption and income data, as well as the consumer-unit level control variables and the CEX sample size. My dependent variable, the consumption-income ratio, is calculated as the ratio of CEX reported consumption and income for each MSA. Figure 2.3 shows the consumption-income ratio for three MSA as an example.

Apart from annual national aggregated statistics, the CEX publishes two-year averaged data for several metro areas in the United States from the 1970s to 2015/2016. These metro areas cover all regions of the continental United States as well as Anchorage and Honolulu and are mapped in figure 2.2. For the period 1995/1996, however, the CEX did not publish any data, and this gap together with the unavailability of CEX MSA definitions prior to 1996 determine the start date of my sample to be 1996/1997. The CEX publishes two-year averages every year and thus their estimates overlap by one year. Since overlapping averages yield biased hypothesis tests, I only use non-overlapping two-year data (Hansen and Hodrick (1980)).

MSA coverage varies over time and publication of consumption data for some MSA was discontinued after 2004/2005[3]. Figure 2.4 show the number of non-overlapping two-year observations for each MSA in the CEX sample, and figure B.1(b) in the appendix the latest year (of the two-year average) for which an MSA estimate was published by the CEX.

2.1.2 IPUMS-CPS

I use the IPUMS-CPS samples from 1996-2016 to construct population size, population growth, the employment time series as well as the Bartik Instrument for each MSA. To match the two-year frequency of the CEX, I pool data from IPUMS-CPS in two-year brackets matching the CEX periods. Aggregation to MSAs is based on the variables *metarea* and *county*. IPUMS-CPS identifies employment of each individual by 234 industries[4] in *ind1990*. Given the varying size of MSAs, not all industries are

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[3]For several of the MSAs that were discontinued after 2004/2005 the CEX started to publish data again more recently. This gap in availability, however, is too large for a reasonable estimation analysis and I do not use data for MSAs after any gap.

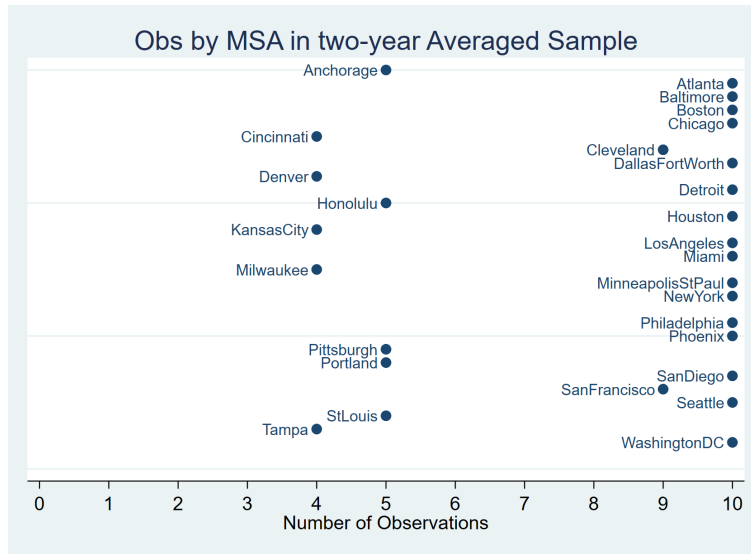[4]Excluding the military categories and the category *other*.

Figure 2.4: Metro Areas in Consumer Expenditure Survey

represented in each MSA. At the low end, workers are employed in 109 industries in Anchorage and at the upper end in 205 industries in New York. Employment growth is based on the variable *empstat* on the individual level, and population size is the sum of individual weights, *asecwt*. I verify my calculations using Census population and employment estimates.

2.2 Adjustment of MSA Definitions

There are two sources of uncertainty regarding statistics computed on the MSA level. First, the definition of several MSAs changed following the two censuses in 2000 and 2010. These definition adjustments were implemented starting in 2005/2006 and 2015/2016. The county composition of each MSA over the period of 1996/1997 until 2015/2016 was provided to me on request from the CEX and are listed in the appendix together with a crosswalk to IPUMS-CPS data.

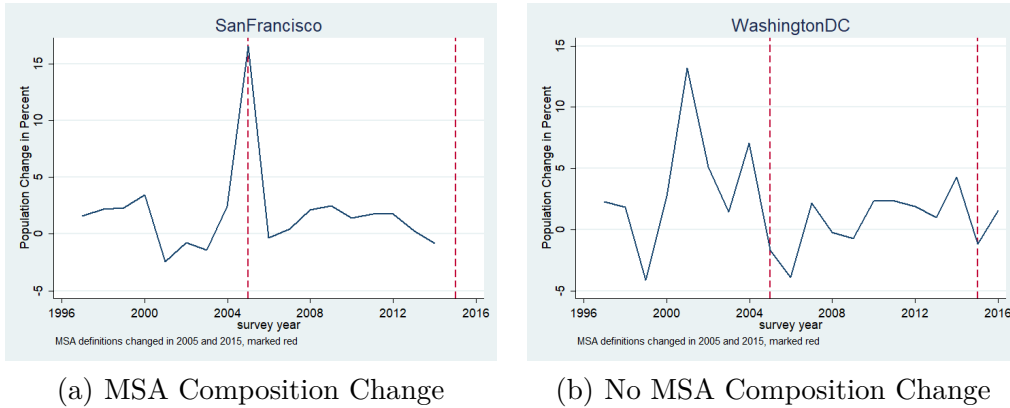(a) MSA Composition Change   (b) No MSA Composition Change

Figure 2.5: Example of an MSA Definition Change Shown as Population Growth

A second source of uncertainty comes from the county coverage of data in IPUMS-CPS which I use to calculate the employment statistics and the Bartik instrument. Not all counties are identified in IPUMS-CPS and for some MSA, sub-components of metro areas were only added to the metro area identifier after 2004.

To evaluate whether the change in the geographic boundary of MSAs in the CEX or identification of metro area components in IPUMS after each Census is too drastic to assume that the consumption and income data or employment statistics represent a time series for the same MSA, I calculate the population growth rate for each MSA from IPUMS-CPS data matching the CEX definition county by county as closely as possible[5] A larger than usual population growth in 2005 or 2015 indicates a meaningful adjustment of the MSA geographic boundary or identification in IPUMS-CPS[6].

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[5]For some MSAs, IPUMS does not identify each county individually, but only aggregated MSA components. I verify the aggregation of observations in IPUMS-CPS to CEX MSAs by comparing total population to population numbers from the CEX if available, or CENSUS population numbers.

[6]In a few limited cases the change of geographic boundary is just the addition or subtraction of one or two minor counties which have virtually no impact on population size.

Figures 2.5(a) and 2.5(b) are two examples of MSA with and without a change in their composition. The years 2005 and 2015 are indicated by the red, vertical line. Over the period of 1996-2016, the Washington, DC MSA ("Washington-Arlington-Alexandria, DC-VA-MD-WV") has a consistent definition and is fully identified in IPUMS-CPS. On the other hand, despite a consistent definition, identification for sub-components of San Francisco ("San Francisco-Oakland-Hayward, CA") changed in 2005.

I define a "significant change" in MSA composition as a population growth rate in 2005 and 2015 that is a clear outlier compared to other years for the same MSA. Based on this criterion, I exclude the following MSA from the sample: after 2004 Anchorage and San Francisco, and after 2014 Boston, Detroit, Miami, New York, Philadelphia and Seattle[7].

Therefore, the final sample includes 211 non-overlapping two-year observations, covering 28 MSAs all of which start in 1996/1997 but with a varying number of observations per MSA.

2.3 BARTIK INSTRUMENT

To instrument for employment growth I construct the Bartik instrument which is widely used in many contexts in the literature and was originally introduced by Bartik (1991) and Blanchard and Katz (1992) in the context of employment growth[8]. It is based on the theory that in the short-term employment growth is driven by firm labor demand and not individual labor supply decisions. The instrument uses industry-level national growth rates as a measure of industry-level firm labor demand and interacts these growth rates with the share of each industry in a geographic area. Across the literature, papers construct the Bartik instrument in slightly different ways and I

---

[7]The regressions are robust to not excluding any MSA observations.

[8]For more recent examples see Bartik (2015) and Furceri, Dao and Loungani (2014).

follow Goldsmith-Pinkham, Paul and Sorkin, Isaac and Swift (2018), a very recent paper that closely investigates the assumptions and properties of Bartik instruments.

Therefore, my Bartik instrument is constructed on MSA level as the sum of the leave-one-out national growth rate of each industry between adjacent non-overlapping two-year time periods multiplied with the initial share of employment in that industry in a given area according to the following formula

$$bartik_{i,t} = \sum_k \alpha_{0,i,k} g_{t,-i,k}, \tag{2.1}$$

where α is the share of industry k in area i in the first year of observation, and g is the national growth rate at time t in industry k excluding area i. The national growth rate of an industry excluding area i is the difference of log employment between t and *t-1*.

Industry shares are fixed in the initial year and the leave-one-out national growth rate factor for an MSA is the national growth rate in an industry excluding employees of that MSA. These adjustments are necessary to prevent that an MSA significantly determines the employment growth rate in an industry and thus its own Bartik instrument, especially relevant given the size of several MSA in my sample. For example, the New York metro area has a population of almost 20 million.[9]

Not every industry out of a total of 234 three-digit industry categories in IPUMS-CPS data are represented in each MSA and the number of industries used to calculate the MSA-level Bartik Instrument is shown in the last column of table 2.1.

---

[9]One concern with the Bartik instrument is that the industry mix in a geographic area at any point in time does not reflect the steady state distribution of industries and some papers average the industry share over several periods. Given that I am using two-year averaged data, the industry shares of each industry by MSA reflect a medium run average.

2.4 ESTIMATION STRATEGY

To test the hypothesis that saving is negatively related to employment growth, I regress the consumption-income ratio on current and lagged employment growth, the lagged consumption-income ratio and MSA size and household controls. The Bartik instrument corrects for potential endogeneity of the OLS regression and thus, in the first stage, I regress current employment growth on the Bartik instrument. The following two equations show the second and first stage of the regression:

$$CI_{i,t} = \alpha + \beta(L)CI_i + \gamma(L)\Delta e_i + \zeta X_{i,t} + \chi_i + \epsilon_{t,i}$$

$$\Delta e_{i,t} = \tilde{\alpha} + \tilde{\pi}bartik_{i,t} + \tilde{\beta}(L)CI_i + \tilde{\gamma}(L)\Delta e_i + \tilde{\zeta}X_{i,t} + \tilde{\chi}_i + u_{i,t}$$

where L refers to current and past lags in the case of employment growth, and past lags only in the case of the consumption-income ratio. $\Delta e_{t,i}$ is the change of the log of employment in area i at time t and $CI_{i,t}$ is the consumption-income ratio in area i at time t. $X_{i,t}$ refers to MSA controls and χ_i is the MSA fixed effect[10]. Standard errors are clustered at the MSA level.

The literature generally uses employment growth instead of the (log) employment level because the hypothesis that employment has a unit root cannot be rejected, see for example Blanchard and Katz (1992). While I use employment growth instead of the employment level because the goal of this paper is to estimate the relationship between employment growth as a proxy for employment risk, I test whether the consumption-income ratio has a unit root. This hypothesis is clearly rejected with a p-value of less than 0.00001[11].

---

[10]I do not include time fixed effects because the Bartik instrument already controls for the time trend of employment as it is a reweighted national employment growth rate. In addition, the size of the data set limits the time variation across MSA.

[11]As a robustness check, I also test whether the employment level has a unit root and this hypothesis cannot be rejected with a p-value of over 0.8.

2.5 RESULTS

The results of the final regression specification with the consumption-income ratio as independent variable and employment growth as the dependent variable are presented in table 2.2. Columns 1 and 2 show the OLS estimates and columns 3 to 6 the 2SLS results, with the first stage estimates in columns 3 and 4 and the second stage outcomes in columns 5 and 6. Even numbered columns include the controls for employed population size, average age of the reference person and the average percentage of homeowners. P-values are in parenthesis and stars indicate significance at the 10% (*), 5% (**) and 1% (***) level. The final regressions include 155 observations after accounting for lagged variables across 28 MSAs. All regressions include MSA fixed effects and standard errors are clustered at the MSA level.

In the OLS regressions, only the coefficients of the lagged consumption-income ratio are significant. This picture changes markedly in the 2SLS regressions and underscores the necessity of correcting for endogeneity, as shown in the columns 5 and 6. The Bartik instrument is highly significant in all cases with an F-statistic of 35.81 and 26.01, respectively, and the coefficient of 0.72 is in line with the literature[12].

The coefficient of employment growth is highly statistically significant with and without controls in the 2SLS regressions. Column 5 in table 2.2 presents the instrumental variable estimate without any control variables apart from lagged employment growth and lagged consumption-income ratio. The estimated coefficient of employment growth is 0.34 with a highly significant p-value of 0.005. When controlling for MSA characteristics, the estimated coefficient increases slightly to 0.42 with a p-value of 0.004.

---

[12]See for example Goldsmith-Pinkham, Paul and Sorkin, Isaac and Swift (2018) and Furceri, Dao and Loungani (2014).

Table 2.2: Main Estimation Results

	OLS		2SLS First Stage		2SLS Second Stage	
	CI	CI	ΔEmp	ΔEmp	CI	CI
	(1)	(2)	(3)	(4)	(5)	(6)
ΔEMP_t	0.0280	0.0298			0.336***	0.418***
p-value	(0.724)	(0.726)			(0.005)	(0.004)
ΔEMP_{t-1}	0.0165	0.0226	-0.255***	-0.298***	0.0756	0.121
p-value	(0.851)	(0.821)	(0.004)	(0.000)	(0.456)	(0.325)
CI_{t-1}	0.191***	0.189**	-0.0157	0.0345	0.174**	0.139*
p-value	(0.007)	(0.016)	(0.887)	(0.765)	(0.035)	(0.099)
$Bartik_t$			0.721***	0.725***		
p-value			(0.000)	(0.000)		
Emp Population		-3.95e-09		3.85e-08***		-2.55e-08
p-value		(0.775)		(0.002)		(0.122)
Pct Homeowner		0.00103		0.00368***		0.000393
p-value		(0.588)		(0.009)		(0.812)
Age		0.00106		0.000117		0.00180
p-value		(0.813)		(0.978)		(0.708)
Bartik F-Stat			36.43	26.49		
MSA	28	28	28	28	28	28
N	155	155	155	155	155	155

The regressions are at the MSA level and the time periods are 1996/1997 to 2015/2016 non-overlapping two-year periods. The Bartik instrument is constructed at the 3-digit industry level where for each MSA the 1996/1997 share of an industry is multiplied with the national growth rates between time periods. All regressions include MSA fixed effects and standard errors are clustered at the MSA level. P-values are in parenthesis and stars indicate significance at the 10% (*), 5% (**) and 1% (***) level.

Thus, these estimates suggest that an increase of one percentage point in employment growth increases the consumption-income ratio by 0.34 or 0.42 percentage

points, respectively. Conversely, the saving rate decreases in response to employment growth. Comparing this result to observed changes in the consumption-income ratio during the Great Recession shows that employment growth is an important determinant of saving. From 2006 to 2010 employment growth dropped to -4.5%[13] in the United States. These estimates imply that the consumption-income ratio decreased by about 1.6 percentage points in response to this negative growth rate. To put this response in perspective, Krueger, Mitman and Perri (2016) find that in PSID data across all households, the consumption to disposable income ratio dropped by a total of 3.8 percentage points between 2006 and 2010[14]. Therefore, employment growth is an important determinant of saving.

Lagged employment growth is not significant in the second stage, underscoring that the change in the consumption-income ratio is driven by current employment risk. The coefficients of the lagged consumption-income ratio are both positive, if only weakly significant with a p-value of 0.027 without controls and 0.079 with controls in the second stage, as shown in row three of table 2.2. In the model with MSA controls, for example, the coefficient of 0.14 indicates that about 50% of the effect of an employment growth shock on saving still persists after two years[15].

To control for potentially confounding factors I also add the percentage of homeowners, the population size and the average age of the reference person in each MSA[16].

---

[13]Nonfarm employment was 136 million in 2006 and 130 million in 2010.

[14]Similarly, Carroll, Sommer and Slacalek (2012) estimate that the response of the saving rate to the expected one-year ahead unemployment rate is about 0.35 and that unemployment risk accounts for about 50% of the change in the saving rate from 2007 to 2009 in aggregate data.

[15]Whether the response of the household saving to employment growth was stronger during and after the Great Recession, a time when the saving rate increased sharply from historical lows is an interesting expansion of the current regressions but data availability is too limited to test this hypothesis with my data set in a meaningful way. In the appendix I show that there is weak evidence that the response was no different in the subsample up to 2007.

[16]Substituting population size with the CEX sample size does not make a difference.

Mian and Sufi (2011) and Mian, Rao and Sufi (2013) show that debt growth is associated with current and new homeowners in MSAs and that areas with higher housing debt leverage experienced stronger consumption declines during the Great Recession. In addition, one concern is that higher income households have the ability to leave MSAs with relatively low employment growth and move to areas with better economic conditions or industry compositions, leaving behind lower income households and a smaller population[17]. Households in the lower income quintiles fare considerably worse during recessions and Krueger, Mitman and Perri (2016) show that their consumption-income ratio drops more than for higher income households. Similarly, retired households are less likely to leave their MSA or respond to employment risk. All three control variables, however, are highly insignificant in the second stage.

2.6   Conclusion

While the downward trend of the savings rate in the United States since the 1970s has been of intense focus in the literature, especially the period before the Great Recession, the fact that the savings rate is also negatively correlated with employment growth has only recently received wider attention. For example, in Stamm (2017), I show that this mechanism helps to break the reliance of monetary policy transmission on intertemporal substitution alone and can explain why the inflation rate has remained lower than expected in traditional New Keynesian models.

Due to limited sub-national data availability, however, the empirical literature has generally either been restricted to comparing summary statistics and the distribution of household balance sheets between time periods or the estimation of structural

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[17]In addition, the size of the employed population as some MSA are significantly larger than in others. For example, New York and Los Angeles account for about 30% of the employed population in the sample.

models. To close this gap, this paper provides direct empirical test of the relationship between the saving rate and employment growth.

Using MSA level data on 28 MSAs from across the United States over the time period of 1996 to 2016 on consumption and income from the Consumer Expenditure Survey and employment statistics from IPUMS-CPS, I employ an instrumental variable strategy to investigate whether saving responds to employment growth, by exploiting across MSA variation in the consumption-income ratio and employment growth.

I find strong evidence that saving responds to employment growth, with an increase of the consumption-income ratio of 0.42 percentage points per one percentage point increase in employment growth. This result is robust to controlling for factors that have been shown in the past as determinants of saving, such as home-ownership, age and population size. The estimated coefficient implies that during the Great Recession, employment growth actually accounted for a large fraction of the increase in the saving rate. Furthermore, the lagged consumption-income ratio is weakly significant with a coefficient of 0.14, suggesting that saving is persistent after an employment growth shock. These results are in line with the model-implied household response, developed in Stamm (2017), and give further evidence for this important mechanism.

Precautionary Saving and the Transmission of Monetary Policy

A.1 Household Data

A.1.1 Total Liquid Investments by Income Quintile

The following graphs shows the ratio of total liquid investment, average checking account balance in the month prior to the survey date, as well as the amount invested into stocks, bonds and money market mutual funds for the same income groups as in the data analysis section. As figure A.1 shows, the few households that own financial investments dominate after aggregation and hide the business cycle variation in saving of all other households.

The results presented in section 1.1 are robust to the exclusion of households that hold financial assets. The pattern of saving changes a bit, but not fundamentally, as shown in figure A.2. The main difference is a stronger increase of saving for middle income households in the mid 90s, a period of high unemployment duration.
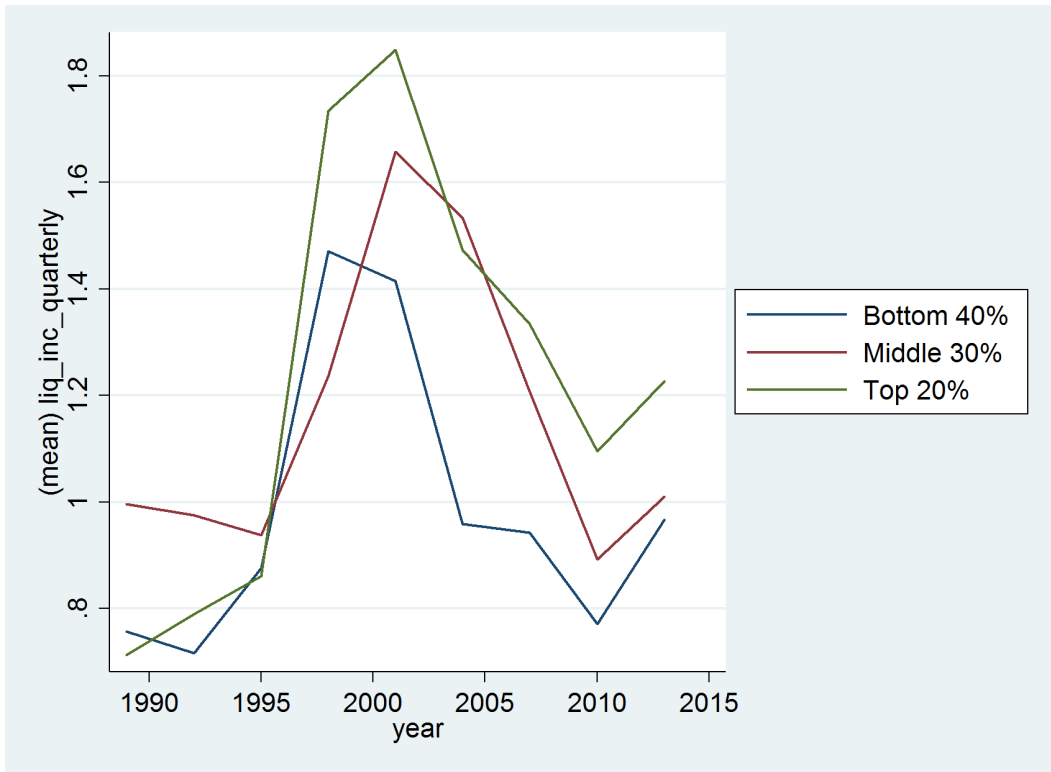
Figure A.1: Liquid Investment to Quarterly Income

Ratio of liquid investment to quarterly income. While few households hold any such investments, their amount dwarfs the savings of all other households after aggregation into income groups, and hides the business cycle variation of savings of households that do not own any financial assets.
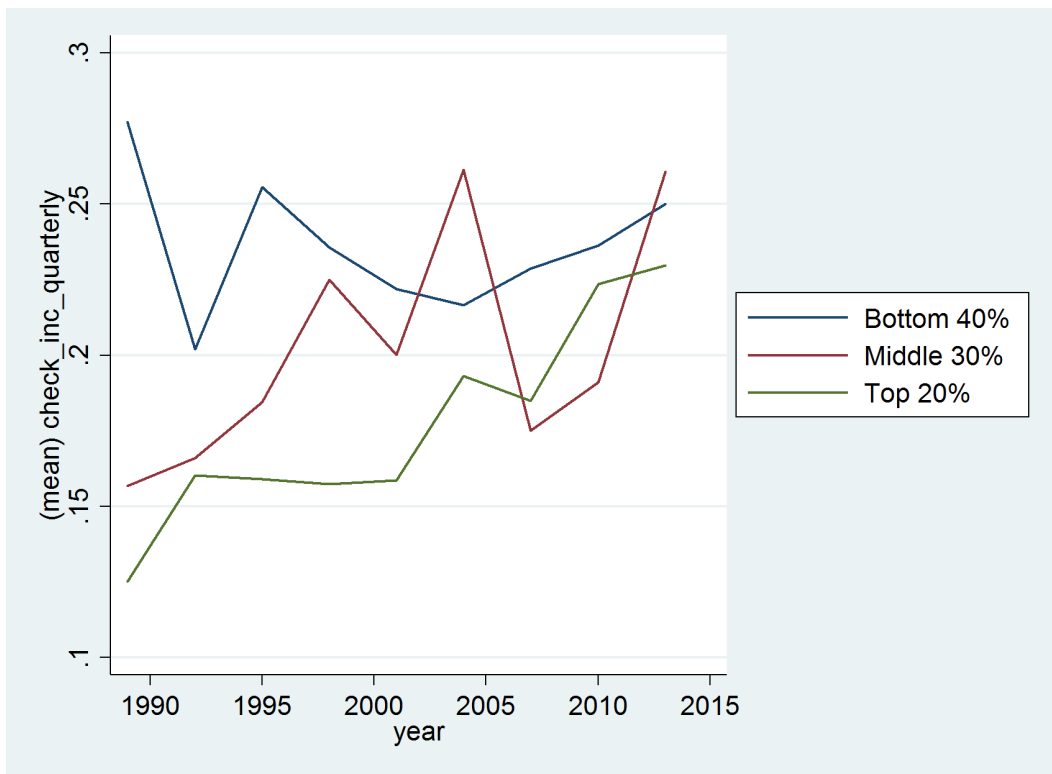
Figure A.2: Checking Account Balance to Income Ratio Excluding Households with Financial Assets

Average monthly checking account balance to quarterly income ratio excluding households with financial assets.

A.1.2 Interest Rates on Illiquid Debt

The following graphs show the distribution of interest rates on credit card debt, car loans and mortgages paid by households in the SCF for from 2007 to 2013. For most of 2007, the Federal Funds target rate was 5.25% and it was lowered to 0-0.25% in December 2008.

The rates shown here were calculated based on SCF data. For each household up to three mortgages, four credit cards and four car loans are given, with the interest rate on each. I use the total amount outstanding and the current annual rate at the time of the interview to generate a weighted interest payment for all loans of the same type per household. To give a simple example: two loans ($100,$20) with i-rate (10%,5%) and thus annual payments ($10,$1). Then, total debt = $120, total payment = $11, weighted i-rate = $11 / $120 * 100% = 9.17%.

What these graphs show is that despite the ZLB, rates paid by households only decreased slowly. While investments that are directly exposed to the FFR might be adjusted in response to rate changes, this these liabilities which constitutes a large part of a household's financial portfolio do not exhibit a strong reaction to the FFR. Household consumption therefore can be assumed to respond less to FFR changes, in line with Vissing-Jørgensen (2002).
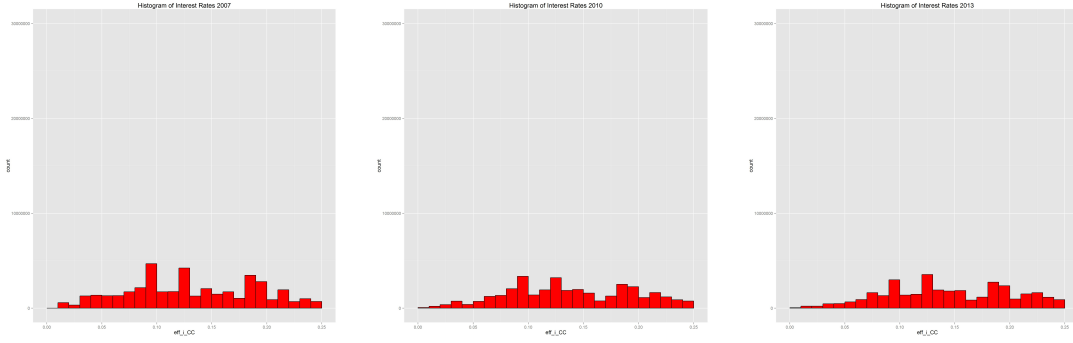
(a) Interest Rate on Credit Card Debt 2007

(b) Interest Rate on Credit Card Debt 2010

(c) Interest Rate on Credit Card Debt 2013

Figure A.3: Distribution of Interest Rates on Credit Card Debt
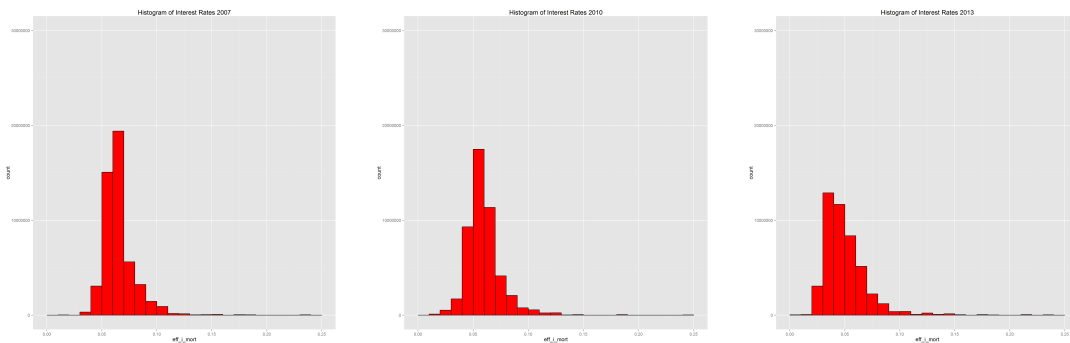
Distribution of interest rates on credit card debt 2007 - 2013 in SCF data
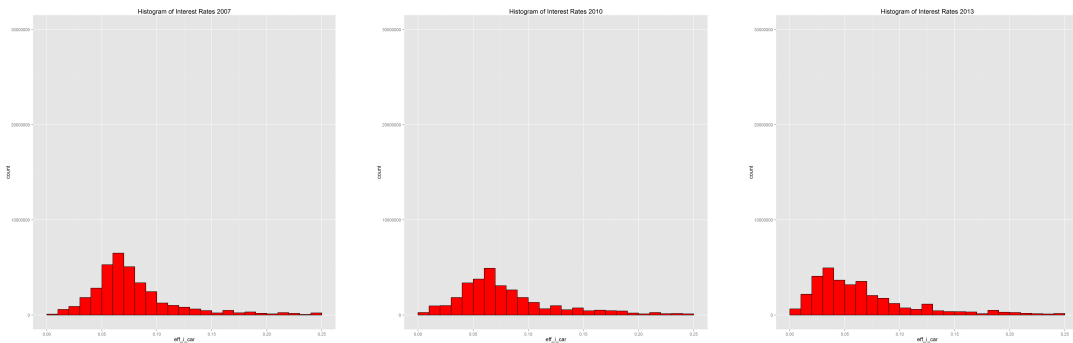
(a) Interest Rate on Car Loans 2007

(b) Interest Rate on Car Loans 2010

(c) Interest Rate on Car Loans 2013

Figure A.4: Distribution of Interest Rates on Car Loans

Distribution of interest Rates on car loans 2007 - 2013 in SCF data

(a) Interest Rate on Mort-
gage Debt 2007

(b) Interest Rate on Mort-
gage Debt 2010

(c) Interest Rate on Mort-
gage Debt 2013

Figure A.5: Distribution of Interest Rates on Mortgage Debt

Distribution of interest rates on mortgage debt 2007 - 2013 in SCF data

A.2 Model Description

A.2.1 The Benchmark Model

Final Good Firms

The final goods firm aggregates the intermediate products into one final good. Each intermediate good is sold at price $P_t(j)$ and the final good has price P_t.

$$y_t = \left(\int y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}$$

Cost minimization gives the demand function for intermediate good $y_t(j)$:

$$\min_{y_t(j)} \left(\int P_t(j) y_t(j) dj \right) - P_t \left(y_t - \left(\int y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} \right) \tag{A.1}$$

$$\frac{\partial}{\partial y_t(j)} = P_t(j) - P_t \left(y_t(j)^{\frac{\epsilon-1}{\epsilon}-1} \left(\int y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}-1} \right) = 0 \tag{A.2}$$

Plugging back in the expression for y_t gives:

$$P_t(j) = P_t y_t(j)^{-\frac{1}{\epsilon}} y_t^{\frac{1}{\epsilon}} \tag{A.3}$$

Solving for $y_t(j)$ yields the demand function:

$$y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon} y_t \tag{A.4}$$

To find an expression for the price level P_t, substitute the demand function (A.4) back into the resource constraint:

$$
\begin{aligned}
y_t &= \left(\int \left(\left(\frac{P_t(j)}{P_t} \right)^{-\epsilon} y_t \right)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} \\
&= \left(\left(\int \left(P_t(j)^{-\epsilon} \right)^{\frac{\epsilon-1}{\epsilon}} dj \right) P_t^{\epsilon-1} y_t^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}
\end{aligned} \tag{A.5}
$$

and solve for P_t

$$
\begin{aligned}
y_t &= \left(\int \left(P_t(j)^{-\epsilon} \right)^{\frac{\epsilon-1}{\epsilon}} dj \right) P_t^{\epsilon} y_t \\
0 &= \left(\int \left(P_t(j)^{-\epsilon} \right)^{\frac{\epsilon-1}{\epsilon}} dj \right) P_t^{\epsilon} \\
P_t &= \left(\int P_t(j)^{1-\epsilon} dj \right)^{-\frac{1}{\epsilon-1}}
\end{aligned}
$$

which yields

$$
P_t = \left(\int P_t(j)^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}} \tag{A.6}
$$

INTERMEDIATE GOOD FIRMS

A continuum of identical intermediate good firms use utilized capital $\hat{K}_t(j)$ and effective labor $\hat{N}_t(j)$ (both defined further below) as well as technology A_t to produce output $y_t(j)$. They minimize cost and maximize profit by choosing the optimal inputs and price $P_t(j)$ given the demand function (1.1) and factor prices . Price setting follows Calvo (1983). Firms can reset their prices with probability $1 - \phi$ every period. Those who cannot optimize price $P_t(j)$ index their prices to the inflation rate. The production function is:

$$
y_t(j) = A_t \hat{K}_t(j)^{\alpha} \hat{N}_t(j)^{1-\alpha}
$$

where α is the share of capital in production.

Cost minimization given factor prices and subject to the demand function of the final goods producer leads to the following first order conditions:

$$
\begin{aligned}
&\min_{\hat{N}_t(j),\hat{K}_t(j)} \quad P_t w_t \hat{N}_t(j) + P_t R_t \hat{K}_t(j) \\
&\text{s.t.} \quad A_t \hat{K}_t(j)^{\alpha} \hat{N}_t(j)^{1-\alpha} \geq \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon} y_t
\end{aligned} \tag{A.7}
$$

Forming the Lagrangian and maximizing the negative of the cost function:

$$\max_{\hat{N}_t(j),\hat{K}_t(j)} \mathcal{L}_t(j) =$$

$$- P_t w_t \hat{N}_t(j) - P_t R_t \hat{K}_t(j) + P_t mc_t(j)\left(A_t \hat{K}_t(j)^\alpha \hat{N}_t(j)^{1-\alpha} - \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} y_t\right)$$

where $P_t mc_t(j)$ is the Lagrangian multiplier, i.e. the marginal cost of producing one extra unit of output. w_t and R_t are the real factor cost for each input good.

The FOCs are, in real terms (dividing by P_t):

$$\begin{aligned}
\frac{\partial}{\partial \hat{N}_t(j)} &= -w_t + mc_t(j)(1-\alpha)y_t \hat{N}_t^{-1}(j) = 0 \\
\frac{\partial}{\partial \hat{K}_t(j)} &= -R_t + mc_t(j)\alpha y_t \hat{K}_t^{-1}(j) = 0
\end{aligned} \tag{A.8}$$

The real marginal cost is thus the ratio of the real wage to the marginal product of labor. Under competitive markets, this cost is equal to 1.

Total cost of production:

$$\hat{N}_t(j)w_t + \hat{K}_t(j)R_t = mc_t y_t(j)$$

Profit for each intermediary thus given by

$$\Pi_t(j) = \frac{P_t(j)y_t(j)}{P_t} - mc_t(j)y_t(j) \tag{A.9}$$

Under Calvo pricing, firms can reset their price $P_t(j)$ with probability $(1-\phi)$ every period. With probability ϕ, prices can only be adjusted by an inflation index. This indexation to lagged inflation (π_{t-1}) is governed by parameter $\xi_p \in [0,1]$. Intermediate firms are owned by traders and future profit is discounted by their SDF $\beta^s \frac{\lambda_{t+s}}{\lambda_t}$, defined in the household problem below. Intermediate firms maximize expected future profit given the demand function:

$$\max_{P_t(j)} \; \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \frac{\lambda_{t+s}}{\lambda_t} \left(\frac{\pi_{t-1,t+s-1}^{\xi_p} P_t(j)}{P_{t+s}} y_{t+s}(j) - mc_{t+s}(j) y_{t+s}(j) \right)$$

$$\text{s.t.} \quad y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon} y_t \tag{A.10}$$

Substituting for $y_{t+s}(j)$, the problem becomes (and splitting it into two terms to make it easier to read):

$$\max_{P_t(j)} \; \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \frac{\lambda_{t+s}}{\lambda_t} \left(\frac{\pi_{t-1,t+s-1}^{\xi_p} P_t(j)}{P_{t+s}} \left(\frac{\pi_{t-1,t+s-1}^{\xi_p} P_t(j)}{P_{t+s}} \right)^{-\epsilon} y_{t+s} \right)$$

$$- \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \frac{\lambda_{t+s}}{\lambda_t} \left(mc_{t+s}(j) \left(\frac{\pi_{t-1,t+s-1}^{\xi_p} P_t(j)}{P_{t+s}} \right)^{-\epsilon} y_{t+s} \right)$$

Simplifying:

$$\max_{P_t(j)} \; \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \frac{\lambda_{t+s}}{\lambda_t} \left(\pi_{t-1,t+s-1}^{(1-\epsilon)\xi_p} P_t^{1-\epsilon}(j) P_{t+s}^{-(1-\epsilon)} y_{t+s} \right)$$

$$- \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \frac{\lambda_{t+s}}{\lambda_t} \left(mc_{t+s}(j) \pi_{t-1,t+s-1}^{-\epsilon\xi_p} P_t^{-\epsilon}(j) P_{t+s}^{\epsilon} y_{t+s} \right)$$

Taking the FOC with respect to $P_t(j)$ results in:

$$\frac{\partial}{\partial P_t(j)}$$

$$= (1-\epsilon) P_t^{-\epsilon}(j) \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \frac{\lambda_{t+s}}{\lambda_t} \left(\pi_{t-1,t+s-1}^{(1-\epsilon)\xi_p} y_{t+s} P_{t+s}^{-(1-\epsilon)} \right)$$

$$+ \epsilon P_t^{-\epsilon-1}(j) \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \frac{\lambda_{t+s}}{\lambda_t} \left(mc_{t+s}(j) \pi_{t-1,t+s-1}^{-\epsilon\xi_p} y_{t+s} P_{t+s}^{\epsilon} \right) \tag{A.11}$$

$$= 0$$

Next, multiply by λ_t and divide by $P_t^{-\epsilon}(j)$:

$$(1-\epsilon) A_t + \epsilon P_t^{-1}(j) B_t(j) = 0$$

where

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$$A_t = \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \lambda_{t+s} \left(\pi_{t-1,t+s-1}^{(1-\epsilon)\xi_p} y_{t+s} P_{t+s}^{-(1-\epsilon)} \right)$$

$$B_t(j) = \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \lambda_{t+s} \left(mc_{t+s}(j) \pi_{t-1,t+s-1}^{-\epsilon\xi_p} y_{t+s} P_{t+s}^{\epsilon} \right)$$

And finally solve for $P_t(j)$

$$\frac{\epsilon}{\epsilon-1} \frac{B(j)}{A} = P_t^{\#}(j) \tag{A.12}$$

Since the optimal choice for $P_t^{\#}(j)$ does not depend on individual firm character-istics j ($mc_t(j)$ is the homogeneous across firms, as can be seen from firm FOCs in equations (A.8)), it is the same for all intermediaries: $P_t^{\#}$.

Further, A_t and B_t can be written in recursive form (dropping j):

$$A_t = \lambda_t y_t P_t^{\epsilon-1} + \beta\phi\pi_t^{\xi_p(1-\epsilon)} \mathbb{E}_t A_{t+1}$$

$$B_t = \lambda_t mc_t P_t^{\epsilon} y_t + \beta\phi\pi_t^{-\epsilon\xi_p} \mathbb{E}_t B_{t+1}$$

Since the price level is not stationary, define $\hat{A}_t = \frac{A_t}{P_t^{\epsilon-1}}$ and $\hat{B}_t = \frac{B_t}{P_t^{\epsilon}}$:

We get:

$$\hat{A}_t = \lambda_t y_t + \beta\phi\pi_{t+1}^{(\epsilon-1)} \pi_t^{\xi_p(\epsilon-1)} \mathbb{E}_t \hat{A}_{t+1}$$

$$\hat{B}_t = \lambda_t mc_t y_t + \beta\phi\pi_{t+1}^{\epsilon} \pi_t^{-\epsilon\xi_p} \mathbb{E}_t \hat{B}_{t+1}$$

Equation (A.12) thus becomes:

$$P_t^{\#} = \frac{\epsilon}{\epsilon-1} \frac{\hat{B}_t}{\hat{A}_t} \frac{P_t^{\epsilon}}{P_t^{(\epsilon-1)}}$$

And optimal price inflation $\pi_t^{\#} = \frac{P_t^{\#}}{P_{t-1}}$ is:

$$\pi_t^{\#} = \frac{\epsilon}{\epsilon-1} \frac{\hat{B}_t}{\hat{A}_t} \pi_t \tag{A.13}$$

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If firms could adjust prices every period, i.e. $\phi = 0$, then the optimality condition reduces to $P_t^\# = \frac{\epsilon}{\epsilon-1} mc_t P_t$. The optimal price is a markup over nominal marginal cost $mc_t P_t$.

Since all intermediate firms are homogeneous, we can integrate across all intermediaries to get aggregate output y_t. As a reminder, individual firm production is given by:

$$A_t \hat{K}_t^\alpha(j) \hat{N}_t^{1-\alpha}(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} y_t \tag{A.14}$$

All intermediaries hire capital and labor in the same ratio, and this ratio has to hold in the aggregate. Plugging in:

$$A_t \frac{\hat{K}_t^\alpha(j)}{\hat{N}_t^\alpha(j)} \hat{N}_t(j) = A_t \frac{\hat{K}_t^\alpha}{\hat{N}_t^\alpha} \hat{N}_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} y_t$$

Next, integrate over all firms:

$$A_t \frac{\hat{K}_t^\alpha}{\hat{N}_t^\alpha} \int \hat{N}_t(j) dj = y_t \int \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} dj$$

By labor market clearing, $\int \hat{N}_t(j) dj = \hat{N}_t$ and define a measure of price dispersion $v_t^p = \int \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} dj$ to get an expression for aggregate output:

$$y_t = \frac{A_t \hat{K}_t^\alpha \hat{N}_t^{1-\alpha}}{v_t^p} \tag{A.15}$$

Next, we need to solve for v_t^p. A fraction of $(1-\phi)$ intermediary firms choose optimal price $P_t^\#(j)$, whereas all other firms index their price to inflation with parameter ξ_p. Thus, we can split the integral in v_t^p into two parts:

$$v_t^p = \int_0^{1-\phi} \left(\frac{P_t^\#(j)}{P_t}\right)^{-\epsilon} dj + \int_{1-\phi}^1 \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} dj$$

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$P_t(j)$ is indexed to lagged inflation by $\pi_{t-1}^{\xi_p} P_{t-1}(j)$. Plugging in and solving the first term:

$$v_t^p = (1 - \phi)\left(P_t^{\#}\right)^{-\epsilon} P_t^{\epsilon} + \int_{1-\phi}^1 \pi_{t-1}^{-\xi_p \epsilon} P_{t-1}^{-\epsilon}(j) P_t^{\epsilon} dj$$

Adding $P_{t-1}^{-\epsilon}$, P_{t-1}^{ϵ} as factors to the integral simplifies the problem:

$$v_t^p = (1 - \phi)\left(P_t^{\#}\right)^{-\epsilon} P_t^{\epsilon} + \pi_{t-1}^{-\xi_p \epsilon} \int_{1-\phi}^1 P_{t-1}^{-\epsilon}(j) P_t^{\epsilon} P_{t-1}^{-\epsilon} P_{t-1}^{\epsilon} dj$$

$$= (1 - \phi)\left(P_t^{\#}\right)^{-\epsilon} P_t^{\epsilon} + \pi_{t-1}^{-\xi_p \epsilon} \pi_t^{\epsilon} \int_{1-\phi}^1 \left(\frac{P_{t-1}(j)}{P_{t-1}}\right)^{-\epsilon} dj$$

$$= (1 - \phi)\left(P_t^{\#}\right)^{-\epsilon} P_t^{\epsilon} + \pi_{t-1}^{-\xi_p \epsilon} \pi_t^{\epsilon} \phi v_{t-1}^p$$

Last, this equation can be written recursively in terms of inflation (since the price levels are not stationary):

$$v_t^p = \pi_t^{\epsilon}\left((1 - \phi)(\pi_t^{\#})^{-\epsilon} + \pi_{t-1}^{-\xi_p \epsilon} \phi v_{t-1}^p\right) \tag{A.16}$$

TRADERS

Traders are similar to the standard representative agent setup in NK models as in Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007). I assume that these agents belong to one large family, fraction n_p of all agents, and within that family are fully insured against unemployment. The family head maximizes utility by choosing consumption, investment, capital utilization, next period's capital stock and saving in real bonds subject to investment adjustment cost and utilization cost for each agent. When employed, an agent provides labor of 1 and 0 otherwise.

Investment is subject to quadratic investment cost $S_t(I_t, I_{t-1})$ when $\tau > 0$ which is paid in consumption units for changes in the level of investment per unit of investment, and includes an investment adjustment cost shock $e^{z_t^I}$. These cost follow the form in

Christiano, Eichenbaum and Evans (2005). Existing capital depreciates at rate δ^K. Investment per period is thus given by:

$$K_{t+1} - (1 - \delta^K)K_t = e^{z_t^I}\left(1 - \frac{\tau}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right)I_t \qquad (A.17)$$

Investment cost play a key role in representative agent NK models and as I will discuss later, one implication of adding households with a precautionary saving motive is that the importance of these costs decreases substantially.

Capital K_t is utilized at rate u_t to yield effective capital $\hat{K}_t = u_t K_t$. Utilization cost $\eta^K(u_t)$ are paid in consumption units and are calibrated that in steady state $u_{ss} = 1$ and $\eta^K(u_{ss}) = 0$. In addition, $\eta^{K'}(u_{ss}) > 0$ and $\eta^{K''}(u_{ss}) > 0$. These are modeled as in Christiano, Trabandt and Walentin (2010), chapter 7.

$$\eta^K(u_t) = \chi_1(1-u) + \frac{\chi_2}{2}(u_t - 1)^2 \qquad (A.18)$$

Traders maximize utility given prices, saving in bonds from last period, the capital stock, the previous level of investment, the previous level of consumption as well as the level of employment:

$$V_t = \max_{c_t, I_t, u_t, b_{t+1}, K_{t+1}} ln(c_t - bc_{t-1}) + \beta\mathbb{E}_t V_{t+1}$$

subject to

$$c_t + I_t + b_{t+1} \leq R_t u_t K_t + w_t \omega N_t - \eta(u_t)K_t + (1 + r_t^i)\frac{1}{\pi_t}b_t + \frac{1}{n_p}\frac{\Pi_t}{P_t} + T_t^G$$

$$K_{t+1} - (1 - \delta^K)K_t = e^{z_t^I}\left(1 - \frac{\tau}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right)I_t$$

$$N_t = (1 - urate_t)$$

where, Π_t is the profit of the intermediaries, $(1 + r_t^i)$ is the nominal interest rate and T_t^G are lump sum taxes.

Let λ_t and μ_t be the multipliers on the budget constraint and capital accumulation equation. The Lagrangian is:

$$\mathcal{L}_t = ln(c_t - bc_{t-1})$$

$$+ \lambda_t \left(R_t u_t K_t + w_t \omega N_t - \eta(u_t) K_t + (1 + r_t^i) \frac{1}{\pi_t} b_t + \frac{1}{n_p} \frac{\Pi_t}{P_t} + T_t^G - c_t - I_t - b_{t+1} \right)$$

$$+ \mu_t \left(e^{z_t^I} \left(1 - \frac{\tau}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right) I_t - K_{t+1} + (1 - \delta^K) K_t \right)$$

$$+ \beta \mathbb{E}_t V_{t+1}$$

The FOCs are:

$$\frac{\partial V_t}{\partial c_t} = \frac{1}{c_t - bc_{t-1}} - \lambda_t + \beta \mathbb{E}_t \left[\frac{\partial V_{t+1}}{\partial c_t} \right] = 0$$

$$\frac{\partial V_t}{\partial K_{t+1}} = -\mu_t + \beta \mathbb{E}_t \left[\frac{\partial V_{t+1}}{\partial K_{t+1}} \right] = 0$$

$$\frac{\partial V_t}{\partial b_{t+1}} = -\lambda_t + \beta \mathbb{E}_t \left[\frac{\partial V_{t+1}}{\partial b_{t+1}} \right] = 0$$

$$\frac{\partial V_t}{\partial I_t} = -\lambda_t + \mu_t e^{z_t^I} \left(\left(1 - \frac{\tau}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right) - \tau \frac{I_t}{I_{t-1}} \left(\frac{I_t}{I_{t-1}} - 1 \right) \right)$$

$$+ \beta \mathbb{E}_t \left[\frac{\partial V_{t+1}}{\partial I_t} \right] = 0$$

$$\frac{\partial V_t}{\partial u_t} = \lambda_t \left(R_t K_t - \eta'(u_t) K_t \right) = 0$$

Where $\eta'(u_t) = \chi_1 + \chi_2 (u_t - 1)$. The envelope conditions are:

$$\frac{\partial V_t}{\partial c_{t-1}} = -b \frac{1}{c_t - bc_{t-1}}$$

$$\frac{\partial V_t}{\partial K_t} = \lambda_t \left(R_t u_t - \eta(u_t) \right) + \mu_t (1 - \delta^K)$$

$$\frac{\partial V_t}{\partial b_t} = \lambda_t (1 + r_t^i) \frac{1}{\pi_t}$$

$$\frac{\partial V_t}{\partial I_{t-1}} = -\mu_t e^{z_t^I} \tau \frac{I_t^2}{I_{t-1}^2} \left(\frac{I_t}{I_{t-1}} - 1 \right)$$

Iterating the envelope conditions forward and plugging in yields the following optimality conditions:

$$\lambda_t = \frac{1}{c_t - bc_{t_1}} - \beta \mathbb{E}_t \left[\frac{1}{c_{t+1} - bc_t} \right] \tag{A.19}$$

$$R_t = \chi_1 + \chi_2(u_t - 1) \tag{A.20}$$

$$\lambda_t = (1 + r_t^i)\beta \mathbb{E}_t \left[\lambda_{t+1} \frac{1}{\pi_{t+1}} \right] \tag{A.21}$$

$$
\begin{aligned}
\lambda_t &= \mu_t e^{z_t^I} \left(\left(1 - \frac{\tau}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right) - \tau \frac{I_t}{I_{t-1}} \left(\frac{I_t}{I_{t-1}} - 1 \right) \right) \\
&\quad - \beta \mathbb{E}_t \left[\mu_{t+1} z_{t+1}^I \tau \left(\frac{I_{t+1}}{I_t} - 1 \right) \frac{I_{t+1}^2}{I_t^2} \right]
\end{aligned} \tag{A.22}
$$

$$\mu_t = \beta \mathbb{E}_t \left[\lambda_{t+1} \left(R_{t+1} u_{t+1} - \eta(u_{t+1}) \right) + \mu_{t+1}(1 - \delta^K) \right] \tag{A.23}$$

Equation 1.14 is the stochastic discount factor. Since traders are also firm owners, the SDF was used in the optimization problem of intermediaries. Equation 1.15 shows the role of capital utilization. By adjusting the utilization rate, interest rate shocks are not transmitted directly to the return on capital services. Equation 1.16 is the Euler Equation. And the last two equations are the optimality conditions for investment and capital utilization.

EMPLOYED, LIMITED AGENTS

The family head then solves the following problem (in real terms):

$$V_t^e = \max_{c_t^e, x_t^e} n_t^e ln(c_t^e) + \beta_e \mathbb{E}\left[V_{t+1}^e + \sigma_{t+1}^u n_t^e V_{t+1}^u\right]$$

subject to

$$n_t^e(c_t^e + x_t^e - T_t^G) \leq X_t^e + n_t^e w_t$$

$$X_{t+1}^e = (1 - \sigma_{t+1}^u)n_t^e \frac{1}{\pi_{t+1}}(1 + r_t^i)x_t^e + D_{t+1}^u$$

$$x_t^e \geq 0$$

where x_t^e represents savings during the consumption period, and T_t^G is a lumpsum tax. Assuming that the BC constraint holds with equality, that $x_t^e > 0$ and substituting for X_t^e and in the BC, the first order conditions and envelope conditions are:

$$
\begin{aligned}
\frac{\partial V_t^e}{\partial c_t^e} &= n_t^e \frac{1}{c_t^e} - n_t^e \lambda_t = 0 \\
\frac{\partial V_t^e}{\partial x_t^e} &= -n_t^e \lambda_t + \beta_e \mathbb{E}_t\left[\frac{\partial V_{t+1}^e}{\partial x_t^e} + \sigma_{t+1}^u n_t^e \frac{\partial V_{t+1}^u}{\partial x_t^e}\right] = 0 \\
\frac{\partial V_t^e}{x_{t-1}^e} &= \lambda_t(1 - \sigma_t^u)n_{t-1}^e \frac{1}{\pi_t}(1 + r_{t-1}^i) \\
\frac{\partial V_t^u}{\partial x_t^e} &= \frac{1}{c_t^u}\frac{1}{\pi_t}(1 + r_{t-1}^i)
\end{aligned}
$$

Where the last envelope condition is given by equation (A.24) of the problem for unemployed agents. Iterating forward the envelope conditions and substituting we get:

$$\lambda_t = \frac{1}{c_t^e}$$

$$n_t^e \lambda_t = \beta_e(1 + r_t^i)\mathbb{E}_t\left[\lambda_{t+1}(1 - \sigma_{t+1}^u)n_t^e \frac{1}{\pi_{t+1}} + \sigma_{t+1}^u n_t^e \frac{1}{c_{t+1}^u}\frac{1}{\pi_{t+1}}\right]$$

which together give the Euler Equation for employed, limited households:

$$\frac{1}{c_t^e} = \beta_e(1 + r_t^i)\mathbb{E}_t\left[(1 - \sigma_{t+1}^u)\frac{1}{c_{t+1}^e}\frac{1}{\pi_{t+1}} + \sigma_{t+1}^u \frac{1}{c_{t+1}^u}\frac{1}{\pi_{t+1}}\right]$$

Limited households are of two types: employed and unemployed. Unemployed house-holds face fixed death probability σ^d and do not receive any income These unemployed households solve the following problem:

$$V_t^u = \max_{c_t^u, x_t^u} ln(c_t^u) + \beta_e(1 - \sigma^d)\mathbb{E}V_{t+1}^u$$

subject to

$$c_t^u + x_t^u \leq \frac{1}{\pi_t}(1 + r_{t-1}^i)x_{t-1}^u$$

$$x_t^u \geq 0$$

where x_t^u are real savings in bonds in period t and there is a no-borrowing limit. Bonds pay nominal interest rate r_t^i. The FOCs are (with λ on the budget constraint[1]):

$$\frac{\partial V_t^u}{\partial c_t^u} = \frac{1}{c_t^u} - \lambda_t = 0$$
$$\frac{\partial V_t^u}{\partial x_t^u} = -\lambda_t + \beta_e(1 - \sigma^d)\mathbb{E}_t\left[\frac{\partial V_{t+1}^u}{\partial x_t^u}\right] = 0$$

The envelope condition is:

$$\frac{\partial V_t^u}{\partial x_{t-1}^u} = \lambda_t(1 + r_{t-1}^i)\frac{1}{\pi_t} \tag{A.24}$$

Iterating forward the envelope condition:

$$\lambda_t = \frac{1}{c_t^u}$$
$$\lambda_t = \beta_e(1 - \sigma^d)\mathbb{E}_t\left[\lambda_{t+1}\frac{1}{\pi_{t+1}}(1 + r_t^i)\right]$$

Combining both results in the Euler Equation:

---

[1]A binding no-borrowing constraint implies zero consumption, and therefore it will never bind

$$\frac{1}{c_t^u} = \beta_e(1 - \sigma^d)(1 + r_t^i)\mathbb{E}_t\left[\frac{1}{c_{t+1}^u}\frac{1}{\pi_{t+1}}\right]$$

From the Euler Equation and the lifetime budget constraint, the perfect foresight solution becomes:

$$c_t^u = (1 - \beta_e(1 - \sigma^d))\frac{1}{\pi_t}(1 + r_{t-1}^i)x_{t-1}^u = k_u\frac{1}{\pi_t}(1 + r_{t-1}^i)x_{t-1}^u$$

Thus, unemployed households consume a constant fraction of their income. This result allows me to aggregate all unemployed households.

AGGREGATE UNEMPLOYMENT VARIABLES

Aggregate dynamics are described by three variables: consumption, $\bar{C}_t^u$, saving, $\bar{S}_t^u$, and transfers from the deceased households, $\bar{D}_t^u$.

Consumption consists of the newly unemployed agents' consumption (no death probability in first period) and consumption of the surviving, previously unemployed agents.

$$\bar{C}_t^u = \sigma_t^u n_{t-1}^e c_t^u + (1 - \sigma^d)k^u\frac{1}{\pi_t}(1 + r_{t-1}^i)\bar{S}_{t-1}^u$$

Aggregate saving combines the saving of the newly unemployed with the saving of the surviving unemployed:

$$\bar{S}_t^u = \frac{1}{\pi_t}(1 + r_{t-1}^i)(1 - k^u)\left(x_{t-1}^e n_{t-1}^e \sigma_t^u + (1 - \sigma^d)\bar{S}_{t-1}^u\right)$$

And, lastly, transfers are the real savings of the deceased agents, out of the group of previously unemployed households:

$$\bar{D}_t^u = \sigma^d\frac{1}{\pi_t}(1 + r_{t-1}^i)\bar{S}_{t-1}^u$$

MONETARY POLICY AND GOVERNMENT

Monetary policy follows a Taylor rule that reacts to deviations of inflation from the target of steady state inflation and to economic growth (see e.g. Guerrieri and Iacoviello (2017)).

$$(1 + r_t^i) = (1 + r_{t-1}^i)^{r_R} \left(\frac{\pi_t}{\pi_{SS}} \right)^{(1-r_R)r_\pi} \left(\frac{y_t}{y_{t-1}} \right)^{(1-r_R)r_y} (1 + r_{SS}^i)^{1-r_R} \epsilon_{r,t}$$

where $\epsilon_{r,t}$ is the monetary policy shock.

Government spending is an exogenous fraction of output:

$$G_t = \omega_t y_t$$

where ω_t is follows an AR(1) process:

$$\omega_t = \rho_g \omega_{t-1} + (1 - \rho_g)\bar{\omega} + \epsilon_t^G$$

The government levies lumpsum taxes on traders and employed, limited households according to a balanced budget rule:

$$G_t = n_t^e T_t^G + n_p T_t^g$$

AGGREGATION AND EQUILIBRIUM

In equilibrium, effective labor and capital markets clear:

$$\hat{N}_t = n_t^e + (1 - urate_t)\eta n_p$$

$$\hat{K}_t = n_p u_t K_t$$

The bond market clears:

$$n_t^e x_t^e + S_t^{ru} = n_p b_{t+1}$$

The aggregate resource constraint is:

$$y_t = G_t + n_t^e c_t^e + C_t^u + n_p(c_t + I_t + \eta^K(u_t)K_t)$$

The law of motion for capital is

$$K_{t+1} - (1 - \delta^K)K_t = e^{z_t^I}\left(1 - \frac{\tau}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right)I_t$$

The law of motion for limited, unemployed agents is:

$$n_t^u = (1 - \sigma^d)n_{t-1}^u + \sigma_t n_{t-1}^e$$

The price index is given by equation (A.6):

$$P_t = \left(\int P_t(j)^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}$$

Since all intermediate firms are identical, we can rewrite this equation using the optimal price derived from Calvo pricing:

$$
\begin{aligned}
P_t^{1-\epsilon} &= \int P_t(j)^{1-\epsilon} \\
&= \int_0^{1-\phi} P_t^{\#(1-\epsilon)}dj + \int_{1-\phi}^1 \pi_{t-1}^{\xi_p(1-\epsilon)}P_{t-1}(j)^{1-\epsilon}dj \\
&= (1-\phi)P_t^{\#(1-\epsilon)} + \phi\pi_{t-1}^{\xi_p(1-\epsilon)}\int_0^1 P_{t-1}(j)^{1-\epsilon}dj \\
&= (1-\phi)P_t^{\#(1-\epsilon)} + \phi\pi_{t-1}^{\xi_p(1-\epsilon)}P_{t-1}^{1-\epsilon}
\end{aligned}
$$

In the last step, I substituted in the term for the aggregate price level last period. Dividing both sides by $P_{t-1}^{(1-\epsilon)}$ yields an equation for inflation:

$$\pi_t^{1-\epsilon} = (1-\phi)\pi_t^{\#(1-\epsilon)} + \phi\pi_{t-1}^{\xi_p(1-\epsilon)} \qquad (A.25)$$

where $\pi_t^{\#}$ is defined in equation (A.13).

The real wage is determined by the wage equation:

$$w_t = \left(\frac{w_{t-1}}{\pi_t}\right)^{\gamma_w} \left(\bar{w}e^{z_t^w}\left[\frac{n_t}{n_{ss}}\right]^{\phi_w}\right)^{(1-\gamma_w)}$$

The shock processes are:

$$z_t^I = \rho_I z_{t-1}^I + \epsilon_t^I$$

$$z_t^w = \rho_w z_{t-1}^w + \epsilon_t^w$$

$$\omega_t = \rho_G \omega_{t-1} + (1-\rho_G)\bar{\omega} + \epsilon_t^G$$

$$A_t = \rho_A A_{t-1} + (1-\rho_A)\bar{A} + \epsilon_t^A$$

Therefore, an equilibrium in this economy is a set of value and policy functions, a set of prices and a set government policies, such that given prices and state variables, (1) the policy functions solve the household problems of traders, limited and employed as well as limited and unemployed households, (2) firms maximize profits, (3) the bond, labor and capital markets clear and (4) government policy is given by the balanced budget equation and monetary policy rule.

A.2.2 THE CASH MODEL

The firm side of this model is the same as in the benchmark economy, only some household equations and the market clearing conditions change.

Traders can also choose to hold cash, with an associated no-borrowing constraint. In addition, they are the sole recipients of transfers from the monetary authority T_t^M.

$$V_t = \max_{c_t, I_t, u_t, b_{t+1}, K_{t+1}} ln(c_t - bc_{t-1}) + \beta \mathbb{E}_t V_{t+1}$$

subject to

$$c_t + I_t + b_{t+1} + m_t \leq R_t u_t K_t + w_t \omega N_t - \eta(u_t) K_t$$
$$+ (1 + r_t^i) \frac{1}{\pi_t} b_t + \frac{1}{\pi_t} m_{t-1} + \frac{1}{n_p} \frac{\Pi_t}{P_t} + T_t^G + \frac{1}{n_p} T_t^M$$
$$K_{t+1} - (1 - \delta^K) K_t = e^{z_t^I} \left(1 - \frac{\tau}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right) I_t$$

$$N_t = (1 - urate_t)$$

$$m_t \geq 0$$

The additional FOC is:

$$\frac{\partial V_t}{\partial m_t} = -\lambda_t + \mu_t^M + \beta \mathbb{E}_t \left[\frac{\partial V_{t+1}}{\partial m_t} \right] = 0$$

and the envelope condition is:

$$\frac{\partial V_t}{\partial m_{t-1}} = \lambda_t \frac{1}{\pi_t}$$

Together with the other FOCs there is an additional cash Euler Equation:

$$\lambda_t = \beta \mathbb{E}_t \left[\frac{1}{\pi_{t+1}} \lambda_{t+1} \right] + \mu_t^M \tag{A.26}$$

Since cash is dominated by bonds as long as the interest rate is non-zero, $m_t = 0$. When I solve the cash model I verify that this condition holds true.

The problem of the household head for employed but limited agents changes to:

$$V_t^e = \max_{c_t^e, x_t^e} n_t^e ln(c_t^e) + \beta_e \mathbb{E} \left[V_{t+1}^e + \sigma_{t+1}^u n_t^e V_{t+1}^u \right]$$

subject to

$$n_t^e(c_t^e + x_t^e - T_t) \leq X_t^e + n_t^e w_t$$

$$X_{t+1}^e = (1 - \sigma_{t+1}^u)n_t^e \frac{1}{\pi_{t+1}} x_t^e + D_{t+1}^u$$

$$x_t^e \geq 0$$

where x_t^e represents cash savings during the consumption period and T_t are lumpsum taxes. Assuming that the BC constraint holds with equality, that and that $x_t^e > 0$, the first order conditions and envelope conditions are:

$$\frac{\partial V_t^e}{\partial c_t^e} = n_t^e \frac{1}{c_t^e} - n_t^e \lambda_t = 0$$

$$\frac{\partial V_t^e}{\partial x_t^e} = -n_t^e \lambda_t + \beta_e \mathbb{E}_t \left[\frac{\partial V_{t+1}^e}{\partial x_t^e} + \sigma_{t+1}^u n_t^e \frac{\partial V_{t+1}^u}{\partial x_t^e} \right] = 0$$

$$\frac{\partial V_t^e}{x_{t-1}^e} = \lambda_t(1 - \sigma_t^u)n_{t-1}^e \frac{1}{\pi_t}$$

$$\frac{\partial V_t^u}{\partial x_t^e} = \frac{1}{c_t^u} \frac{1}{\pi_t}$$

Where the last envelope condition is given by equation (A.27). Iterating forward the envelope conditions and substituting we get:

$$\lambda_t = \frac{1}{c_t^e}$$

$$n_t^e \lambda_t = \beta_e \mathbb{E}_t \left[\lambda_{t+1}(1 - \sigma_{t+1}^u)n_t^e \frac{1}{\pi_{t+1}} + \sigma_{t+1}^u n_t^e \frac{1}{c_{t+1}^u} \frac{1}{\pi_{t+1}} \right]$$

which together give the Euler Equation for employed, limited households:

$$\frac{1}{c_t^e} = \beta_e \mathbb{E}_t \left[(1 - \sigma_{t+1}^u) \frac{1}{c_{t+1}^e} \frac{1}{\pi_{t+1}} + \sigma_{t+1}^u \frac{1}{c_{t+1}^u} \frac{1}{c\pi_{t+1}} \right]$$

This Euler Equation does not feature the interest rate.

UNEMPLOYED, LIMITED AGENTS

As with limited, employed households, the problem of unemployed agents does not contain the interest rate.

$$V_t^u(x_{t-1}^u, c_t^u, x_t^u) = \max_{c_t^u, x_t^u} ln(c_t^u) + \beta_e(1 - \sigma^d)\mathbb{E}V_{t+1}^u(x_t^u)$$

subject to

$$c_t^u + x_t^u \leq \frac{1}{\pi_t}x_{t-1}^u$$

$$x_t^u \geq 0$$

where x_t^u are real savings in cash in period t and there is a no-borrowing limit. The FOCs are (with λ on the budget constraint[2]):

$$\frac{\partial V_t^u}{\partial c_t^u} = \frac{1}{c_t^u} - \lambda_t = 0$$

$$\frac{\partial V_t^u}{\partial x_t^u} = -\lambda_t + \beta_e(1 - \sigma^d)\mathbb{E}_t\left[\frac{\partial V_{t+1}^u}{\partial x_t^u}\right] = 0$$

The envelope condition is:

$$\frac{\partial V_t^u}{\partial x_{t-1}^u} = \lambda_t\frac{1}{\pi_t} \tag{A.27}$$

Iterating forward the envelope condition:

$$\lambda_t = \frac{1}{c_t^u}$$

$$\lambda_t = \beta_e(1 - \sigma^d)\mathbb{E}_t\left[\lambda_{t+1}\frac{1}{\pi_{t+1}}\right]$$

Combining both results in the Euler Equation:

---

[2] A binding no-borrowing constraint implies zero consumption, and therefore it will never bind

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$$\frac{1}{c_t^u} = \beta_e(1 - \sigma^d)\mathbb{E}_t\left[\frac{1}{c_{t+1}^u}\frac{1}{\pi_{t+1}}\right]$$

From the Euler Equation and the lifetime budget constraint, the perfect foresight solution becomes:

$$c_t^u = (1 - \beta_e(1 - \sigma^d))\frac{1}{\pi_t}x_{t-1}^u = k_u\frac{1}{\pi_t}x_{t-1}^u$$

Thus, unemployed households consume a constant fraction of their income. This result allows me to aggregate all unemployed households.

AGGREGATE UNEMPLOYMENT VARIABLES

The aggregate laws of motion for unemployed agents become:

$$\bar{C}_t^u = \sigma_t^u n_{t-1}^e c_t^u + (1 - \sigma^d)k^u\frac{1}{\pi_t}\bar{S}_{t-1}^u$$

$$\bar{S}_t^u = \frac{1}{\pi_t}\left(x_{t-1}^e n_{t-1}^e \sigma_t^u(1 - k^u) + (1 - \sigma^d)(1 - k^u)\bar{S}_{t-1}^u\right)$$

$$\bar{D}_t^u = \sigma^d\frac{1}{\pi_t}\bar{S}_{t-1}^u$$

EQUILIBRIUM

In addition to the equilibrium conditions of the benchmark model, the following changes apply:

Bond market clearing

$$\int_0^{n_p} b_t^i di = 0$$

Money market clearing

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$$n_t^e x_t^e + S_t^u + n_p m_t = M_t$$

where M_t is the aggregate real money supply which evolves according to:

$$M_t = \frac{1}{\pi_t} M_{t-1} + T_t^M$$

with T_t^M is the transfer from the monetary authority.

A.2.3 Representative Agent Model

The representative agent version of the benchmark model essentially sets the fraction of limited agents to 0 and therefore $n_p = 1$. The representative agent solves the same problem as traders in the benchmark model. Substituting $n_t^e = n_t^u = 0$ into the benchmark model yields the representative agent model.

Estimation

The representative agent model is calibrated as the benchmark model and estimated with the same priors. The result is shown in table A.1:

Table A.1: Estimated Parameters Representative Agent Model

Parameter	Parameters Description	Prior distribution [bounds]	Mode
γ_w	wage inertia	beta [0.5,0.1]	0.8058
ϕ_w	wage adjustment	gamma [1,0.2]	1.0053
b	habit persistence	beta [0.7,0.1]	0.7761
τ	investment cost	normal [1,0.5]	1.6071
ϕ_p	calvo probability	beta [0.5,0.1]	0.7071
ζ_p	inflation index	beta [0.5,0.2]	0.0697
ϕ_y	output Taylor	normal [0.125 0.05]	0.1797
ϕ_π	inflation Taylor	normal [1.5,0.1]	1.6905
ρ_i	inertia Taylor	beta [0.9,0.05]	0.8280
ρ_w	AR(1) wage shock	beta [0.9,0.05]	0.9243
ρ_a	AR(1) TFP shock	beta [0.9,0.05]	0.9588
ρ_g	AR(1) gov shock	beta [0.9,0.05]	0.9790
ρ_z	AR(1) investment cost shock	beta [0.9,0.05]	0.9163
σ_w	sd wage shock	inv gamma [0.01,0.002]	0.0590
σ_i	sd Taylor shock	inv gamma [0.002,0.002]	0.0014
σ_a	sd TFP shock	inv gamma [0.01,0.002]	0.0052
σ_g	sd gov shock	inv gamma [0.01,0.002]	0.0046
σ_z	sd investment cost shock	inv gamma [0.01,0.002]	0.0147

A.2.4 Steady State

The steady state wage is derived as follows: Prices are constant in steady state and real marginal cost are given by equation (A.12) as $mc = \frac{\epsilon-1}{\epsilon}$, where I set $\epsilon = 10$. As discussed in the data section, the share of traders is set to $n^p = 40\%$. Next, the equilibrium unemployment rate of 6.28% gives $n^e = (1 - n^p)N_{SS}^{agg}$ and the effective labor supply as $\hat{N} = n^e + n^p \omega N_{SS}^{agg}$. I follow Challe and Ragot (2016) and set the wage premium to $\omega = 1.5$.

From here, the steady state wage is:

$$w_{ss} = (\chi_1(mc\alpha\hat{N}^{1-\alpha})^{-1})^{1/(\alpha-1)}$$

with $\alpha = 1/3$.

A.2.5 Calibration of Discount Factor for Employed Households

The limited, employed household discount factor is set to $\beta_e = 0.96$ to match the average checking to income ratio in the data to more closely align the implied time series of this ratio with the data. Figure A.6 shows that the higher value of beta mainly reduces the magnitude of this ratio but not the trend.
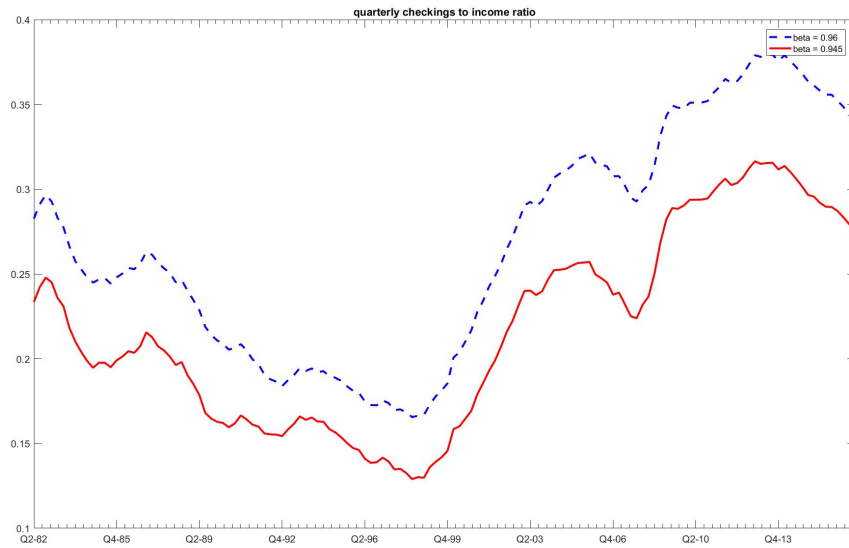
Figure A.6: Calibration of Beta Coefficient

Comparison of model implied checking account balance to income ratio with beta of 0.96 and 0.945. The higher beta helps to quantitatively match the SCF data, but does not change the qualitative result

A.2.6 TIME SERIES

All time series were extracted from the St.Louis Fed FRED data base fred.stlouisfed.org for the time 1982Q1 to 2017Q1.

The following time series were used in the estimation of the model:

1. Model variable: Δy_t. Change in log real GDP per capita: GDPC1 divided by CLF16OV and detrended.

2. Model variable: $\pi_t - 1$. GDPDEF demeaned and divided by 400.

3. Model variable: $1 - N_t$. Unemployment rate UNRATE.

4. Model variable: $r_t^i - 1$. Interest Rate: TB3MS divided by 400 and minus average inflation.

5. Model variable: ΔI_t. Change in log real investment per capita: Weighted average of PCDG and PNFI. Both time series were converted to real terms with DDURRD3Q086SBEA and A008RD3Q086SBEA respectively and to per capita terms with CLF16OV. The weights are the one period lagged share of nominal PCDG (D) and PNFI (FI):

$$ln\Delta I_t = \Delta lnD_t \left(\frac{D_{t-1}^N}{D_{t-1}^N + FI_{t-1}^N} \right) + \Delta lnFI_t \left(\frac{FI_{t-1}^N}{D_{t-1}^N + FI_{t-1}^N} \right)$$

where the superscrip N indicates nominal variable.

To calibrate the death probability of limited, unemployed agents I convert UEMP-MEAN to quarters and take the average. Table A.2 shows the names and descriptions of the individual times series.

Table A.2: Time Series

Name	Description
CLF16OV	Civilian Labor Force, Thousands of Persons, Quarterly, Seasonally Adjusted
GDPC1	Real Gross Domestic Product, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate
GDPDEF	Gross Domestic Product: Implicit Price Deflator, Index 2009=100, Quarterly, Seasonally Adjusted
UEMPMEAN	Average (Mean) Duration of Unemployment, Weeks, Quarterly, Seasonally Adjusted
UNRATE	Civilian Unemployment Rate, Percent, Quarterly, Seasonally Adjusted
TB3MS	3-Month Treasury Bill: Secondary Market Rate, Percent, Quarterly, Not Seasonally Adjusted
PCDG	Personal Consumption Expenditures: Durable Goods, Billions of Dollars, Quarterly, Seasonally Adjusted Annual Rate
DDURRD3Q086SBEA	Personal consumption expenditures: Durable goods (implicit price deflator), Index 2009=100, Quarterly, Seasonally Adjusted
PNFI	Private Nonresidential Fixed Investment, Billions of Dollars, Quarterly, Seasonally Adjusted Annual Rate
A008RD3Q086SBEA	Gross private domestic investment: Fixed investment: Nonresidential (implicit price deflator), Index 2009=100, Quarterly, Seasonally Adjusted

A.2.7 Estimation Plots

The following figures show the posterior distributions and estimated shocks of the benchmark model.
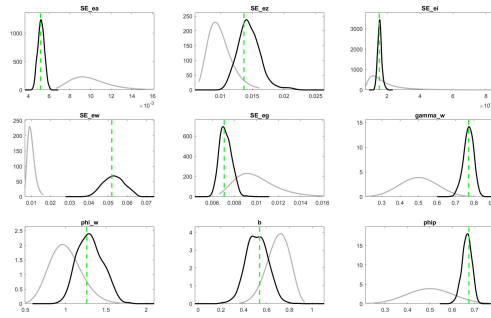
(a) Posterior Distributions 1
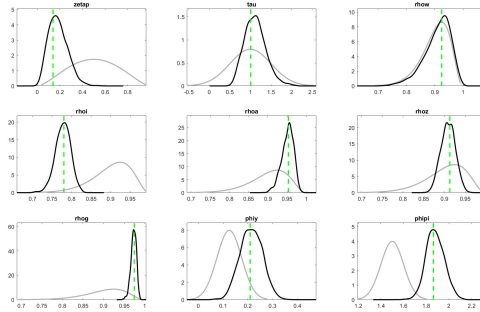
(b) Posterior Distributions 2
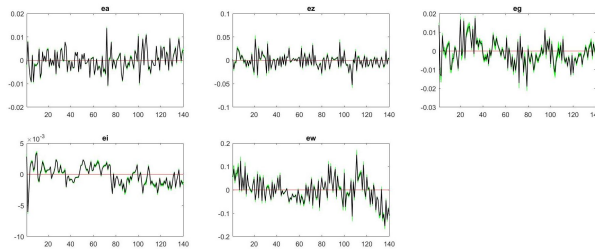
(c) Smoothed Shocks

Figure A.7: Posterior Distributions

A.3   COMPARISON OF REAL INTEREST RATES

Canzoneri, Cumby and Diba (2007) show that for representative agent models, the model implied real interest rate is negatively correlated with the real interest rate in the data. The benchmark model is able to partially solve this puzzle. While the correlation of real interest rates is not negative, the actual interest rate in the model moves in opposite direction from the interest rate that is implied by aggregate consumption in this model especially at the beginning and end of recessions.

After estimating the benchmark model, I feed the shocks back into the model and calculate the implied aggregate interest rate following Canzoneri, Cumby and Diba (2007) by feeding aggregate consumption growth as well as inflation into a representative agent version of the Euler Equation: $\frac{1}{C_t^{agg}} = \beta(1 + r_t^i)\frac{1}{C_{t+1}^{agg}}\frac{1}{\pi_{t+1}}$. Figure A.8 plots the resulting $(1 + r_t^i)\frac{1}{\pi_{t+1}}$ together with the actual real interest rate of the benchmark model. The graph looks similar to figure 1 in their paper (which covers the period 1966 to 2004).
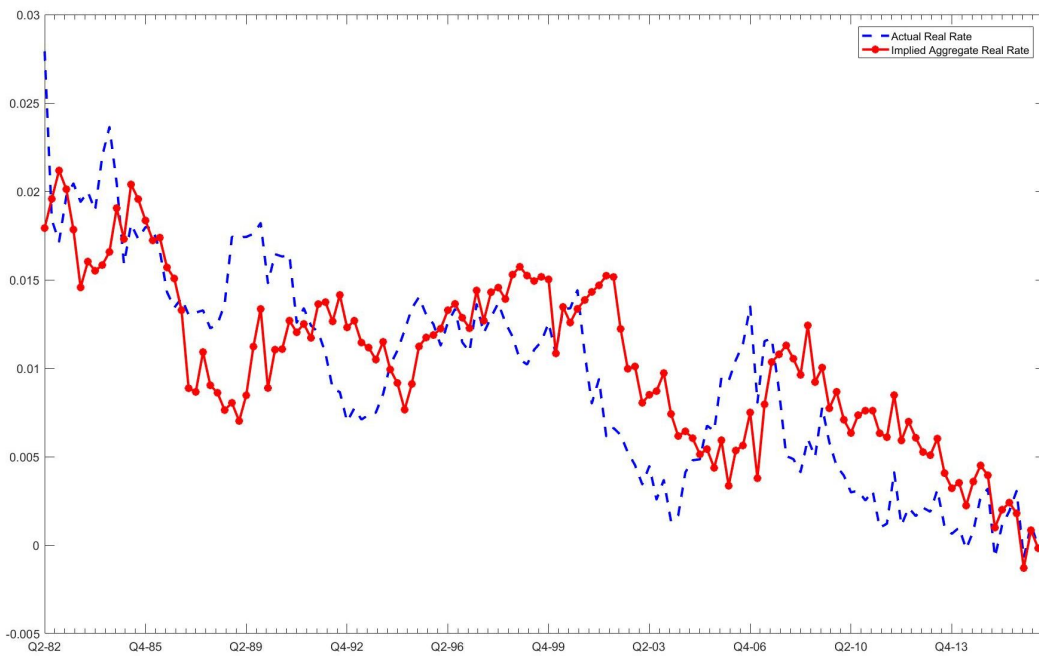
Figure A.8: Comparison of Aggregate and Actual Real Interest Rate

Comparison of the Aggregate (dashed) and Actual Real Interest Rate (dotted).

A.4 Downward Rigid Wages

To simulate downward rigid wages, I change the wage parameter5 γ_w to 0.95. The algorithm switches between both models based on whether the nominal wage is increasing or decreasing. The more rigid wage equation takes effect when nominal wages are decreasing. Thus, if $w_t - \frac{1}{\pi_t} w_{t-1}$ is positive, the economy is in the unconstrained state. And if this expression is negative, the economy is in the more rigid state. In the unconstrained model, w_t is determined by the flexible equation, and thus $w_t^{flex} > \frac{1}{\pi_t} w_{t-1}$. On the other hand, in the constrained model, w_t is determined by the rigid wage equation.

Figure A.9 displays the response of the benchmark model in red, and the model with downward wage rigidity in black. The bottom right panel shows that the constraint is binding for 6 periods after the initial shock.
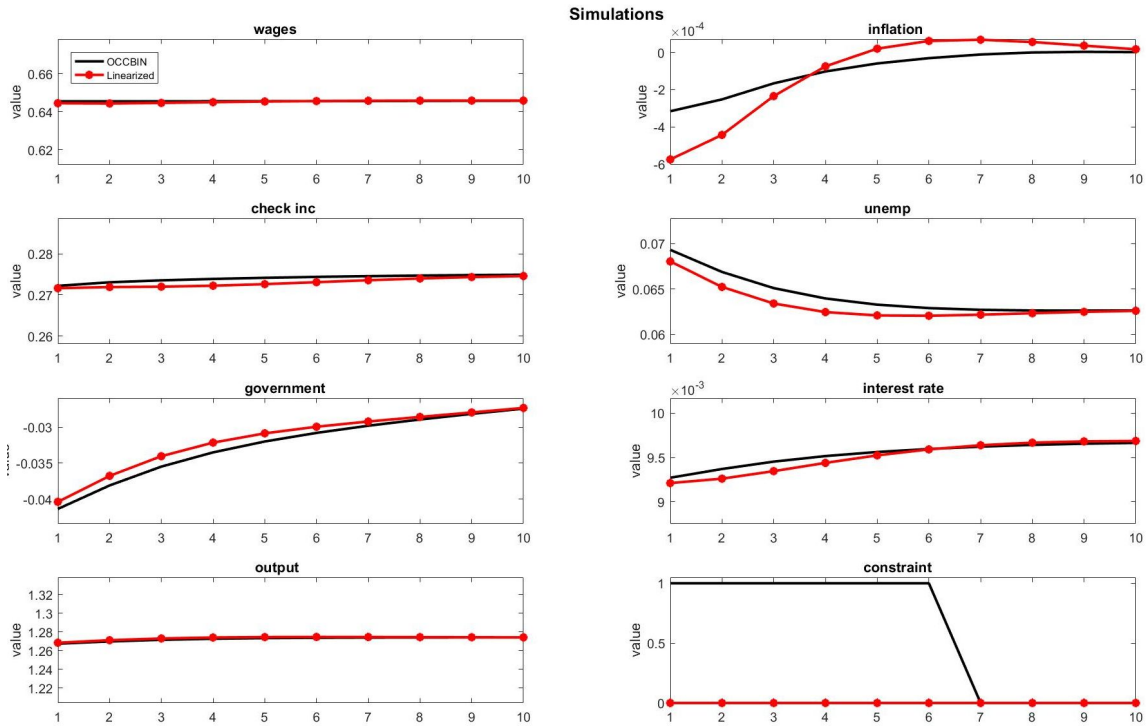
Figure A.9: Comparison of IRFs with Downward Rigid Wages

Lastly, figure A.10 shows the response of nominal wages in the benchmark model and the augmented model in more detail. The red line is the same response as in the benchmark model, the black line displays the response of the nominal wage in the rigid-wage economy, and the blue dotted line shows how the wage would adjust in the rigid-wage economy if it was not constrained.

As long as the blue line is below the black line, nominal wages should fall more than they can and the constraint binds. Though hard to see, the blue dot in period 6 is just below the black line and the constraint therefore binds for 6 periods. To put these movements into perspective, the nominal steady state wage (adjusted by inflation in period one) is shown as a red dot. Though it looks like the constrained nominal wage increases in the first period, it actually drops below the steady state nominal wage. Initially, the unconstrained, red wage and the blue (as if unconstrained) nominal wage have the same initial movement. After the first period, however, given the divergent path of the realized wage in the constrained and unconstrained economy, the wage dynamics differ.
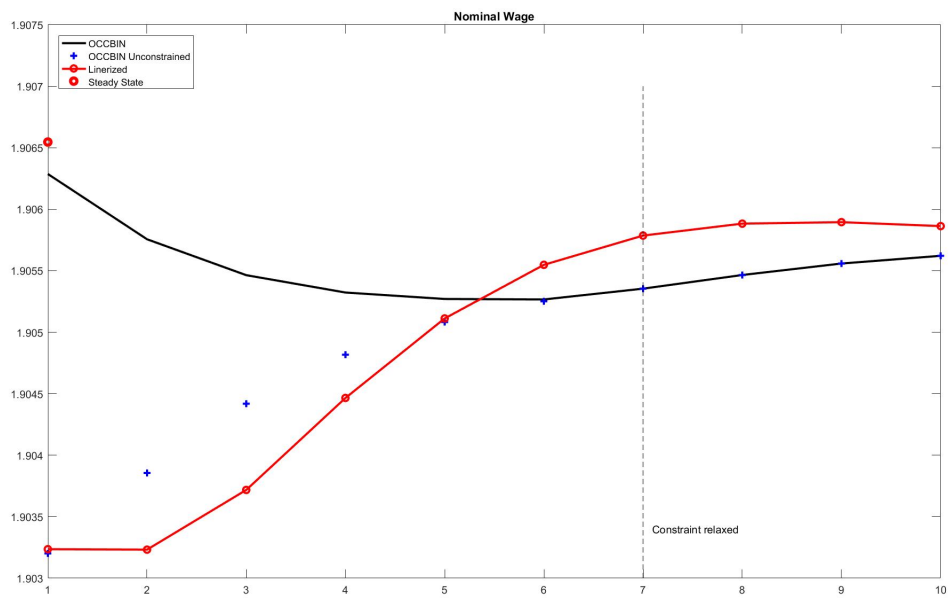
Figure A.10: Response of Nominal Wage in Constrained and Unconstrained Model

Household Consumption-Income Ratio and Employment Risk, an Empirical Analysis

B.1 Data

The data on consumption, income, the CEX sample size (measured in consumer units), as well as average age of the reference person in the survey and the percentage of MSA homeowners are taken from the Metropolitan Statistical Area tables of the Consumer Expenditure Survey. These are available for a varying number of MSA for two-year periods starting in 1996-1997. Figure B.1 provides an overview of the MSA in the CEX data and the latest year of the two year period that data for each MSA was published.

From IPUMS-CPS, I pool data from 1996-2016 into CEX-matching two-year brackets and compute employment by 3-digit industry and population for each MSA matching the CEX MSA definition as closely as possible. For employment I count all individuals with *empstat* equal to 10 (category "at work") or 12 (category "has job, not at work last week"). I exclude individuals in the armed forces.

3-digit industry codes for each employed individual in the IPUMS-CPS sample used to construct the Bartik instrument are contained in the variable *ind1990* and consistent throughout the sample period. Here, I exclude the category *niu*, code 0, and the different branches of the armed forces, codes 940 to 960. In addition, I exclude the category *unknown*, code 998.
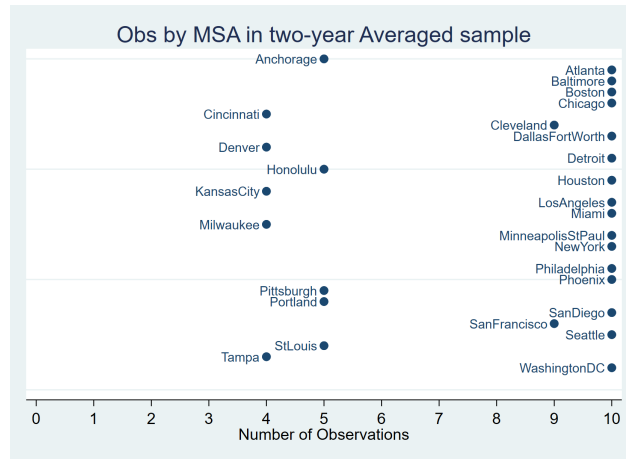
(a) Number of Observations
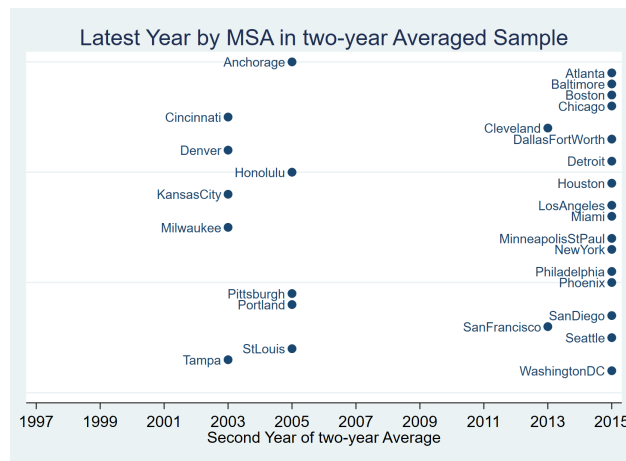
(b) Latest Survey Year

Figure B.1: Metro Areas in Consumer Expenditure Survey

Lastly, the sampling methodology of IPUMS-CPS changed slightly in 2014 and the sample for that year contains two samples that are representative for the United States. I use the *hflag* identifier with code 0 to select one of the samples. The person weight is contained in the variable *asecwt*.

B.1.1 MSA Definition Change

There are two sources of uncertainty regarding statistics computed on the MSA level. First, the definition of several MSAs changed following the two censuses in 2000 and 2010. These definition adjustments were implemented starting in 2005/2006 and 2015/2016. The county composition of each MSA over the period of 1996/1997 until 2015/2016 was provided to me on request from the CEX and are listed in appendix B.2 together with a crosswalk to IPUMS-CPS data.

A second source of uncertainty comes from the county coverage of data in IPUMS-CPS which I use to calculate the employment statistics and the Bartik instrument. Not all counties are identified in IPUMS-CPS and for some MSA, sub-components of metro areas were only added to the metro area identifier after 2004. For example, while Kitsap County is part of the Seattle metropolitan area definition from 1996 to 2004, this county was not sampled by IPUMS-CPS. Yet, with a population of under 200,000 this did not have a big impact on the population of the Seattle MSA in 2005, with a population of over 4 million, as shown in figure B.5(a). Similarly, St. Croix County and Pierce County were not included (or identified) in the Minneapolis St. Paul MSA before 2005, Chambers County in the Houston MSA, Kenosha County and kankakee County in the Chicago MSA, and the Santa Cruz-Watsonville PMSA with over 250,000 inhavitants in the San Francisco MSA before 2005.[1]

Figures B.2 and B.3 show the population growth by MSA for the period 1996 to 2016. MSA definitions were adjusted by the Census Bureau in 2005 and 2015 and these adjustment dates are indicated by the red vertical lines.

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[1]A detailed description of the counties that were either not identified by the CPS or in the sample can be found in the technical documents https://www2.census.gov/programs-surveys/cps/techdocs/ .
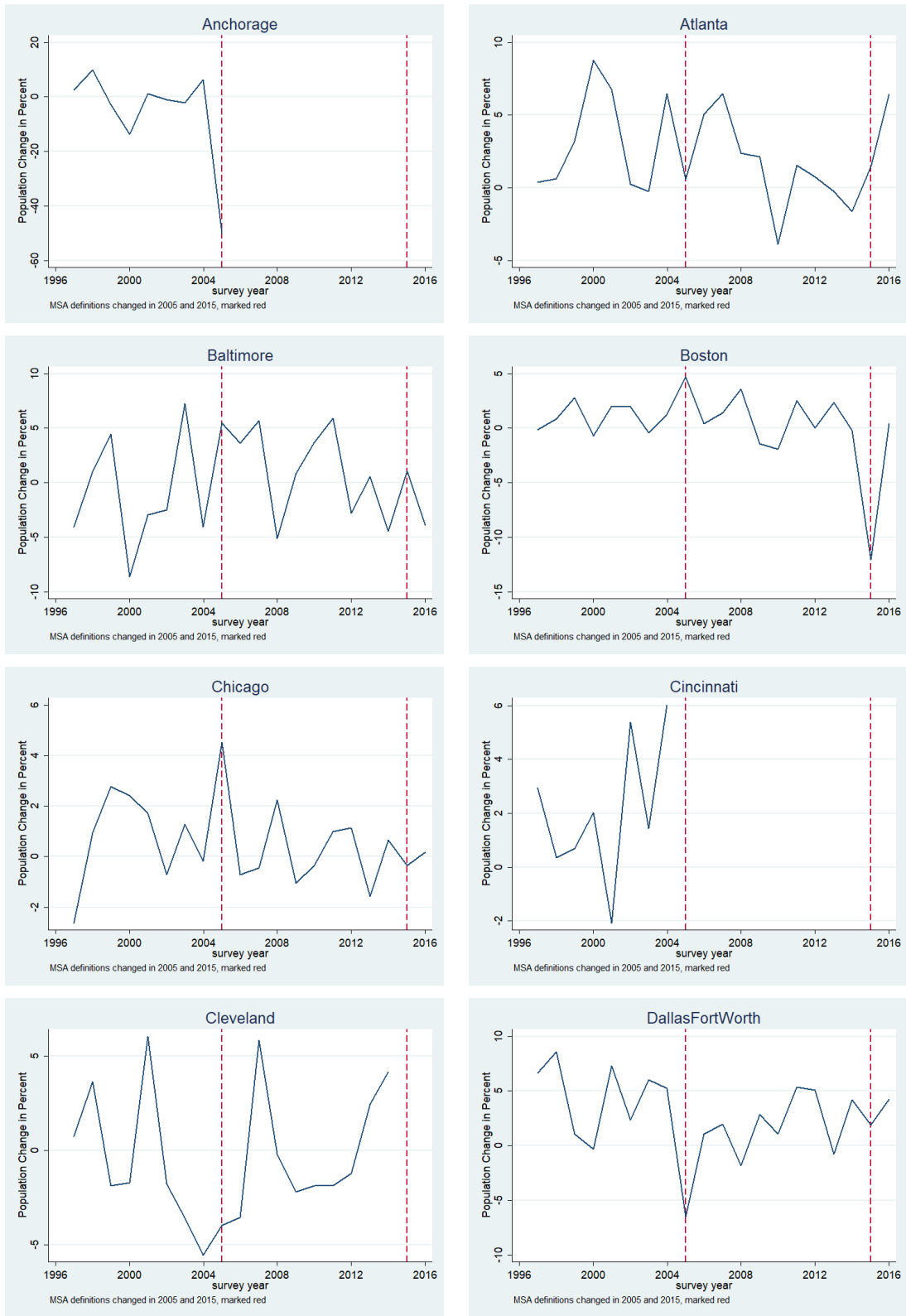
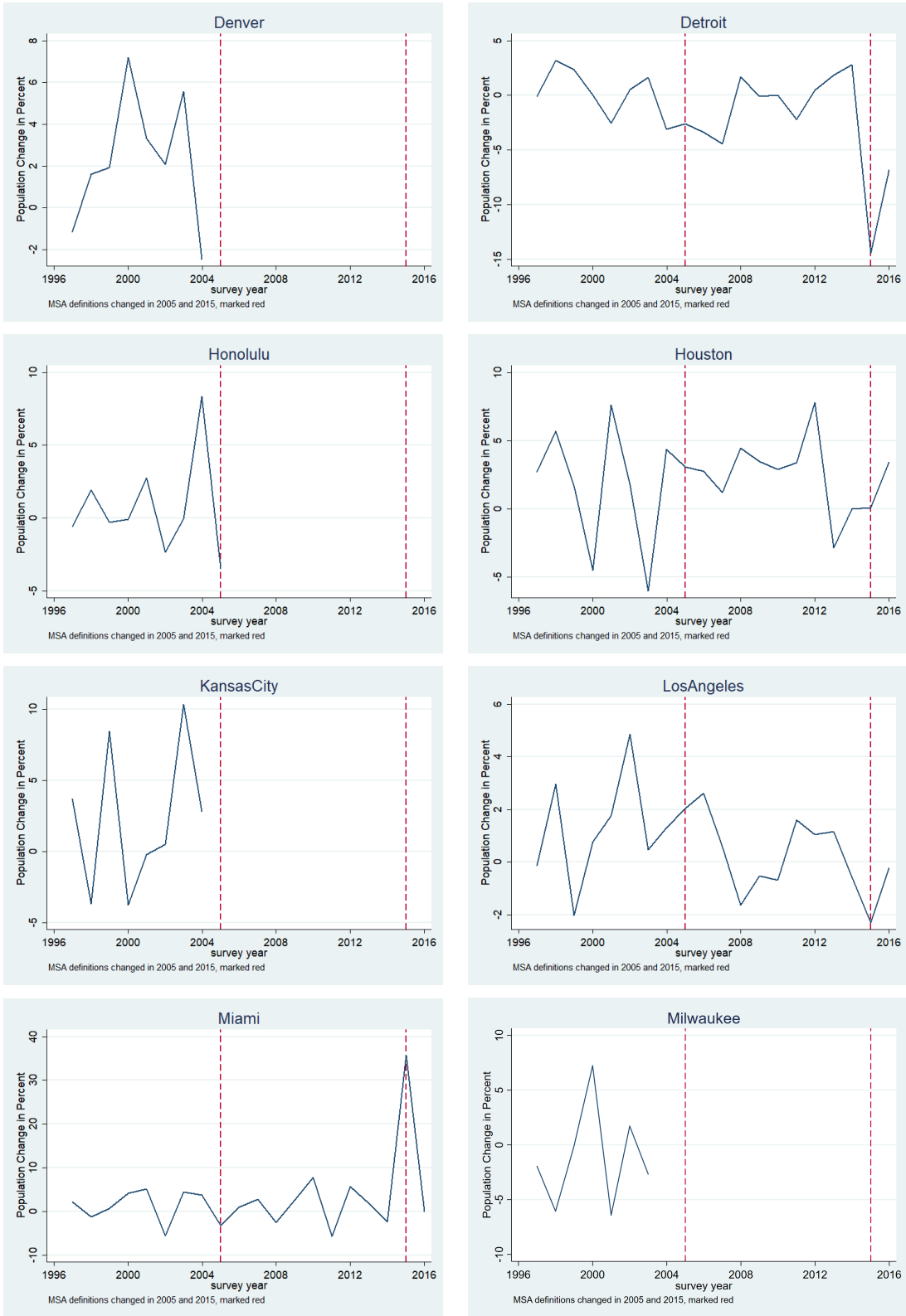Figure B.2: Annual Population Growth by MSA 1

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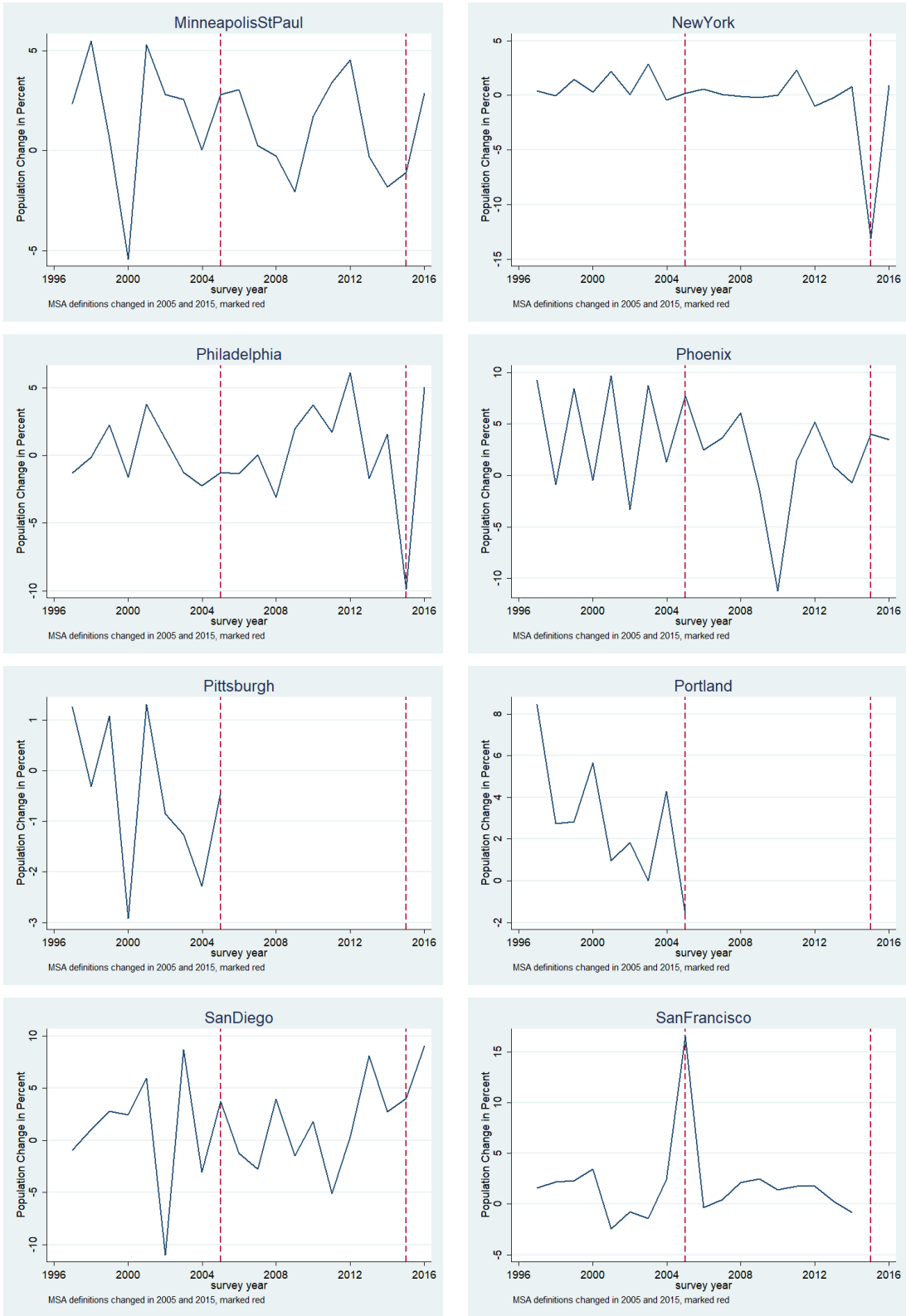Figure B.3: Annual Population Growth by MSA 2

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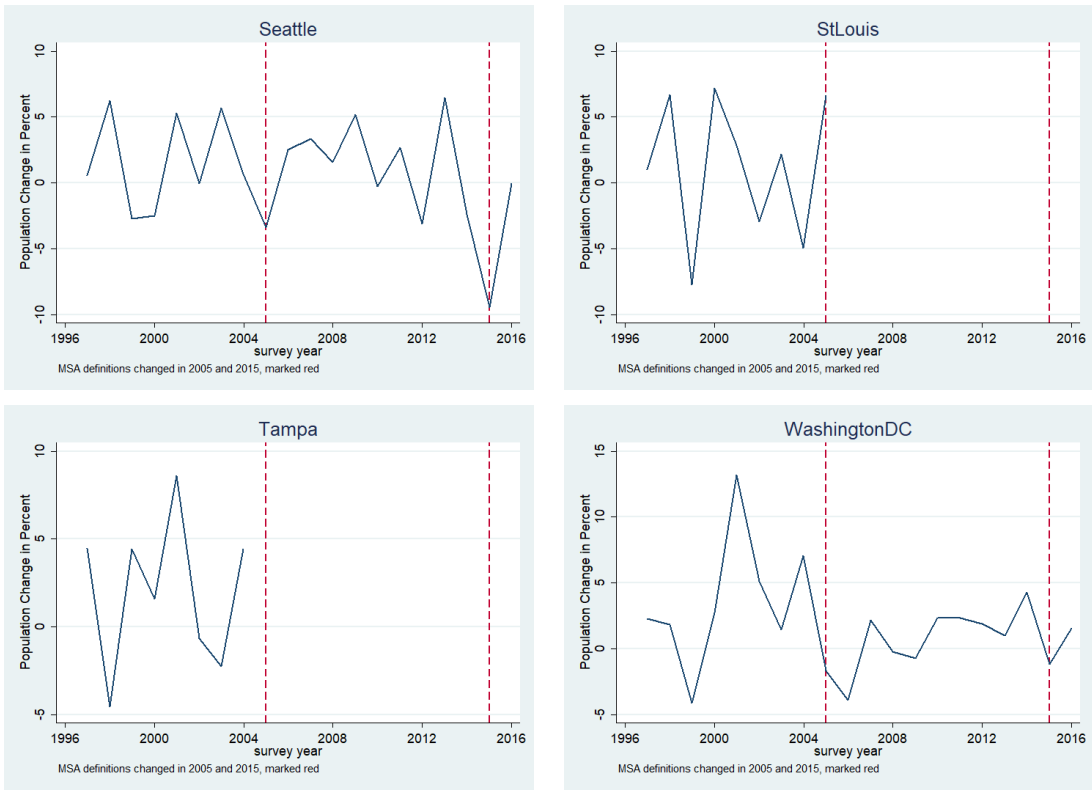Figure B.4: Annual Population Growth by MSA 3

Figure B.5: Annual Population Growth by MSA 4

B.2   CEX MSA Definition and IPUMS-CPS Crosswalk

Table B.1 lists the MSAs and their definitions based on the 1990, 2000 and 2010 Census. County definitions were provided to me by the CEX, and the IPUMS-CPS codes show the corresponding definition in IPUMS-CPS. I match MSAs using the *metarea* and *county* variables. All MSAs defined here match the CEX provided population numbers (if available) or Census estimates for their respective geographic boundaries.

Table B.1: MSA Definitions

	MSA	1990 counties	1990 IPUMS	2000 counties	2000 IPUMS	2010 counties	2010 IPUMS
1	Anchorage	Anchorage, AK	380	Anchorage, Matanuska-Susitna, AK	380	NA	NA
2	Atlanta	Barrow, Bartow, Carroll, Cherokee, Clayton, Cobb, Coweta, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Henry, Newton, Paulding, Pickens, Rockdale, Spalding, Walton, GA	520	Cleburne, AL; Barrow, Bartow, Butts, Carroll, Cherokee, Clayton, Cobb, Coweta, Dawson, De Kalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Haralson, Henry, Newton, Paulding, Pickens, Pike, Rockdale, Spalding, Walton, GA	521	GA: Barrow, Bartow, Butts, Carroll, Cherokee, Clayton, Cobb, Coweta, Dawson, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Haralson, Heard, Henry, Jasper, Lamar, Meriwether, Morgan, Newton, Paulding, Pickens, Pike, Rockdale, Spalding, Walton	521
3	Baltimore	Anne Arundel, Baltimore, Carroll, Harford, Howard, Queen Anne's, Baltimore City, MD	720	Anne Arundel, Baltimore, Baltimore city, Carroll, Harford, Howard, Queen AnneâĂŹs, MD	721	MD: Anne Arundel, Baltimore, Baltimore City, Carroll, Harford, Howard, Queen AnneâĂŹs	722
4	Boston	Windham, CT(part); Bristol(part), Essex, Hampden(part), Middlesex, Norfolk, Plymouth, Suffolk, Worcester(part), MA; York, ME(part); Hillsborough(part), Merrimack(part), Rockingham(part), Strafford(part), NH	1120, 1121, 1122, 1200, 4760, 5350, 6450	Windham, CT; Bristol, Essex, Hampden, Hampshire, Middlesex, Norfolk, Plymouth, Suffolk, Worcester, MA; York, ME; Hillsborough, Merrimack, Rockingham, Strafford, NH	1124, 2601, 6452, 9240	MA: Essex, Middlesex, Norfolk, Plymouth, Suffolk NH: Rockingham, Strafford	1125+1124 in 2015 and 1125 in 2016
5	Chicago	Cook, DeKalb, DuPage, Grundy, Kane, Kankakee, Kendall, Lake, McHenry, Will, IL; Lake, Porter, IN; Kenosha, WI	1602, 1600	Cook, DeKalb, Du Page, Grundy, Kane, Kankakee, Kendall, Lake, McHenry, Will, IL; Lake, Newton, Porter, IN; Kenosha, WI	1605, 3741	IL: Cook, De Kalb, Du Page, Grundy, Kane, Kendall, Lake, McHenry, Will IN: Jasper, Lake, Newton, Porter WI: Kenosha	1605
6	Cincinnati	Dearborn, Ohio, IN; Boone, Campbell, Gallatin, Grant, Kenton, Pendleton, KY; Brown, Butler, Clermont, Hamilton, Warren, OH	1640, 3200	NA	NA	NA	NA
7	Cleveland	Ashtabula, Cuyahoga, Geauga, Lake Lorain, Medina, Portage, Summit, OH	1680, 80	Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, Summit, OH	1681, 80	NA	NA

Continued on Next Page...

Table B.1 – Continued

	MSA	1990 counties	1990 IPUMS	2000 counties	2000 IPUMS	2010 counties	2010 IPUMS
8	DallasFortWorth	Collin, Dallas, Denton, Ellis, Henderson, Hood, Hunt, Johnson, Kaufman, Parker, Rockwall, Tarrant, TX	1921,1920	Collin, Dallas, Delta, Denton, Ellis, Henderson, Hood, Hunt, Johnson, Kaufman, Parker, Rockwall, Tarrant, Wise, TX	1922	TX: Collin, Dallas, Denton, Ellis, Hood, Hunt, Johnson, Kaufman, Parker, Rockwall, Somervell, Tarrant, Wise	1922
9	Denver	Adams, Arapahoe, Boulder, Denver, Douglas, Jefferson, Weld, CO	2080, 2081, 3060	NA	NA	NA	NA
10	Detroit	Genesee, Lapeer, Lenawee, Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, Wayne, MI	440, 2640, 2160	Genesee, Lapeer, Lenawee, Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, Wayne, MI	2161, 440, 2640	MI: Lapeer, Livingston, Macomb, Oakland, St. Clair, Wayne	2161
11	Honolulu	Honolulu, HI	3320	NA	NA	NA	NA
12	Houston	Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller, TX	2920, 3361, 3360	Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, San Jacinto, Waller, TX	3362	TX: Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller	3362
13	KansasCity	Johnson, Leavenworth, Miami, Wyandotte, KS; Cass, Clay, Clinton, Jackson, Lafayette, Platte, Ray, MO	3760	NA	NA	NA	NA
14	LosAngeles	Los Angeles, Orange, Riverside, San Bernardino, Ventura, CA	6780, 8730, 4480, 4482	Los Angeles, Orange, Riverside, San Bernardino, Ventura, CA	4483, 6780, 8731	CA: Los Angeles, Orange	4483+4484 in 2015, 4484 in 2016, 6780
15	Miami	Broward, Dade	5000, 2680	Broward, Miami Dade, FL	5001 excluding county 12099	FL: Broward, Miami-Dade, Palm Beach	5001
16	Milwaukee	Milwaukee, Ozaukee, Racine, Washington, Waukesha, WI	5080, 6600	NA	NA	NA	NA

Continued on Next Page...

Table B.1 – Continued

	MSA	1990 counties	1990 IPUMS	2000 counties	2000 IPUMS	2010 counties	2010 IPUMS
17	MinneapolisStPaul	Anoka, Carver, Chisago, Dakota, Hennepin, Isanti, Ramsey, Scott, Sherburne, Washington, Wright, MN; Pierce, St. Croix, WI	5120	Anoka, Benton, Carver, Chisago, Dakota, Hennepin, Isanti, Ramsey, Scott, Sherburne, Stearns, Washington, Wright, MN; Pierce, St. Croix, WI	5121, 6980	MN: Anoka, Carver, Chisago, Dakota, Hennepin, Isanti, Le Sueur, Mille Lacs, Ramsey, Scott, Sherburne, Sibley, Washington, Wright WI: Pierce, St. Croix	5121
18	NewYork	Bronx, Kings, New York, Queens, Richmond, Dutchess, Nassau, Orange, Putnam, Rockland, Suffolk, Westchester, NY; Fairfield(part), Litchfield(part), Middlesex (part), New Haven(part), CT Bergen, Essex, Hudson, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Ocean, Passaic, Somerset, Sussex, Union, Warren, NJ; Pike, PA;	1160, 1930, 2281, 3285, 5190, 5480, 5660, 5601, 5602, 5603, 5604, 5605, 5607, 8040, 8480, 8880	Bronx, Kings, New York, Queens, Richmond, NY Fairfield, Hartford, Litchfield, Middlesex, New Haven, Tolland, CT; Dutchess, Nassau, Orange, Putnam, Rockland, Suffolk, Westchester, NY Bergen, Essex, Hudson, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Ocean, Passaic, Somerset, Sussex, Union, Warren, NJ	1161, 1930, 3284, 5481, 5606, 6461, 8040, 8481, 8880	NJ: Bergen, Essex, Hudson, Hunterdon, Middlesex, Monmouth, Morris, Ocean, Passaic, Somerset, Sussex, Union NY: Bronx, Dutchess, Kings, Nassau, New York, Orange, Putnam, Queens, Richmond, Rockland, Suffolk, Westchester PA: Pike	5606
19	Philadelphia	Atlantic, Burlington, Cape May, Camden, Cumberland, Gloucester, Salem, NJ; New Castle, DE; Cecil, MD; Bucks, Chester, Delaware, Montgomery, Philadelphia, PA	6160, 560, 8760, 9160	New Castle, DE; Cecil, MD; Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Salem, NJ; Bucks, Chester, Delaware, Montgomery, Philadelphia, PA	6160, 560, 8760	DE: New Castle MD: Cecil NJ: Burlington, Camden, Gloucester, Salem PA: Bucks, Chester, Delaware, Montgomery, Philadelphia	6161
20	Phoenix	Maricopa, Pinal, AZ	6200	Maricopa, Pinal, AZ	6201	AZ: Maricopa, Pinal	6201
21	Pittsburgh	Alleghany, Beaver, Butler, Fayette, Washington, Westmoreland, PA	6280	Allegheny, Armstrong, Beaver, Butler, Fayette, Washington, Westmoreland, PA	6280	NA	NA
22	Portland	Clackamas, Columbia, Marion, Multnomah, Polk, Washington, Yamhill, OR; Clark, WA	6440, 7080	Clackamas, Columbia, Marion, Multnomah, Polk, Washington, Yamhill, OR; Clark, Skamania, WA	6442, 7080	NA	NA
23	SanDiego	San Diego, CA	7320	San Diego, CA	7321	CA: San Diego	7321

Continued on Next Page. . .

	MSA	1990 counties	1990 IPUMS	2000 counties	2000 IPUMS	2010 counties	2010 IPUMS
24	SanFrancisco	Alameda, Contra Costa, Marin, Napa, Santa Clara, Santa Cruz, San Francisco, San Mateo, Solano, Sonoma, CA	7360, 7361, 7500, 7400	Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, Sonoma, CA	7363, 7364, 7500, 7481, 7401, 7365	CA: Alameda, Contra Costa, Marin, San Francisco, San Mateo	7365
25	Seattle	Island, King, Kitsap, Pierce, Snohomish, Thurston, WA	8200, 5910, 7600	Island, King, Kitsap, Pierce, Snohomish, Thurston, WA	7601, 5910, 1150	WA: King, Pierce, Snohomish	7601
26	StLouis	Clinton, Jersey, Madison, Monroe, St. Clair, IL; Crawford(part), Franklin, Jefferson, Lincoln, St. Charles, St. Louis, Warren, St. Louis City, MO	7040	Bond, Clinton, Jersey, Macoupin, Madison, Monroe, St. Clair, IL; Franklin, Jefferson, Lincoln, St. Charles, St. Louis, St. Louis city, Warren, Washington, MO	7040	NA	NA
27	Tampa	Hernando, Hillsborough, Pasco, Pinellas, FL	8280	NA	NA	NA	NA
28	WashingtonDC	District of Columbia; Calvert, Charles, Frederick, Montgomery, Prince George's, Washington, MD; Arlington, Clarke, Culpeper, Fairfax, Fauquier, King George, Loudoun, Prince William, Spotsylvania, Stafford, Warren, Alexandria City, Fairfax City, Falls Church City, Fredericksburg City, Manassas City, Manassas Park City, VA; Berkeley, Jefferson, WV;	8840	District of Columbia, DC; Calvert, Charles, Frederick, Montgomery, Prince GeorgeâĂŹs, Washington, MD; Alexandria city, Arlington, Clarke, Fairfax, Fairfax city, Falls Church city, Fauquier, Fredericksburg city, King George, Loudoun, Manassas Park city, Manassas city, Prince William, Rappahannock, Spotsylvania, Stafford, Warren, VA; Berkeley, Jefferson, WV	8840	DC: District of Columbia MD: Calvert, Charles, Frederick, Montgomery, Prince GeorgeâĂŹs VA: Alexandria City, Arlington, Clarke, Culpeper, Fairfax, Fairfax City, Falls Church City, Fauquier, Fredericksburg City, Loudoun, Manassas City, Manassas Park City, Prince William, Rappahannock, Spotsylvania, Stafford, Warren WV: Jefferson	8840

Codes are given for IPUMS-CPS *metarea* variable unless otherwise indicated. NA denotes that an MSA is not in the CEX sample in that period.

B.3 ROBUSTNESS CHECKS

The following table shows robustness checks that support the results in the main text. All regressions are 2SLS regressions with the Bartik instrument as an instrument for employment growth. Standard errors are clustered at the MSA level and the regressions include MSA fixed effects.

Column 1 shows that the main regression result is robust to not excluding any MSA. The coefficient on employment growth remains highly significant with a value of 0.4 instead of 0.42. Column 1 is the only regression that includes all MSA observations.

Using the CEX sample size of surveyed consumer units instead of the population size as a control variable (in column 2) changes the coefficient on employment growth only sightly, and the coefficient remains equally significant.

Column 3 shows the simple 2SLS regression without any control variables. In the main regression table 2.2, however, the lagged consumption-income ratio was slightly significant and positive, and therefore in a regression without this control variable, the coefficient on employment growth increases to 0.65.

The last column repeats the benchmark regression for the period before the Great Recession.[2]. Though only indicative given the low sample size of just 94 observations, the coefficient on employment growth is of similar magnitude, even if only slightly significant.

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[2]There are not enough observations to run this regression for the period since the Great Recession.

Table B.2: Robustness Checks

	CI	CI	CI	CI
	(1)	(2)	(3)	(4)
ΔEMP_t	0.404***	0.348***	0.653***	0.444*
p-value	(0.001)	(0.004)	(0.000)	(0.078)
CI_{t-1}	0.148**	0.168*		-0.0826
p-value	(0.047)	(0.073)		(0.518)
ΔEMP_{t-1}	0.135	0.0769		0.230*
p-value	(0.237)	(0.451)		(0.081)
Emp Population	-1.66e-08			-4.79e-08**
p-value	(0.211)			(0.037)
Pct Homeowner	0.000437	0.000309		-0.00314
p-value	(0.751)	(0.851)		(0.137)
Age	0.00383	0.000844		0.00131
p-value	(0.330)	(0.855)		(0.784)
Consumer Units		-0.00000607		
p-value		(0.668)		
N	166	155	183	94

These regressions show the consumption-income ratio as independent variable. Column 1 repeats the benchmark regression without dropping any MSA. Column 2 replaces the employed population control with the CEX sample size. Column 3 shows the simple regression and column 4 an indicative regression for the period up to 2008. As before, employment growth is instrumented for with the Bartik instrument, all regressions contain 28 MSA, MSA fixed effects and standard errors are clustered at the MSA level. P-values are in parenthesis and stars indicate significance at the 10% (*), 5% (**) and 1% (***) level.

The following table B.3 shows the regression results of the consumption-income ratio on employment growth on simulated data from the NK model developed in Stamm (2017). As dependent variable I use the consumption-income ratio of both types of households as well as the aggregate consumption-income ratio. Columns 1-3 give the estimated coefficient of a simple OLS regression of the consumption-income ratio on employment growth, and columns 4-6 are similar regressions to the ones in the main text. Here, the instrument for contemporary employment growth is the twice-lagged employment growth.

CI_U refers to the consumption-income ratio of uninsured households who face unemployment risk, CI_R to insured households, and CI_{AGG} to the aggregate consumption-income ratio. The data are a simulation of 5000 quarters based on the estimated model.

The results show that for insured agents the response to employment growth is either negative or not significant, whereas uninsured agents increase their relative consumption if employment growth is high. In the aggregate, these two responses average out in the simple regression, and a positive coefficient of 0.88 in the instrumental variable regression.

Overall, the correlation between the consumption-income ratio and employment growth is 0.0721 for uninsured households, -0.1024 for insured households and -0.0193 in the aggregate. In the CEX data, this correlation is equal to 0.0962[3].

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[3]In a simulation of 5000 periods of the estimated representative agent version of the model, this correlation is -0.0545, the coefficient of employment growth is a highly significant -0.16 in the OLS regression and not significant in the 2SLS regression.

Table B.3: Model Estimation Results

	OLS			2SLS		
	CI_U	CI_R	CI_{AGG}	CI_U	CI_R	CI_{AGG}
	(1)	(2)	(3)	(4)	(5)	(6)
ΔEMP_t	0.367***	-0.226***	-0.0510	2.390***	0.0697	0.875**
p-value	(0.000)	(0.000)	(0.173)	(0.000)	(0.707)	(0.014)
ΔEMP_{t-1}				-0.453***	-0.0959***	-0.220***
p-value				(0.000)	(0.000)	(0.000)
$CI_{U,t-1}$				0.884***		
p-value				(0.000)		
$CI_{R,t-1}$					0.950***	
p-value					(0.000)	
$CI_{AGG,t-1}$						0.910***
p-value						(0.000)
N	5000	5000	5000	4998	4998	4998

These regressions show the consumption-income ratio of insured, subscript R, uninsured, subscript U, and in the aggregate as dependent variable and employment growth as independent variable for 10,000 simulated quarters of the estimated model in Stamm (2017). For the 2SLS regressions, I use twice-lagged employment growth as an instrument for current employment growth. P-values are in parenthesis and stars indicate significance at the 10% (*), 5% (**) and 1% (***) level.

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