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Essays on Macroeconomics

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Abstract

My dissertation consists of three essays on Macroeconomics. In the first two chapters, I study the implications of uncertain expenses for households' savings and for their consumption adjustment in response to monetary policy. In the third chapter, I study how asset liquidity affects households' ability to smooth idiosyncratic income shocks.

In the first chapter, I characterize uncertain expenses using U.S. Consumer Expenditure Survey data. Here, my goals are twofold. First, I classify households' spending that captures uncertainties in expenses (for example, car and home repairs or out-of-pocket medical expenses) and measure their overall importance. Second, I aim to understand how households adjust expenditures in response to monetary policy. I find that uncertain expenses represent 14.5% of total expenditures for a typical household in the U.S. and display significantly larger fluctuations than other expenses. I further show that uncertain expenses drive 41.8% of households' short-run consumption adjustment in response to monetary policy.

In the second chapter, I develop a model to study the quantitative importance of uncertain expenses for households' savings, especially for portfolio choice among assets with different liquidity, and examine monetary policy implications. The model features heterogeneous agents with incomplete markets for two assets, a low-return/liquid asset (money) and a high-return/illiquid asset (bonds). Households can use these assets to self-insure idiosyncratic risk with respect to both income and expenses. Due to frictions in the goods market and in the portfolio choice problem, self-insurance against expenditure risk is a significant driver of money demand and household portfolio rebalancing explains 80% of households' short-run adjustment in uncertain expenses in response to monetary policy. In addition, the model is consistent with the high level of concentration in the distribution of money holdings observed in the data, a feature hard to explain with traditional transaction motives for money demand.

In the third chapter, I study how asset market illiquidity affects risk-sharing among asset holders. I build a model where assets are traded subject to search and matching frictions with the transaction price determined as the solution to a bargaining problem between buyers and sellers. In addition, matching efficiency in this market endogenously determines the degree of asset illiquidity. After a loss in liquidity, the pricing mechanism derived from the bargaining problem tightens the budget constraint for sellers of the asset, who can then finance less consumption. Consequently, the consumption wedge between asset holders increases, and there is a deviation from perfect risk sharing.

Keywords: Money demand, Incomplete markets, Portfolio choice, Monetary policy

Summary for the Lay Audience

In the first two chapters, I study how monetary policy affects households' ability to meet uncertain expenses, like car and home repairs or out-of-pocket medical expenses. I show that self-insurance motives against expenditure risk imply a novel direct channel for the transmission of monetary policy to consumption. The mechanism operates through households' optimal portfolio rebalancing, among assets with different liquidity (and different returns), in response to changes in the policy rate. The main contributions are the following. First, I empirically document that the basket of uncertain expenses is highly sensitive to changes in the policy rate, accounting for almost half of households' short-run consumption adjustment in response to monetary policy shocks (in the form of unanticipated adjustments in the policy rate). Second, I propose a novel transmission channel for monetary policy to explain these empirical results, in which the key mechanism operates through household portfolio rebalancing. Third, I show how this channel works in a quantitative macroeconomic model and find that it explains 80% of households' adjustment in uncertain expenses. Overall, this allows us to refine our understanding of the channels through which monetary policy operates. In particular, on both this rebalancing channel and the speed of the transmission of monetary policy, since this rebalancing channel operates in the quarters immediately after a policy change, affecting the short-run response of consumption. Last, in the third chapter, I study how lower asset liquidity due to search frictions, affects households' ability to smooth idiosyncratic income fluctuations.

Dedication

To my wife Xime and my daughter Inés

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Chapter 1

Uncertain Expenses

1.1 Introduction

Uncertain expenses have gained attention as an important precautionary savings motive for households. However, there is as yet no consensus concerning the set of expenditure items that can be considered uncertain. For example, these items have ranged from only medical expenses (De Nardi et al., 2021) to include car repairs (Miranda-Pinto et al., 2020), or to also include job training and enrichment activities for children (Chase et al., 2011; Collins, 2015). In this chapter, I use U.S. Consumer Expenditure Survey data to characterize uncertain expenses as those for which the exact timing is difficult to predict by households. Here, my goals are twofold. First, I classify households' spending that captures uncertainties in expenses and measure their overall importance. Second, I aim to understand how households adjust different types of expenditures in response to monetary policy decisions.

I distinguish between three broad types of expenditures with different implications for Household savings that will be further studied in Chapter 2. First are expenses that I label as "certain" since households have a good idea of how much liquidity they need. Examples are food at home, utilities, or gasoline purchases. These expenses happen regularly, with similar magnitude; therefore, they have low volatility. They represent around 60% of total expenses. The second group includes volatile expenses that are anticipated. These include "durable" expenses, for example, home furnishings and appliances, and also those labelled by previous work as "memorable," like vacations or entertainment. I will focus most of my analysis on the third category, which corresponds to uncertain expenses. This category includes volatile expenses that are unanticipated by households. Examples are car and home repairs and out-of-pocket medical expenses, but also include some education services (like tutoring, test preparation and materials) and also some household operations (like termite/pest control or vet services) representing around 15% of the total consumption basket.

Having defined these three expenditure categories, I evaluate how households adjust their spending on them in response to changes in monetary policy. In particular, I compute the response to a 25bp interest rate cut over a 15-quarter horizon.

I find a stark difference in the dynamic adjustments of these expenditure categories. Certain expenses are not sensitive to monetary policy shocks at all. This is not surprising as they are often fixed and recurrent expenses, and it is easier for households to plan them, making them very inelastic. The important implication here is that although they represent the bulk of Household expenses, most of the consumption response to monetary policy comes from the other two categories. The response of memorable and durable expenses is lagged and peaks at around 12 quarters after the shock, consistent with what the literature finds. This leaves uncertain expenses as an important driver of the short-run consumption response. Accordingly, the response of uncertain expenses peaks much earlier, at around 5 quarters after the shock and dissipates sooner.

To gain some perspective on the magnitudes of these adjustments, I convert these impulse response functions into a cumulative dollar change per household. Households' average total expenses increase by $120 in the short run (after 5 quarters), and uncertain expenses are responsible for around 40% of this increase. This is a large response for a category representing only 15% of total expenses. And also signals a high elasticity of uncertain expenses to changes in the policy rate. This picture changes in the long run as the bulk of households' adjustment over the 15-quarter forecast period is on memorable and durable expenses, which increase by around $350, while uncertain expenses increase by $75.

Related literature. This chapter contributes to two strands of the literature. First, it contributes to the literature showing that expenditure risk drives savings behavior. For example, De Nardi et al. (2010, 2021) have found that out-of-pocket medical expenses are an important precautionary savings motive for retirement. I find that this precautionary savings motive is also present at other stages of the life cycle and for a broader set of expenditure items. Second, this chapter contributes to the empirical literature on the consumption response to monetary policy shocks. Previous work has focused on the overall response (Kaplan et al., 2018; Nakamura, 2019; Slacalek et al., 2020; Luetticke, 2020a; Wong, 2021; Eichenbaum et al., 2022) or on the response in durable expenses (Sterk and Tenreyro, 2018; Cloyne et al., 2019; McKay and Wieland, 2021). I provide novel insights on the short-run transmission of monetary policy to consumption by studying the response of uncertain expenses.

1.2 Consumer Expenditure Survey (CEX)

The CEX is a rotating panel that gathers detailed information on consumption expenditures for a representative sample of households in the US. Each household is interviewed up to four times during a 12-month period and is asked to report expenses for the preceding three months. In addition to consumption data, the survey gathers comprehensive information on household income and other characteristics. After completing the four interviews, each household is replaced, so at any given quarter, 20% of the sample is replaced by new households.

Each expenditure item reported by a household is identified by a Universal Classification Code (UCC). There are around 600 UCCs. I use the BLS defined "major categories", which summarize UCCs into groups of around 40 types of expenses, to have a broad enough set of items that ensures consistency across the various waves of the survey, but narrowly enough to exploit the richness of the data. Then, I map each one of these items into nondurables, services, or durables, as defined by the National Income and Product Accounts (NIPA).[1] Each of these items is deflated by the corresponding price index in the NIPA tables, while household income is deflated by the Consumer Price Index (CPI) for all items. I use 3-month expenditures for each household.[2]

The sample is from 1984 to 2007. As is common in the literature, I exclude households that are incomplete income reporters, those that report zero food expenditures, and also those that report negative or zero net income. In addition, I only include households for which the reference person is 25-64 years of age, and exclude those who are self-employed. Lastly, I exclude those households that do not have all four periods of expenses reported, as well as those for whom inconsistent information on major characteristics (age, sex, or race) of the reference person is reported at any interview.

1.3 A volatility-based approach

My main interest is to capture uncertainties in expenses that households face when making portfolio decisions. In general, I distinguish between two broad types of expenditures: (i) spending

[1] See Table A.1, in Appendix A.1, for this mapping.

[2] Although the data is available at a monthly frequency, the within-interview variation is much lower than the between-interview variation because the BLS processes many individual expenditure categories assigning a third of the reported spending to each of the three months. This mechanical adjustment affects the volatility measures described in the following section.

on goods that are frequently purchased with little variability over time, and (ii) spending on items that vary considerably over time, even conditional on household income. To determine the set of uncertain expenses, I remove from these variable expenditure items those that may be infrequently purchased but also fairly anticipated, such as durables and memorable goods as defined by Hai et al. (2020).

As a broad approach to assess expenditure risk, I use a volatility measure for a detailed set of expenditure categories $\{exp^j\}_{j=1}^J$. Raw volatility in expenditures might not be fully informative about uncertainty, as it could reflect predictable variation, or seasonal volatility. Following a similar approach to Telyukova (2013); Telyukova and Visschers (2013), I filter out the predictable component of expenditures by estimating the following model for each expenditure item:[3]

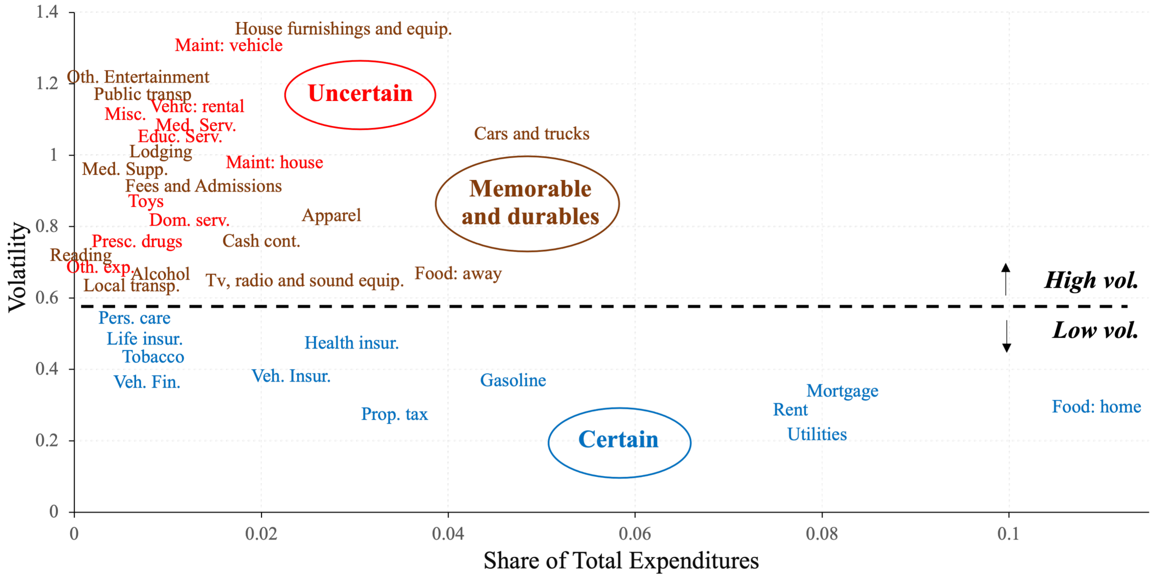
$$\begin{aligned} \log(exp_{i,t}) &= \alpha_i + \delta_t + \gamma X_{i,t} + \varepsilon_{i,t} \\ \varepsilon_{i,t} &= \rho\varepsilon_{i,t-1} + \eta_{i,t}, \end{aligned} \tag{1.1}$$

where α_i is a household fixed effect; δ_t are $\{month, year\}$ time indicators; $X_{i,t}$ are observable demographic characteristics (such as age, race, sex, education, household size); and, $\varepsilon_{i,t}$ is an idiosyncratic persistent component of expenditures. The relevant volatility measure for each category is defined as the standard deviation of unpredicted innovations to the persistent component (σ^η).

Figure 1.1 shows this volatility measure for each category j in $\{exp^j\}_{j=1}^J$ (y-axis) and its relative share of total expenditures (x-axis). We observe that the least volatile items are also those with the largest share in total expenditures (for example, food at home, utilities, rent, mortgage payments, property taxes, insurance), while the more volatile expenditure items each represent

[3]This approach has been widely used to measure income uncertainty. However, as noted in Telyukova (2013), there is an important difference between measuring income versus consumption uncertainty, in that the measures of income uncertainty can be interpreted directly as measures of income shocks, while consumption uncertainty measures only a discretionary response to the shock.

Figure 1.1: Volatility of expenditure categories



Note: Calculations are based on the CEX, the sample is from 1984 to 2007. Each volatility measure is computed by estimating the model described in (1.1), where the set $\{exp\}$ are all those expenditure items that add up to nondurables and services, as defined in the NIPA aggregates (See Table A.1 for this mapping).

a lower share of total expenditures. The dotted line represents a weighted average volatility of all expenditure items ($\overline{\sigma^{\eta}}$).[4] These items belong to one of the two major components (i) or (ii), discussed earlier, if its specific volatility measure is below or above $\overline{\sigma^{\eta}}$, respectively.

Part of the volatility in expenses may be an anticipated optimal non-smooth household consumption plan due to durable or memorable goods as noted by Hai et al. (2020) (HKP). According to their definition, a good is memorable if a consumer draws utility from her past consumption experience. For example, a large vacation once in a while will be enjoyed for months afterwards. They find that the set of memorable goods is around 16% of total expenses and include items such as: Trips and vacations; Entertainment; Food and alcohol out; and, Clothing (see Table 1 in HKP).

In defining uncertain expenses, I remove from the set of volatile expenses all those items that are considered as durables or as memorable in HKP, since high volatility in these goods does

[4]Weighted by the share of total expenses for each individual item.

not reasonably reflect uncertainty with respect to the timing of the expenses. I then define three major categories. “Certain” expenses correspond to the set of non-volatile items, which reflect those regularly purchased and known to the household. “Uncertain” expenses are those unanticipated-volatile items. Last, anticipated-volatile items are defined as “memorable and durables”. Figure 1.1 shows the set of uncertain items in red, certain items in blue and, the set of memorable and durables in brown.

The main interest in this dissertation is to study the importance of uncertain expenses for household savings, while Campbell and Hercowitz (2019) study the case in which households accumulate liquid assets to pay for a foreseen durable or memorable expense. Although these items are anticipated by households, they are distinct from certain expenses as they have different implications for household savings.

1.3.1 By household groups based on income

I compliment the analysis presented above by further exploring how uncertain expenses vary across the income distribution. This allows us to understand whether the expenditure patterns, as shown in Figure 1.1, are dominated by a particular group of households. It also shows the relative importance of uncertain expenses with respect to total expenses.

First, I estimate model (1.1) using total expenditures in certain, uncertain and, memorable and durables (separately), for three household groups based on their income: low (deciles 1-3), medium (deciles 4-7) and high (deciles 8-10). As shown in Panel I of Table 1.1, uncertain expenses are around four times more volatile than certain expenses for all three household groups, since their relative volatility is constant.[5] This suggests that uncertainties in expenses are present for all household groups. The fact that volatility for all categories is decreasing in

[5]Measured by the volatility ratio of uncertain to certain expenses.

Table 1.1: Expenditure Risk by Household Groups
(based on income)

	(A) **Certain**		(B) **Uncertain**		(C) **Memorable and durables**		*Relative*	
I. Volatility							*(B)/(A)*	*(C)/(A)*
Low	0.23		0.93		0.88		4.1	3.9
Medium	0.18		0.78		0.83		4.3	4.6
High	0.16		0.69		0.78		4.2	4.8
All	**0.19**		**0.81**		**0.84**		**4.2**	**4.3**
II. Shares (%)		*(vs Low)*		*(vs Low)*		*(vs Low)*		
Low	69.1		9.4		21.5			
Medium	61.3	(-7.8)	14.2	(4.8)	24.5	(3.0)		
High	54.3	(-14.8)	18.3	(8.8)	27.4	(5.9)		
All	**61.5**		**14.5**		**24.0**			

Note. Calculations based on the CEX. Groups are based on household income: low (decile 1-3), medium (decile 4-7) and high (decile 8-10).

income reveals that lower income households are hitting a borrowing constraint more often than higher income households.

Second, I calculate the average share of the three major categories, with respect to total expenditures, for the three household income groups. Panel II of Table 1.1 shows that uncertain expenses represent 14.5% of total expenditures for the full sample. Also, the share of both uncertain and, memorable and durable expenses is increasing in income. However, the relative increase for high income households, with respect to low income households, in uncertain expenses (8.8%) is higher than that observed in memorable and durable expenses (5.9%), revealing that higher income households are better able to self-insure expenditure risk.

1.4 Consumption response to monetary policy

This section documents that a large fraction of the short-run consumption response to monetary policy shocks is driven by uncertain expenses. I measure the sensitivity of the three broad expenditure categories, defined in the previous subsection, to changes in the policy rate using pseudo-panels from the CEX.[6] In particular, I use a local projection to construct impulse response functions of these expenditure categories to monetary policy shocks as in Jorda (2005).

*Monetary policy shock*s. I use an updated series of policy shocks identified using the narrative approach by Romer and Romer (2004). The method first derives a series of intended Fed funds rate movements around FOMC meetings, which eliminates much of the endogenous relationship between interest rates and economic conditions.[7] Then, the change in the intended rate is regressed on the Federal Reserve's internal forecasts of inflation and real activity, to filter policy actions taken in response to expected future economic developments.[8] The residuals from this two step procedure show changes in the policy rate relatively free from both endogenous and anticipatory actions.

Pseudo-panels. I build pseudo-panels in the CEX based on the household's housing tenure status (renters, mortgagors, and owners) as in Cloyne et al. (2019) (CFS). I focus on renters and mortgagors, since CFS show that these household groups drive the consumption response to monetary policy shocks, while owners do not change their expenditures. In order to build a quarterly time series consistent with the series of monetary policy shocks, I assign household monthly expenses to the specific calendar-quarter when the expense took place.[9]

Empirical specification. I follow the empirical specification from CFS. The expenditure item

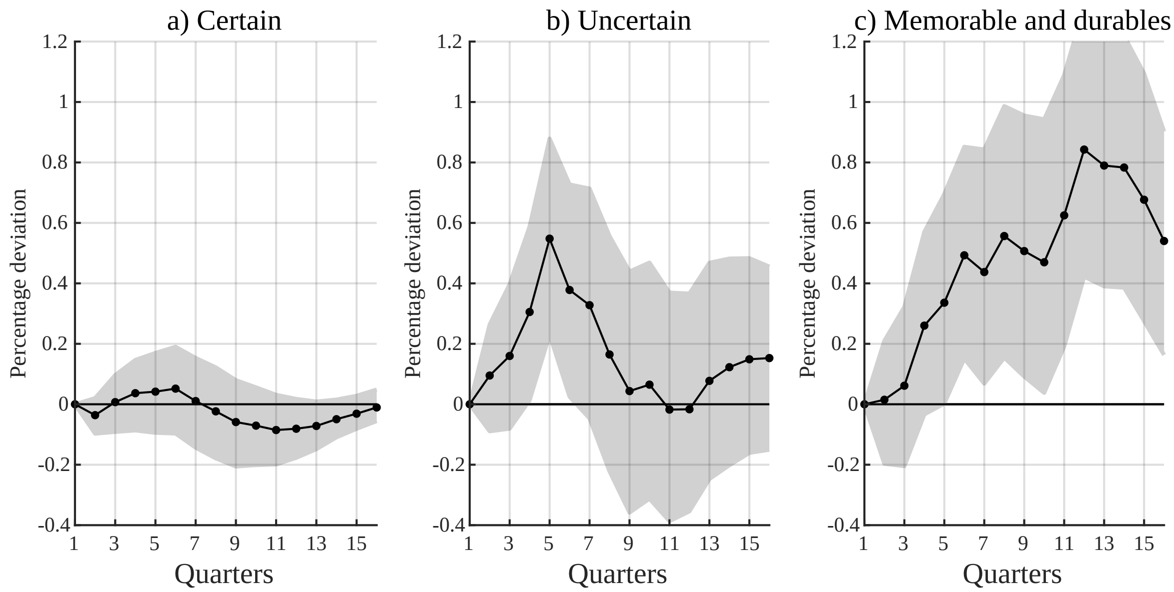
[6]The response of durable goods has been widely studied in the literature (Sterk and Tenreyro, 2018; Cloyne et al., 2019; McKay and Wieland, 2021)

[7]Romer and Romer use the Weekly Report of the Manager of Open Market Operations with detailed readings of the Federal Reserve's narrative accounts of each FOMC meeting.

[8]The "Greenbook" forecasts are prepared by the Federal Reserve staff before each meeting of the FOMC.

[9]The 3-month expenditure period for each household does not always coincide with a calendar-quarter.

Figure 1.2: Dynamic effects of a 25 bp unanticipated interest rate cut*



*This figure shows how households adjust their spending on the three expenditure categories, defined in Section 1.3, in response to monetary policy shocks (Certain: regular, low-volatility expenses; Uncertain: unanticipated volatile expenses; Memorable and durables: anticipated volatile expenses). Note: Gray areas are bootstrapped 90% confidence bands.

is regressed on a distributed lag of the monetary policy shocks, while also controlling for the lagged endogenous variable. In particular, I estimate the following equation:

$$X_{j,t} = \alpha_0^j + \alpha_1^j trend + B^j(L)X_{j,t-1} + C^j(L)S_{t-1} + \sum_{q=2}^{4} D_q^j Z_q + u_{j,t}, \tag{1.2}$$

where X_j is an expenditure item (certain, uncertain, or memorable and durables), S is the monetary policy shock, Z is a vector of quarterly dummies, and the α's represent a linear time trend.

Figure 1.2 displays the dynamic response of the expenditure categories to a 25 bp unanticipated interest rate cut. A striking feature about uncertain expenses revealed in this Figure is that they are highly sensitive to changes in the interest rate, while certain expenses are not. In addition, there is a stark difference in the shape of the response of uncertain expenses compared to the response of memorable and durable expenses. The response of memorable and durables tends to be lagged and peaks at around 12 quarters after the shock, while the peak of the response

Table 1.2: Average Cumulative Consumption Response
(in 2000 US dollars, per household)

Time after the shock *(in quarters)*	**Certain**	**Uncertain**	**Memorable and durables**
5	15.0	51.3	56.3
10	-10.3	67.8	179.2
15	-45.7	75.2	347.5

Note: The table reports the dollar change in expenditure after 5, 10 and 15 quarters following a temporary 25 bp unanticipated interest rate cut. The magnitudes are per household averages.

of uncertain expenses comes much earlier, at around 5 quarters after the shock, and dissipates sooner.[10]

In Table 1.2, I convert these impulse response functions into an average cumulative dollar change (per household) for 5, 10 and 15 quarters after the shock. The bulk of households' adjustment over the 15-quarter forecast period is on memorable and durable expenses, which increase by $347, while uncertain expenses increase by $75. However, when looking at the short-run response (after 5 quarters), we observe an increase in uncertain expenses of $51, comparable to the $56 increase in memorable and durable expenses during that same period. The increase in uncertain expenses represents 41.8% of the total short-run increase in households' expenses of $122.

1.5 Conclusion

Using micro-data from the Consumer Expenditure Survey (CEX), I characterize uncertain expenses using a volatility-based approach. I document the following three novel facts of uncertain expenses. First, uncertain expenses represent 14.5% of total expenses. Second, expenditure risk is present at all levels of household income. Third, uncertain expenses represent a larger

[10]It is commonly found in the literature that the response of durables presents lags at around 10 to 12 quarters after the shock (Sterk and Tenreyro, 2018; Cloyne et al., 2019; McKay and Wieland, 2021).

share of total expenses for high-income households than for low-income households. In addition, I show that uncertain expenses are highly sensitive to changes in the policy rate and are an important driver of the short-run consumption response to monetary policy.

In the next chapter, I will develop a dynamic quantitative model to help understand the implications of expenditure risk for household savings, particularly liquidity management. In this model household portfolio rebalancing, among assets with different degrees of liquidity, will be an important mechanism that explains the shape of the response to monetary policy shocks of uncertain expenses documented in Figure 1.2.

Chapter 2

Household Liquidity Management with Uncertain Expenses

2.1 Introduction

In this chapter, I study the quantitative importance of uncertain expenses for households' savings, especially for portfolio choice among assets with different liquidity. I then examine the implications for monetary policy. Following the interpretation from Chapter 1, uncertain expenses are those for which the exact timing is difficult to predict, for example car and home repairs or out-of-pocket medical expenses. I show that self-insurance motives against expenditure risk imply a novel direct channel for the transmission of monetary policy to consumption, through households' optimal portfolio rebalancing in response to changes in the central bank's policy rate. Concretely, changes in the relative price of assets impact consumption by affecting households' ability to meet uncertain expenses.

The main contribution of this chapter is to develop a model in which self-insurance against expenditure risk is a significant driver of money demand, and to show that household portfolio rebalancing is an important mechanism for understanding the short-run transmission documented in the previous chapter. Notably, the model is consistent with the high level of concentration in the distribution of money holdings observed in the data, a feature hard to explain with traditional transaction motives for money demand.[1]

The model features heterogeneous agents with incomplete markets in two assets, a low-return/ liquid asset (money) and a high-return/illiquid asset (bonds). Households can use these assets to self-insure idiosyncratic risk with respect to both income and expenses. Income risk is standard in that households have partially persistent labour income and may receive shocks in each period. To capture expenditure risk, I follow the results from Chapter 1. Households can purchase two consumption goods, a certain consumption good that captures regular and predictable spending, and a second good with fluctuating marginal utility capturing uncertain expenses. I allow for a nonhomothetic utility function between the two goods in the model that will help match differences in expenditure shares that I observe in the data.

Differences in asset liquidity and money demand arise from two frictions that I introduce in the model. First, I introduce real transaction costs in the goods market requiring households to make a certain fraction of their transactions using money. Second, a timing friction in the portfolio choice problem creates liquidity differences between money and bonds. Households allocate their portfolio after income risk is resolved but before they know the marginal utility of uncertain expenditures. Only a fraction of the uncertain expense can be financed using bonds, and the rest must be financed with money. The model captures the necessity of planning for uncertain expenses given large penalties associated with selling illiquid assets, or some might be subject to fixed-term contracts (retirement accounts or fixed-period savings accounts).

[1] Theories that focus on a pure transaction role for money have been unsuccessful in matching the concentration of money holdings since money is much more unequally distributed than consumption, instead resembling inequality in financial wealth (Ragot, 2014). For example, the *Gini* coefficient for money and bonds is around 0.80, while for consumption it is 0.29. In addition, the fraction of the stock of money and bonds held by the top 10% of the population is 58% and 78%, respectively, while the top 10% accumulates only 23% of total consumption.

This generates a micro-founded and tractable money-demand relationship consistent with the novel facts I establish in the previous chapter. In particular, this relationship encompasses traditional motives for holding money—transaction purposes and the opportunity cost of holding it (i.e., giving up the higher return on bonds)—as well as a novel precautionary motive based on the need for liquidity to meet uncertain expenses. I further derive necessary conditions under which money demand, relative to total consumption, increases along with wealth, generating inequality in money holdings.[2] I use moments from the Consumer Expenditure Survey, documented in Chapter 1, to assess these conditions, while their overall quantitative importance depends on the strength of both the timing friction in the portfolio choice problem and the goods market friction.

The main mechanism in this model operates through households' self-insurance motives given expenditure risk, where expenditure shocks generate an inefficient ex-post allocation of money. Some households hold money but have no current need for it because they have a low-marginal utility of uncertain goods, creating liquidity accumulation. In contrast, others hold insufficient money for their needs because they have high marginal utility for uncertain goods. However, since holding money is costly, they are constrained in how much uncertain goods they can purchase.[3] This leaves some room for monetary policy to impact aggregate demand by directly affecting the cost of holding money.

Monetary policy changes the relative price between money and bonds. For example, a lower nominal interest rate reduces the return of bonds (relative to money), which makes it cheaper for households to hold more money. This allows them to better self-insure expenditure risk and increases average uncertain expenses. I label this novel direct effect the "portfolio rebalancing

[2]While higher wealth is associated with greater absolute money holdings, they represent a smaller fraction of the portfolio. Following the Bewley-Huggett-Aiyagari tradition, *inequality* refers to the endogenous outcome of uninsurable risk combined with households' ability to self-insure.

[3]Berentsen et al. (2015) show that a money market can provide insurance against similar liquidity shocks by providing short-term loans and paying interest on money market deposits. However, under the definition of NewM1 (which includes money market deposits), the inefficient allocation remains as households would be better off if they could earn the nominal interest rate paid by bonds.

channel" for the transmission of monetary policy to consumption.

To assess the importance of this transmission channel I compute a model-implied impulse response to an aggregate nominal interest rate shock. I solve for the sequence of policy functions and distributions of agents along the transition path, given a path for the nominal interest rate that summarizes monetary policy, using the method of Boppart et al. (2018). I find that the portfolio rebalancing channel explains both the magnitude and the shape of the consumption response found in the data. This differs from other transmission channels that take longer to materialize (through adjustments in labor income or housing assets, for example).[4] This fast consumption response is explained by a relatively quick portfolio adjustment by households after changes in the nominal interest rate.[5]

Finally, I show that the model is able to generate concentration in the distribution of money holdings by comparing the stationary distribution of both assets in the model, to a version without uncertain expenses in which money demand is equivalent to that obtained in a standard Heterogeneous-Agent Cash in Advance (HACIA) model. I find that incorporating uncertain expenses increases the *Gini* coefficient for the distribution of money to 0.51, while it is only 0.29 in the HACIA model, similar to that of consumption. Incorporating uncertain expenses also produces a modest increase in the *Gini* coefficient for the distribution of bond holdings, suggesting that the precautionary motive towards uncertain expenses studied in this chapter contributes to understanding overall wealth concentration.

Related literature. This chapter contributes to a large literature studying the transmission of monetary policy to consumption. In particular, it presents a novel transmission channel, based on self-insurance motives towards expenditure risk, that helps us understand the short-run monetary policy transmission. Previous work has focused on the overall consumption response

[4] See the evidence provided by Cloyne et al. (2019).

[5] See Drechsler et al. (2017) for evidence at the aggregate level, and Luetticke (2020a) for evidence at the household level.

(Kaplan et al., 2018; Nakamura, 2019; Slacalek et al., 2020; Luetticke, 2020a; Wong, 2021; Eichenbaum et al., 2022) or on the response in durable expenses (Sterk and Tenreyro, 2018; Cloyne et al., 2019; McKay and Wieland, 2021). Others have studied the implications of idiosyncratic income risk for monetary policy (Bayer et al., 2019; Bilbiie and Ragot, 2021); this chapter is the first to analyze idiosyncratic expenditure risk.

This chapter also contributes to the literature on the determinants of money demand in models with heterogeneous agents and incomplete markets. Early studies consider money as the only available asset to self-insure idiosyncratic income (Bewley, 1983; Imrohoroglu, 1992), while more recent work introduces additional frictions to justify a positive money demand in environments where money is dominated by other assets. Erosa and Ventura (2002) use a transaction technology that exhibits economies of scale (wealthier households use less money–*cash* in transactions) to study the redistributive effects of inflation. Akyol (2004) studies an economy where money is valued due to a similar timing friction as in this chapter.

The liquidity-accumulation mechanism studied in this chapter provides a complementary explanation to the financial approach to money demand developed by Ragot (2014). The financial approach postulates that with sufficiently high participation costs in financial markets, money is a good vehicle to self-insure income risk. The approach developed in this chapter is closer to that found in Allais et al. (2020), who propose non-homothetic preferences towards liquidity to capture inequality in money holdings, where wealthier households accumulate more money balances. In contrast to them, I infer liquidity preferences by using expenditure data at the household level.

The model developed in this chapter shares some similarities with the cash-credit specification found in Telyukova (2013), based on the idea from Lucas and Stokey (1987) that households choose to purchase goods using either cash or credit. However, this approach is not well suited for my purposes. First, it relies on the assumption that a particular set of items need to be purchased with cash, which is hard to justify. In addition, it ignores that there are important differences in the choice of payment methods across the wealth distribution (Erosa and Ventura, 2002). Second, there are no major volatility differences between these cash and credit goods in the data, so they do not capture the relevant uncertainty that is key in the portfolio choice problem studied in this chapter.

To my knowledge, this chapter is the first to study households' liquidity management with expenditure risk, within a literature that relates heterogeneous agents and incomplete markets in a monetary framework.

2.2 Model

In this section, I develop a heterogeneous-agent incomplete markets model (Bewley, 1983; Huggett, 1993; Aiyagari, 1994) with two assets: money and bonds. Households are subject to income and expenditure risk and decide their allocation over the two assets at the beginning of each period, after the uncertainty over income has been resolved, but before the realization of expenditure uncertainty. This timing friction in the portfolio choice problem creates liquidity differences between the two assets, as in Aiyagari and Williamson (2000) and Akyol (2004). I also introduce frictions in the goods market (representing real transaction costs) that allow me to generate a tractable money demand relationship. When expenditure risk is absent, money demand in this model is equivalent to that obtained in a standard Heterogeneous-Agent Cash in Advance (HACIA) model.

There are two types of consumption goods. First, a “certain” good c that tends to be less volatile and fluctuates with wealth, and represents expenditures that are known at the time when households decide over their portfolio allocation. Second, an “uncertain” good q that tends to be more volatile, even conditional on wealth, and represents those expenses unknown to the household. I model these differences in volatility by introducing a random preference ϑ for consuming the uncertain good q, which captures that some goods are only being consumed from time to time, making the exact timing of this expense difficult to predict. However, not having the liquidity to meet such expenditure needs might entail a high utility cost (for example, not repairing your vehicle if it broke down, or not going to the doctor if sick).

The timing friction in the portfolio choice problem implies that only a fraction $(1-\nu)$ of the uncertain good can be financed with bonds, and the remainder ν must be financed using money. This is meant to capture that some financial assets are subject to fixed term contracts or are costly to liquidate (for example insurance plans, retirement accounts, or fixed-term saving accounts), while money has almost no such restrictions and can be easily accessed at any time during the period (checking and money market deposit accounts, following the approach by Lucas and Nicolini, 2015). Basically, money is more liquid than bonds.

2.2.1 Households

There is a measure one of ex-ante identical households indexed by $i \in [0,1]$ who live for infinite periods in discrete time. Each household's expected discounted utility is given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t [u(c_{i,t}, q_{i,t}; \vartheta_{i,t}) \equiv \xi \frac{c_{i,t}^{1-\sigma}}{1-\sigma} + (1-\xi) \frac{\vartheta_{i,t} {q_{i,t}}^{(1-\theta)}}{1-\theta}], \tag{2.1}$$

where β is the discount factor; $c_{i,t}$ is the quantity of the certain good; $q_{i,t}$ is the quantity of the uncertain good; $\vartheta_{i,t}$ represents a preference shock for consuming the uncertain good, that is unknown at the time when households decide over their portfolio allocation; the weight ξ, governs the relative expenditure shares between certain and uncertain goods, and, $\theta < \sigma$ controls for differences in expenditure shares of the uncertain good for household's with different wealth.

Households maximize (2.1), subject to the following budget constraint:

$$\overbrace{c_{i,t} + \underbrace{q_{i,t}}_{exp.\ risk}}^{\mathbb{C}_{i,t}} + m_{i,t+1} + b_{i,t+1} = \underbrace{y_{i,t}}_{inc.\ risk} + \frac{m_{i,t}}{1+\pi_t} + (1+r_t)b_{i,t}, \tag{2.2}$$

where $\mathbb{C}_{i,t}$ denotes total expenses during the period; $y_{i,t}$ is household's income subject to shocks; $m_{i,t}$ are real money balances accumulated in the previous period, which are discounted by the inflation rate π_t, and $b_{i,t}$ are bond holdings that pay a real return of r_t, with $(1 + r_t) > {}^1/_{(1+\pi_t)}$. The details of the portfolio decision among real money balances or bond holdings are described in the following subsections.

2.2.2 Frictions

Goods Market (ϕ). Goods must be purchased with money according to the following reduced-form transactions constraint:

$$\phi[\underbrace{c_{i,t} + q_{i,t}}_{\mathbb{C}_{i,t}}] \leq m_{i,t+1}, \tag{2.3}$$

where ϕ represents real transaction costs, so the cost of consuming one unit of C is $(1 + \phi)$. This specification leads to an equivalent money demand relation as in models with a Cash-in-Advance constraint, as discussed in Section 2.4.2.

Timing in portfolio (ν). The timing friction in financial markets is meant to capture that money is more liquid than bonds. Only a fraction $(1 - \nu)$ of the uncertain good can be financed with bonds, and the remainder ν must be financed using money. Then, by combining expressions (2.2) and (2.3)

$$\phi\mathbb{C}_{i,t} \leq m_{i,t+1} = \underbrace{y_{i,t} + \frac{m_{i,t}}{1+\pi_t} + (1+r_t)b_{i,t}}_{Y_{i,t}} - b_{i,t+1} - \mathbb{C}_{i,t}, \tag{2.4}$$

where Y is known at the time when households decide the portfolio allocation, rearranging terms and dropping the time subscripts for simplicity leads to:

$$(1+\phi)[\underbrace{c+q}_{\mathbb{C}}] + b \leq Y. \tag{2.5}$$

So at the time when households decide their portfolio allocation, they take into account that only a fraction $(1-\nu)$ of the uncertain good can be financed by selling bonds, and the reminder fraction with money, so rearranging terms leads to:

$$\underbrace{\phi c + \underbrace{(\phi+\nu)q}_{\tilde{m}}}_{m^d} + \underbrace{b + (1-\nu)q}_{\tilde{b}} = Y - c, \tag{2.6}$$

where $(\tilde{m}, \tilde{b})$ are the relevant choice variables in the portfolio allocation problem, and money demand (m^d) has two components: one that is proportional to certain expenses ϕc, and another related to uncertain expenses $(\phi+\nu)q$.

The timing restriction imposed in the portfolio choice problem captures two broad costs. First, there are large penalties associated with liquidating bonds (illiquid assets), or some assets might be subject to fixed term contracts (retirement accounts, or fixed period savings accounts). Second, it is capturing the fact that credit is costly. Even in the case in which the uncertain good is purchased using credit, it is in the household's interest to liquidate the outstanding balance at the end of the period since, in general, holding extra money is cheaper than revolving credit card debt.

2.2.3 Idiosyncratic Risk

Income. A household's income evolves according to the following process:

$$\begin{aligned} \log y_{i,t} &= z_{i,t} + \varepsilon_{i,t} \\ z_{i,t} &= \rho z_{i,t-1} + \eta_{i,t} \end{aligned} , \tag{2.7}$$

where ε and η are persistent and transitory shocks.

Expenditure. The preference shock is drawn from the following distribution:

$$\log \vartheta_{i,t} \sim i.i.d\ N(0, \sigma_{\vartheta}^2), \tag{2.8}$$

where σ_{ϑ} is the standard deviation of the preference shock.

2.2.4 Recursive Formulation of the Household's Problem

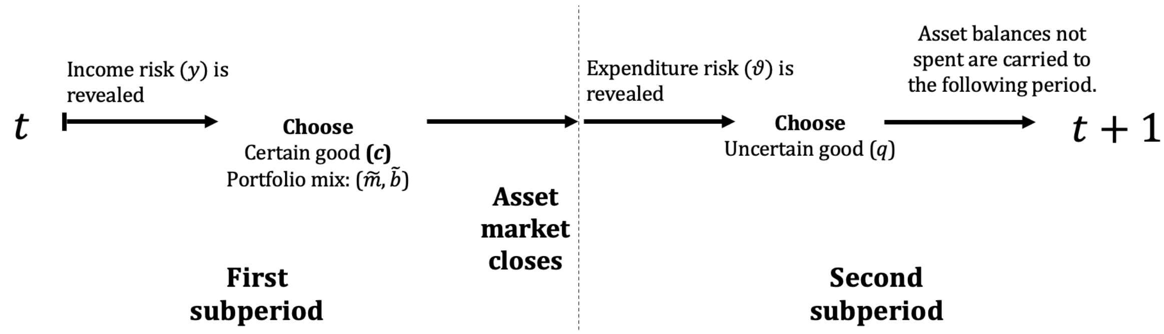
The timing of events leads to a natural division of the household's problem into two subperiods (as shown in Figure 2.1), let $V^1(\cdot)$ and $V^2(\cdot)$ be the value functions at the first and second sub-period, respectively. Then, the Bellman equations that characterize the dynamic programming problem for a household at each subperiod are as follows.[6]

First sub-period: Each household knows their income realization y, chooses their consumption of the certain good c and decides its portfolio allocation between money $\tilde{m}$ and bonds $\tilde{b}$

$$V^1(m, b, z, \varepsilon) = \max_{c, \tilde{m}, \tilde{b}} \left\{ E_{\vartheta} \left[V^2(c, \tilde{m}, \tilde{b}, z, \vartheta) \right] \right\} \tag{2.9}$$

[6]See Appendix B.1 for a simple two period model that illustrates the main mechanism in the model.

Figure 2.1: Timing of events



$$s.t. \qquad (1+\phi)c + \tilde{m} + \tilde{b} = \underbrace{z+\varepsilon}_{y} + \frac{m}{1+\pi} + (1+r)b, \tag{2.10}$$

the expectation operator is taken over the preference shock ϑ, which is unknown at this stage. According to the intuition developed in expression (2.6), money demand m^d for each household is:

$$m^d = \phi c + \tilde{m}. \tag{2.11}$$

Second sub-period: The preference shock ϑ is realized and households decide their consumption of the uncertain good q.

$$V^2(c, \tilde{m}, \tilde{b}, z, \vartheta) = \max_q \left\{u(c, q; \vartheta) + \beta \left[E_{\varepsilon'} E_{z'|z}\{V^1(m', b', z', \varepsilon')\}\right]\right\} \tag{2.12}$$

$$s.t. \qquad 0 < q \leq \min\left\{\frac{\tilde{m}}{(\nu+\phi)}, \frac{\tilde{b}-\underline{b}}{(1-\nu)}\right\}, \tag{2.13}$$

where end-of-period asset balances are given by the remainder after expenses of the uncertain good:

$$m' = \tilde{m} - (\nu+\phi)q \geq 0; \quad and, \quad b' = \tilde{b} - (1-\nu)q \geq \underline{b}. \tag{2.14}$$

2.2.5 Solution method

I solve the model in partial-equilibrium, given prices (π, r), in order to focus on the details of the household problem. In this section, I briefly describe the overall computational strategy to solve the household's problem and to obtain the stationary distribution of the model. Details are in Appendix B.4.

I start by reducing the dimensionality in the household's problem by redefining the state variables. I define household's *savings* as $x \equiv {}^{m}/_{(1+\pi)} + (1+r)b$, so that the evolution of savings can be expressed as:

$$x' = \frac{m'}{1+\pi} + (1+r)b', \tag{2.15}$$

where m' and b' are defined as in (2.14). Because the transitory component of the income process ε is i.i.d., it can be interpreted as a wealth shifter in the first subperiod of the household's problem. Then, define $\hat{x} \equiv x+\varepsilon$ as the relevant state variable for each household that summarizes total available resources (i.e., $V^1(\hat{x}, z)$); see the transformed version of the household's problem in Appendix B.2.

Decision rules. I solve for the value functions $\{V^1(\hat{x}, z), V^2(c, \tilde{m}, \tilde{b}, z, \vartheta)\}$, and for the corresponding policy functions $\{c(\hat{x}, z), \tilde{m}(\hat{x}, z), \tilde{b}(\hat{x}, z), q(\hat{x}, z, \vartheta)\}$ of the household's problem by adapting the Envelope Condition Method (ECM), developed by Maliar and Maliar (2013), to a multi asset environment. The general procedure is as follows. I start by solving the consumption-portfolio $(c, \tilde{m} + \tilde{b})$ decision in the first subperiod by inverting the envelope condition. Then, given a desired portfolio level in the first subperiod $(\tilde{m} + \tilde{b})$, I solve the optimal allocation problem considering the uncertainty in expenditures during the second subperiod (ϑ). The detailed procedure is developed in Appendix B.4.1.

Stationary distribution $\Gamma(\hat{x}, z)$. I adapt the non-stochastic simulation routine developed by Young (2010). There are two modifications made with respect to the standard routine. First, I do an additional iteration step in order to consider the idiosyncratic preference shock that captures expenditure risk. Second, I modify the algorithm to consider the arrival rates in the labor process. See Appendix B.4.2 for more details.

2.3 Calibration

The model period is one quarter and I calibrate the model in two steps. First, I set a group of parameters externally, with values commonly used in the literature. I then choose a second group of parameters to match targeted moments using micro-data from the Consumer Expenditure Survey (CEX) and the Survey of Consumer Finances (SCF). When matching consumption moments, I simulate a panel of households consistent with the structure of the CEX by using the stationary distribution of the model $\Gamma(\hat{x}, z)$, and the stochastic processes for idiosyncratic income and expenditure risk.

Before discussing the parameter values, I discuss the parametrization of both the income and the preference processes.

I discretize the income process (2.7) with the Rouwenhorst (1995) method and use three grid points for each of the persistent (η) and the transitory (ε) innovations. I then transform this process into a quarterly frequency by assuming that the innovations are drawn independently for each household from the following distributions:

$$\eta_{i,t} \begin{cases} 0 & 1-\lambda_\eta \\ N(0,\sigma^2_\eta) & \lambda_\eta \end{cases} ; \qquad \varepsilon_{i,t} \begin{cases} 0 & 1-\lambda_\varepsilon \\ N(0,\sigma^2_\varepsilon) & \lambda_\varepsilon \end{cases} , \tag{2.16}$$

where the arrival rates for both shocks $\lambda_{\eta,\varepsilon}$ are set to 0.25 so that each household receives income shocks on average once per year. As noted by Fuster et al. (2021), the alternative assumption in which households receive income shocks each period, generates unrealistically large transitory income risk. In addition, when the arrival rate for the transitory shock is too small (i. e. when $\lambda_\varepsilon \to 0$), the model is not capable of generating enough consumption volatility as observed in the CEX data. Similarly, I discretize the process for preference shocks and use two grid points.

Table 2.1: Benchmark Calibration

Exogenously chosen

Parameter	Description	Value	Source
Preferences			Standard values
β	Discount factor	0.98	·
σ	Coeff. of relative risk aversion	2.5	·
Labor innovation			Fuster et al. (2021)
Persistent component			
ρ_η	Persistence	0.987	·
σ_η	SD of innovation	0.043	·
λ_η	Arrival rate	0.25	·
Transitory component			
σ_ε	SD of innovation	0.6	·
λ_ε	Arrival rate	0.25	·
Other			
r	Real Interest rate (%)	0.47	Return on 3mo trasury bonds of 1.89% (1990-2007), see Ragot (2014)
π	Inflation rate (%)	0.58	Average annual inflation of 2.33% (1990-2007)

Endogenously calibrated

Parameter	Description	Value	Target	Model	Data
ξ	Relative weight	0.84	Average share of uncertain expenses. (CEX)	0.23	0.19
θ	Non-homotheticity	1.38	(H-L) diff. in the share of uncertain expenses. (CEX)	0.09	0.08
σ_ϑ	SD of preference shock	0.56	SD of uncertain/SD of certain expenses. (CEX)	4.26	4.20
ϕ	Goods market friction	0.04	Aggregate Money/Income. (SCF)	0.07	0.08
ν	Timing friction	0.86	Average liquidity: Aggregate Money/Bonds. (SCF)	0.12	0.12

2.3.1 Parameters and targets

Exogenously chosen. I take standard values from the literature for the the discount factor β and the coefficient of relative risk aversion σ. I follow Fuster et al. (2021) in exogenously setting the idiosyncratic income process terms $(\rho, \sigma_\eta^2, \sigma_\varepsilon^2, \lambda_\eta, \lambda_\varepsilon)$ to match the persistence and standard

Table 2.2: Untargeted Moments: Expenditure Risk by Household Groups
(based on income)

Volatility	(A) **Certain**	(B) **Uncertain**	*Relative* *(B)/(A)*
Low	0.17	0.67	4.1
Medium	0.14	0.60	4.2
High	0.12	0.53	4.4

deviation of earnings at a quarterly frequency. The real interest rate r is set to match the average real return on 3mo treasury bonds for 1990-2007. The inflation rate π is set to match average quarterly inflation in the period from 1990-2007.

Endogenously calibrated. These parameters concern the liquidity accumulation mechanism in the model and are jointly calibrated to match the following targets. The relative weight ξ is set to match the expenditure shares of certain and uncertain goods. θ, which captures the non-homotheticity in preferences, is calibrated to match the difference in shares of the uncertain component for the High and Low income groups. The standard deviation of the preference shock σ_ϑ, is set to match the relative volatility between certain and uncertain expenses. The goods market friction ϕ, is set to match the average aggregate money over income ratio from the (SCF). Last, the timing friction parameter ν is set to match average liquidity in the (SCF).

Un-targeted moments. Table 2.2 shows that the model generates two key features of certain and uncertain expenses as in the data. First, there is a constant relative volatility between certain and uncertain expenses for all household groups. This highlights that expenditure risk in the model is present for all households. Second, there is an overall decline in expenditure volatility among household groups. This decline in expenditure volatility stems from borrowing constraints and the presence of transitory income shocks, since the consumption response for lower income households tends to be greater than for higher income households.

2.4 Results

There are two main results in this chapter. First, portfolio rebalancing is an important mechanism that explains the short-run transmission of monetary policy to consumption. Second, the distribution of money holdings, when self-insurance against expenditure risk is an important driver of money demand, is consistent with the high level of concentration observed in the data.

2.4.1 Consumption response to monetary policy in the model

I study the portfolio rebalancing channel for the transmission of monetary policy to consumption in the model by computing a model-implied impulse response to a monetary shock (Boppart et al., 2018). To assess the importance of this channel, I evaluate how much of the response in the data, as shown in Section 1.4, can be accounted for in the model and highlight the timing of this channel compared to other potential transmission channels studied in the literature.

The transmission mechanism in the model is triggered by monetary policy affecting the relative price between money and bonds: for example, a lower nominal interest rate reduces the return of bonds (relative to money), which enables households to better self-insure uncertain expenses by reducing the cost of holding money, and thus increasing average consumption of the uncertain good. This transmission channel differs from other direct, or partial-equilibrium, effects (as summarized in Slacalek et al., 2020) since it involves an optimal decision for the household to adjust its relative asset composition, in response to the change in the central bank's policy rate.

The objective is to measure the importance of the proposed direct transmission channel that works through household portfolio rebalancing in isolation. This involves rewriting the model in terms of an explicit object that can be directly related to monetary policy, a short term nominal interest rate R. Then, define the monetary policy shock as ϵ, so we can find an explicit expression in terms of the policy instrument $R(\epsilon)$ by rewriting the evolution of savings (2.15) as:

$$\overline{x}' \equiv (1+r)\left[\frac{m'}{(1+R(\epsilon))} + b'\right], \tag{2.17}$$

where $(1+R) = (1+r)(1+\pi)$ and the relative price between money and bonds is $1/(1+R)$, which implies solving the model in terms of the pair of prices (r, R).

In order to be consistent with the empirical evidence provided in Section 1.4 and to measure the portfolio rebalancing channel in isolation, the experiment consists in calculating an impulse response to a change in R (the return on the 3-month treasury bill, congruent with the calibration of the model), induced by a one-time unanticipated monetary policy shock ϵ (an exogenous shift in the Fed funds rate, as described in Chapter 1, Section 1.4), while holding constant the real interest rate r.[7] Then, following a similar approach as in Nakamura (2019); Wong (2021), there are two broad steps:

i) Estimate a path for $\{R_t\}_{t=0}^{T}$. I define the length of the transition path $T = 15$ quarters, consistent with the length of the projections in Section 1.4. I estimate equation (1.2) with the 3-month treasury bill rate as the dependent variable, and compute the local projection to a monetary policy shock (ϵ). See Appendix B.6 for the trajectory.

ii) Compute the sequence of value and policy functions induced by $\{R_t\}_{t=0}^{t=T}$:

$$\left\{V_t^1, V_t^2, c_t, q_t, \tilde{m}_t, \tilde{b}_t, \bar{x}_t; \{R_{t'}\}_{t'=t}^{T})\right\}_{t=o}^{T}, \tag{2.18}$$

[7] There are two alternative interpretations for holding the real interest rate fixed in this partial-equilibrium exercise. First, it can be viewed as turning off other potential direct channels operating in the model that may be contaminating the consumption response (inter-temporal substitution, for example). Second, it can be interpreted as assuming a *neo-Fisherian* inflation dynamics in the model so that any change in the nominal interest rate (R) has a one-to-one effect on inflation (π). Under either interpretation, the consumption response in the model is due only to the change in the relative price between money and bonds.

by backward-solving the model imposing that $V_T^1 \equiv V_{SS}^1$. Then, to obtain the sequence of distribution of agents along the transition path, iterate-forward on the stationary distribution $\Gamma_{t=0} \equiv \Gamma_{SS}$, using $\overline{x}_t$, to obtain:

$$\left\{\Gamma_t; \{R_{t'}\}_{t'=t}^{T}\right\}_{t=o}^{t=T}. \tag{2.19}$$

Having the sequence of policy functions and the corresponding sequence of distributions of agents over the different states, we can compute the path for average uncertain expenses (Q):

$$Q_t(\{R_{t'}\}_{t'=t}^{T}) = \int q_t d\vartheta d\Gamma_t, \quad for \;\; t = 1, ..., T, \tag{2.20}$$

that can be directly compared to the response of uncertain expenses in Figure (1.2). Note that this sequence for average uncertain expenses only considers a path for the change in the relative price of money and bonds ($^1/_{(1+R)}$) and does not take into account any other potential transmission channels.

Table 2.3 compares the average cumulative consumption response (converted into 2000 US dollars) generated in the model, according to expression 2.20, to the consumption response in the data, as shown in Figure 1.2. The model is able to capture that uncertain expenses are sensitive to changes in the nominal interest rate, while certain expenses are not. In addition, the model can explain 83.4% of the response in uncertain expenses during the first 5 quarters after the shock, and 76.3% of the response over the 15-quarter forecast. While portfolio rebalancing can explain the dynamic response of uncertain expenses and helps us understand the short-run transmission of monetary policy to consumption, in the following subsection I explore other potential transmission mechanisms commonly studied in the literature.

Table 2.3: Average Cumulative Consumption Response
(in 2000 US dollars, per household)

Time after the shock *(in quarters)*	**Certain**		**Uncertain**		**Memorable and durables**
	Data	Model	Data	Model	Data
5	15.0	-3.1	51.3	42.8	56.3
10	-10.3	-6.8	67.8	55.6	179.2
15	-45.7	-7.4	75.2	57.4	347.5

Note: The table reports the dollar change in expenditure after 5, 10 and 15 quarters following a temporary 25 bp unanticipated interest rate cut. The magnitudes are per household averages.

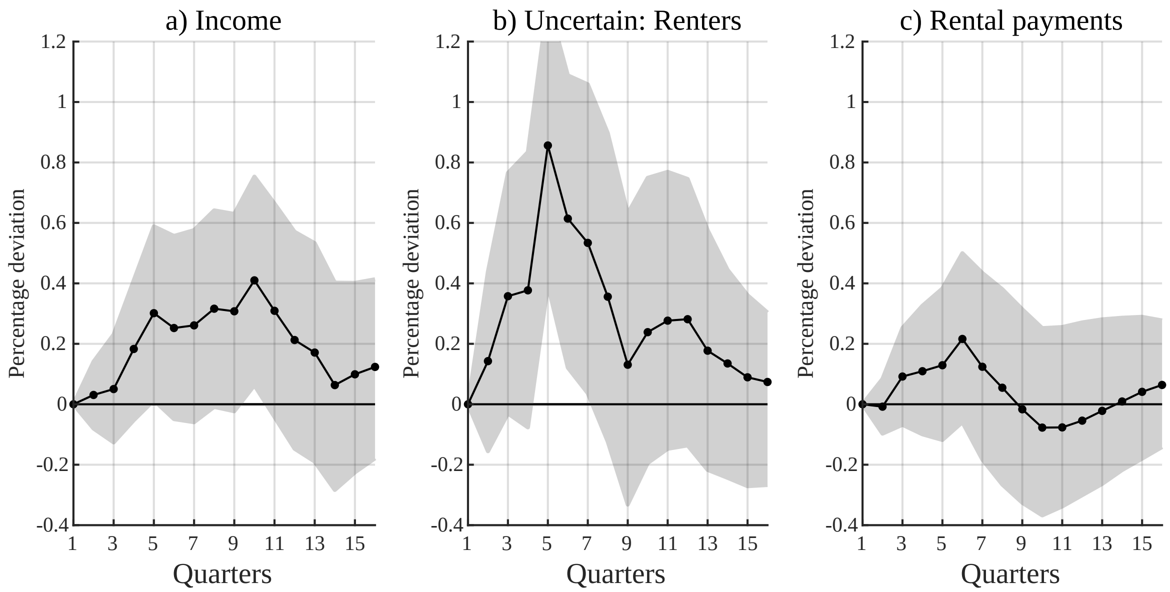
2.4.1.1 Inspecting other transmission channels

The recent body of literature revisiting the monetary policy transmission channels to consumption, in models with heterogeneous households that face idiosyncratic income risk and borrowing constraints, has placed a greater importance on *indirect* (or, budget constraint effects through general-equilibrium forces) rather than on *direct* (or, partial-equilibrium) effects.[8] In this context, monetary policy affects household consumption since the marginal propensity to consume out of transitory changes in households' cash-flow is higher than in models with a representative agent (see Luetticke, 2020b). In this section, I explore the two major sources of households' cash-flow after a monetary policy easing proposed by this literature, labor income and housing assets, and argue that although they are important mechanisms for the overall consumption response, they are unlikely the main drivers of the dynamic response in uncertain expenses.

Labor income. This channel captures the idea that a lower interest rate expands private investment, increasing the capital stock and the marginal product of labor, thus increasing wages. Then, household consumption increases due to this windfall effect in labor income. In Figure 2.2.a, I report the point estimates and confidence bands for the response of household income

[8] Kaplan et al. (2018); Cloyne et al. (2019); Slacalek et al. (2020)

Figure 2.2: Dynamic effects of a 25 bp unanticipated interest rate cut (other channels)



Note: Gray areas are bootstrapped 90% confidence bands.

net of taxes. This figure shows that the dynamic response of income to monetary policy shocks through these general equilibrium effects tends to be lagged.

Housing assets. There are two broad channels operating through housing assets. First, there is a direct portfolio revaluation effect since house prices increase after an interest rate cut (Corsetti et al., 2018). Second, mortgage refinancing decisions are an important determinant of household consumption response to monetary policy (Wong, 2021). In Figure 2.2.b, I show that there is a significant response in uncertain expenses for renters, who do not hold housing assets and, hence, are not affected by these transmission channels. However, it may still be the case that disposable income for renters increases due to a fall in rental payments after a monetary policy easing. In Figure 2.2.c, I show that rental payments display a modest (not statistically significant) increase after a 25bp unanticipated interest rate cut, ruling out a consumption response due to an increase in disposable income for this household group.

2.4.2 Distribution of Money

Recent evidence has shown that the distribution of money holdings is highly concentrated, contrary to the implications of standard models of money demand (Ragot, 2014); those theories that focus on a pure transaction role for money, have been unsuccessful in matching the concentration of money holdings observed in the data (or *liquid* assets more generally, as a broad measure for money as in Lucas and Nicolini, 2015).[9] As shown in Table 2.4, money is much more unequally distributed than consumption in the data, instead resembling inequality in financial wealth.[10] For example, the *Gini* coefficient for money and bonds is around 0.80, while for consumption it is 0.29.

2.4.2.1 Money demand

In this section, I study the money demand function generated in the model with uncertain expenses, and compare it to a version without uncertain expenses, which is equivalent to money demand in a model with a Cash-in-Advance constraint. I will show that the case with expenditure risk generates liquidity-accumulation (wealthier households accumulate more money, relative to their total consumption level) as observed in the data. For any two wealth levels $X > Y$, define liquidity-accumulation ($\mathcal{M}$) as:

$$\mathcal{M} \equiv \frac{m_i^d(X)}{\mathbb{C}_i(X)} - \frac{m_j^d(Y)}{\mathbb{C}_j(Y)} > 0 \quad \underline{\text{in data}}. \tag{2.21}$$

No uncertain expenses. Suppose that $\vartheta = \overline{\vartheta}$, then constraint (2.3) is binding whenever $(1+r) > {}^1/_{(1+\pi)}$, so that money holdings of household i are proportional to their total consumption level.

[9]Most of the literature has used a similar approach (Erosa and Ventura, 2002; Doepke and Schneider, 2006; Aruoba et al., 2011; Ragot, 2014; Gottlieb, 2015; Allais et al., 2020; Aoki et al., 2021).

[10]I map the assets in the Survey of Consumer Finances (SCF) to those in the monetary aggregates "M1" and "NewM1" (which adds money market deposit accounts, MMDAs) as defined by Lucas and Nicolini (2015).

Table 2.4: Distribution of Money, Other Financial Assets and Consumption*

	Assets			**Consumption**
	Money		**Bonds+**	
	M1	***NewM1***		***Certain + Uncertain***
Gini coefficient				
Data	0.73	0.79	0.83	0.29
Benchmark model		0.51	0.69	0.31
HACIA model		0.29	0.64	0.29

*Calculations for assets are based on the Survey of Consumer Finances, 2007 (SCF) and those for Consumption are from the Consumer Expenditure Survey, 2007 (CEX). **Money:** *M1*: Checking accounts; *NewM1*: M1 + Money market deposit accounts, as in Lucas and Nicolini (2015). **Bonds+**: Rest of Financial Assets.

$$m_i^d = \phi \mathbb{C}_i, \tag{2.22}$$

since money holdings are proportional to $\mathbb{C}$, any properties from this distribution will be mapped into the distribution of money holdings. In addition, liquidity accumulation, as defined in (2.21), is:

$$\mathcal{M} = \phi - \phi = 0$$

Uncertain expenses. In this case, money demand can be expressed as:

$$m_i^d = \underbrace{\phi c_i^*}_{certain} + \underbrace{(\nu + \phi) q_i^*(\vartheta^h)}_{\tilde{m}_i}, \tag{2.23}$$

where ϑ^h is the highest realization of the preference shock, and liquidity accumulation is given by (see Appendix B.5):

$$\mathcal{M} = \underbrace{\nu}_{\substack{\text{Timing}\\ \text{friction}}} \Delta(\text{Share of q}) + \underbrace{\phi}_{\substack{\text{Goods mkt.}\\ \text{friction}}} \Delta(\text{Dispersion of q}) \tag{2.24}$$

so wealthier households accumulate more money, relative to total consumption *if*

i) The share of the uncertain component, and *ii) self-insurance motives [expenditure risk]*

are increasing in wealth.

2.4.2.2 Inequality measures in the distribution of assets

Table 2.4 shows inequality measures in the distribution of money holdings generated in the model with uncertain expenses ("Benchmark model") and also those for a version of the model without expenditure risk ("HACIA model"). I find that incorporating uncertain expenses increases the *Gini* coefficient for the distribution of money to 0.51; while in the HACIA model it is 0.29, similar to that of consumption. This result suggests that "financial motives" for holding money (Ragot, 2014), are less important once uncertain expenses are considered.

In addition, I find a modest increase in the *Gini* coefficient in the distribution of bond holdings, suggesting that the precautionary motive towards uncertain expenses contributes to explain overall wealth concentration as in De Nardi et al. (2021).

2.5 Conclusion

This chapter presents a quantitative evaluation of uncertain expenses for household's savings and the transmission of monetary policy to consumption. In particular, the model is used to quantify the importance of the portfolio choice among assets with different liquidity.

The main findings can be summarized as follows. Household portfolio rebalancing is an important mechanism that explains the shape of the response to monetary policy shocks of uncertain expenses and, hence, helps us understand the short-run transmission of monetary policy to consumption. The liquidity-accumulation mechanism studied in this chapter, based on expenditure risk, can generate concentration in the distribution of money holdings consistent with the data.

In addition, this chapter shows how studying expenditure risk contributes to our understanding of overall wealth concentration.

Chapter 3

Risk Sharing and Illiquid Assets

3.1 Introduction

Households accumulate assets to smooth consumption in the presence of income uncertainty.[1] In the buffer-stock tradition, the interaction of precautionary motives with liquidity constraints creates a motive for accumulating assets in good times, given the inability to borrow when times are bad (see Deaton, 1991; Carroll, 1992, 1994). However, recent studies have challenged this view by documenting a heterogeneous degree of risk-sharing and consumption smoothing across US households. For example, Gervais and Klein (2010) find that households with larger quantities of financial assets smooth consumption less than those with lower assets, while Guvenen (2007) finds a similar result for stockholders. Another example is Kaplan et al. (2014), who introduce a resaleability dimension to asset holdings (or illiquidity) and find that a large fraction of households that hold sizable wealth in illiquid assets, exhibit hand-to-mouth behavior. These findings suggest that further research on asset illiquidity is important for understanding this behavior for households.

[1] Other motives may include providing resources during predictable income changes, such as retirement. In this paper, I focus on the insurance role for asset holdings.

In this chapter, I build a model to study risk-sharing when assets are to some degree illiquidity. and then I provide evidence on the consumption drop during the 08/09 Great Recession in the US, particularly, for those households with illiquid assets.

In the model, assets are traded subject to search and matching frictions with two types of agents: large households and financial intermediaries. Members of a typical household receive an idiosyncratic endowment shock: those who receive a high endowment, participate in the market as buyers of the asset, while those who receive a low endowment, are sellers. The matching technology is owned by financial intermediaries, who process buy-sell claims, at a cost. The transaction price is determined as the solution to a bargaining problem between buyers and sellers. Matching efficiency in this market determines endogenously the degree of asset illiquidity. I show that the combination of lower liquidity, along with the pricing mechanism derived from the bargaining problem, tightens the constraint for the members of the household that receive the low endowment, who are less able to finance consumption. As a consequence, the consumption wedge between household members increases, departing from perfect risk sharing within the household.

During the Great Recession, there was a considerable reduction in asset resaleability. Gorton and Metrick (2009, 2012) explain the source of the disturbance that lead to the Great Recession as financial: a drying up of liquidity in the secondary markets for privately issued securities. For the model developed in this project, I interpret the financial shock as a lower matching efficiency in the market for assets, which leads to lower liquidity. I use the Consumer Expenditure Survey (CEX) to explore the consumption behavior among households with illiquid assets during this period, and provide some evidence on the degree of risk sharing for asset-holders. The evidence suggests that, within this group of households, those that reported an income drop experienced a reduction in their ability to smooth consumption during the Great Recession.

Related literature. The large body of literature that has explored the macroeconomic implications of asset resaleablity has highlighted an inefficiency that inhibits investment through the balance sheets of entrepreneurs. That is, investment is bounded above by the liquid portion of net worth. The seminal work by Kiyotaki and Moore (2019) shows that some impediments to the resale of assets may have important macroeconomic implications.[2] More recently, the literature has provided new insights regarding liquidity by introducing search and matching frictions (see Cui and Radde 2016, 2019), clarifying important connections with the finance literature developed by Duffie et al. (2005) (see also Trejos and Wright, 2016 for a detailed treatment). An important dimension is the recognition of price spreads, where the pricing mechanism reflects strategic behavior for each of the counterparties (see Lagos and Rocheteau, 2009).

But, less attention has been devoted in this literature to agents reselling assets to finance current consumption. As summarized in Kaplan and Violante (2018), a large body of empirical evidence points to substantial heterogeneity in the marginal propensity to consume that is correlated with access to liquidity. In particular, Kaplan et al. (2014) identify a large proportion of the U.S population that holds sizable amounts of wealth in illiquid assets and consumes all disposable income every period. That is, their consumption is bounded above by their liquid wealth, analogous to entrepreneurs financing investment opportunities.[3]

In this project, I provide a simple model that combines the financial frictions literature à la Kiyotaki and Moore with endogenous asset liquidity due to search frictions, and the consumption smoothing literature.

With respect to consumption patterns during the Great Recession, this project is related to the findings documented in Berger et al. (2019). They show an increase in the cross-sectional dispersion of consumption within the group of savers, driven by a reduction in their ability to smooth negative income shocks. While not providing a specific mechanism for this result, they emphasize the importance of household's credit constraints during the Great Recession.

[2] While published in 2019, the first version of this started circulating in 2002.
[3] They refer to these agents as the “wealthy hand-to-mouth”.

The rest of this chapter is organized as follows. Section 2 describes the basic structure of the model with idiosyncratic shocks, and provides the details of the asset market. Section 3 characterizes the stationary equilibrium, and the relationship between asset liquidity, risk sharing within household members and asset prices. Last, I provide a quantitative exercise and empirical evidence in Sections 4 and 5, respectively.

3.2 Model

Consider a discrete time infinite horizon economy with two types of agents: a continuum of large households with measure one; and financial intermediaries. A single asset with fixed supply $\overline{s}$ is available, with each unit of the asset paying a fixed return r. The asset is traded in an over the counter market.

All members of a representative household are identical at the beginning of a period $t = 1, 2, ...$ During every period, each member receives a random endowment z^l with probability γ, or z^h with probability $1-\gamma$; where $z^h > z^l$, and the random draws are independent across members and over time. Before the endowments are revealed, the household divides the asset stock s_t among its members who thereafter remain temporarily separated until the end of each period. Before the next period starts, all members pool all their resources within the household. The large household structure facilitates aggregation with only ex post heterogeneity among the household members. This structure has been widely used in the macro-finance literature (Andolfatto and Williamson, 2015; Cui and Radde, 2019, among others).

The household maximizes utility according to[4]

[4]Given the properties of the endowment process, the law of large numbers dictates a fixed fraction γ of members who receive the low endowment, and a fraction $1 - \gamma$ who receive the high endowment.

$$\sum_{t=0}^{\infty} \beta^t [\gamma u(c_t^l) + (1-\gamma) u(c_t^h)] \tag{3.1}$$

where c_t^h and c_t^l denote consumption of a high and low endowment members, respectively; $u(\cdot)$ is a strictly increasing, concave, differentiable function that satisfies $\lim_{c \to 0} u'(c) \to \infty$; and $\beta \in (0,1)$ denotes the discount factor. The household makes consumption and savings plans for each member (c_t^j, s_{t+1}^j) for $j \in \{h, l\}$, given that each one has a stock of s_t units of the asset. The constraints for each member are explained in detail in the following subsection.

After the endowments have been revealed, the asset market opens. Each member trades $a_{t+1}^j = s_{t+1}^j - s_t$ in order to satisfy c_t^j according to the household's plan; however, search frictions limit the liquidity of these assets.[5] Search and matching for would-be trading partners in the asset market is more costly than delegating this process to a financial intermediary, which facilitates the flow of funds from buyers to sellers of the asset. Buyers place $a_{t+1} > 0$ of buy requests with the financial intermediary which are filled with probability $f \in [0,1]$, and are purchased at a price of q_t^{buy}, in terms of the consumption good.[6] Sellers post $a_{t+1} < 0$ of sell requests with the financial intermediary which are filled with probability $\phi \in [0,1)$, and are sold at $q_t^{sell} < q_t^{buy}$. These buy-sell orders are processed by the financial intermediary, at a cost of κ per order, with the financial intermediary bargaining on behalf of each counterparty and determining a transaction price.[7] More details will be given in the following subsections.

In sum, search and matching in this market determines how easily assets can be sold in exchange for consumption goods. As in Kiyotaki and Moore (2019), only a fraction ϕ of the asset stock can be resold, however, this fraction is endogenous and determined by search and matching frictions in my work. So the asset stock for each household member satisfies:

[5] Duffie et al. (2005) argue that search-and-bargaining features are empirically relevant in many markets, such as those for mortgage-backed securities, corporate bonds, emerging-market debt, bank loans, derivatives, certain equity markets, and real-estate markets,

[6] Note that buyers can post a sufficient number of buy claims so that they purchase their desired amount.

[7] An interpretation would be that financial intermediaries own the matching technology.

$$s^j_{t+1} \geq (1-\phi)\, s_t \; for \; j \in \{l, h\} \tag{3.2}$$

where s^j_{t+1} is the asset stock for household member j in the following period.

3.2.1 Budget Constraints

After the endowment shock has been realized, each member's asset trading position is:

$$a^j_{t+1} = s^j_{t+1} - s_t,$$

where a^j_{t+1} can be positive or negative depending on the household plan (c^j_t, s^j_{t+1}). Suppose that the realizations $(z^l = 0, z^h)$ are such that

$$\begin{cases} a^j_{t+1} \geq 0 & if \; z^j_t = z^h \\ a^j_{t+1} = -\phi s_t & if \; z^j_t = z^l = 0 \end{cases},$$

for $z^j_t \in \mathbb{R}$. Then, for the fraction γ of household members that receive the endowment $z^l = 0$, they finance consumption by liquidating their asset stock at price q^{sell} and their budget constraint is:

$$c^l_t = (r + \phi q^{sell}_t) s_t, \tag{3.3}$$

where these household members exhibit hand-to-mouth behavior. For the remaining fraction $1-\gamma$ of household members that receive the high endowment z^h, and are buying assets at price q^{buy}, their budget constraint is:

$$c^h_t + q^{buy}_t [s^h_{t+1} - s_t] = z^h_t + r s_t. \tag{3.4}$$

Household-wide aggregation. Define household-wide aggregates for consumption, endowments, and next period asset holdings as

$$X = \gamma X^l + (1-\gamma)X^h \; for \; X \in \{c_t, z_t, s_{t+1}\}. \tag{3.5}$$

The objective is to characterize the optimal household plans (c_t^j, s_{t+1}^j) for $j \in \{h, l\}$. Next period's asset holdings for the low endowment members s_{t+1}^l is $(1-\phi)s_t$. Then, the problem reduces to characterizing the choice for next period's asset holdings for the high endowment members s_{t+1}^h. By using (3.5), this is equivalent to solving for the household-wide asset holdings s_{t+1}. Then, by expressing (3.4) in terms of s_{t+1}

$$c_t^h + q_t^{buy}\left[\frac{s_{t+1} - (1-\gamma\phi)s_t}{(1-\gamma)}\right] = z_t^h + rs_t, \tag{3.6}$$

it is then straightforward to derive the household wide aggregate budget constraint by adding up the constraints for the low and high endowment members

$$c_t + q_t^{buy}s_{t+1} = z_t + \{r + [(1-\gamma\phi)q_t^{buy} + \gamma\phi q_t^{sell}]\}s_t, \tag{3.7}$$

where c_t and z_t are given by (3.5). To derive some intuition from this expression, note that the portfolio valuation from the household's perspective consists of the return r, plus a convex combination between the purchase price (or "book" value) and the sell price (or "market" value). The weights assigned to each one, depend on the household's need for liquidating the asset γ, and the ease with which this can be done ϕ.

3.2.2 Recursive Formulation of the Household's Problem

The household's problem consists of maximizing the utility of its members as given by (3.1), subject to the household-wide budget constraint (3.7), and the constraint for the low endowment members (3.3). In this section, I present this problem in recursive form. Let $v(s)$ be the value for a household with assets s, then the household's problem can be written recursively as

$$v(s_t) = \max_{\{c_t^l, c_t^h, s_{t+1}\}} \left\{ \gamma u(c_t^l) + (1-\gamma)\, u(c_t^h) + \beta v(s_{t+1}) \right\}$$

$$s.t.$$

$$\gamma c_t^l + (1-\gamma) c_t^h + q_t^{buy} s_{t+1} = z_t + \{r + [(1-\gamma\phi) q_t^{buy} + \gamma\phi q_t^{sell}]\} s_t \tag{3.8}$$

$$c_t^l = z_t^l + [r + \phi q_t^{sell}] s_t \tag{3.9}$$

and

$$c_t^l > 0,\ c_t^h > 0 \tag{3.10}$$

Let λ_t, and φ_t be the Lagrange multipliers for (3.8) and (3.9), respectively. Here, the multiplier φ_t is a measure of how costly consumption is for the household members who receive the low shock. This will be central in the analysis of this paper. The household solves this problem taking the return on asset holdings r, liquidity ϕ, and prices as given. The first order conditions for this problem can be simplified as the following expressions.

The consumption wedge can be expressed as

$$u'(c_t^l) = \underbrace{(1+\varphi_t)}_{\text{wedge}} u'(c_t^h) \tag{3.11}$$

since $\varphi_t > 0$, then $u'(c_t^l) > u'(c_t^h)$ which implies that $c_t^l < c_t^h$; that is, consumption for the members who receive the low endowment is more expensive from the household's perspective.

The Euler equation for assets can be expressed as

$$q_t^{buy} = \beta \frac{u'(c_{t+1}^h)}{u'(c_t^h)} \{r + q_{t+1}^{buy} + \underbrace{\gamma[\varphi_{t+1}(r + \phi q_{t+1}^{sell}) - \phi(q_{t+1}^{buy} - q_{t+1}^{sell})]}_{Premium}\} \tag{3.12}$$

This Euler equation carries a premium on holding the asset, which can be separated in two parts. First, each additional asset relaxes (3.9) by $(r+\phi q_{t+1}^{sell})$, where ϕq_{t+1}^{sell} is the saleable fraction valued at next period's sell price. The second component incorporates that intermediation costs reduce this premium, as for each effective transaction the household loses $(q_{t+1}^{buy} - q_{t+1}^{sell})$.

The following subsection develops in detail the asset market structure, and how the asset prices are determined. As will be explained, these prices are a function of the consumption wedge φ.

3.2.3 Asset Market

The structure of the asset market is related to what is done in Cui and Radde (2019), however with different agents participating in the market. Recall that competitive intermediaries process buy-sell orders posted by market participants at a unit cost of κ. Then, they operate a matching technology to execute the processed orders. This process determines asset liquidity ϕ and the settlement price q^*, which is the solution to a bargaining problem between buyers and sellers. I first describe the matching technology and asset liquidity. Then, I describe the bargaining problem that leads to the settlement price. Last, I derive asset prices q_t^{buy}, q_t^{sell}, and q_t^* as a function of the consumption wedge φ_t between household members.

3.2.3.1 The Matching Technology and Illiquidity

The matching technology is captured by a matching function $M(N^{sell}, N^{buy}; \xi)$ which is homogeneous of degree one, continuous and increasing in both arguments (N^{sell}, N^{buy}). The arguments are the total quantities of sell and buy claims, respectively; and ξ is the matching efficiency. I define asset market tightness θ as the ratio of total purchase orders divided by the total number of selling orders $\theta \equiv N^{buy}/N^{sell}$.

Given the matching technology, asset liquidity captures the fraction of assets that can be sold ex-post, as a function of market tightness θ and efficiency ξ

$$\phi = \phi(\theta; \xi) = \frac{M(N^{sell}, N^{buy}; \xi)}{N^{sell}} = M(1, \theta; \xi), \tag{3.13}$$

where $M(1, \theta; \xi)$ is a non-decreasing and concave function in θ.[8] Analogously, The fraction of buy orders that are satisfied ex-post can be expressed as

$$f = f(\theta; \xi) = \frac{M(N^{sell}, N^{buy}; \xi)}{N^{buy}} = M(\theta^{-1}, 1; \xi). \tag{3.14}$$

In terms of the objects in the model, the number of buy claims is $N_t^{buy} = {}^{(1-\gamma)[s^h_{t+1} - s_t]}/_f$.[9] While the number of sell claims is $N_t^{sell} = \gamma s_t$ then, asset market tightness is:

$$\theta_t = \frac{N_t^{buy}}{N_t^{sell}} = \frac{(1-\gamma)[s^h_{t+1} - s_t]}{\gamma s_t} = \frac{s_{t+1} - (1 - \phi\gamma)s_t}{\gamma s_t}. \tag{3.15}$$

[8] With the standard properties $M(1, 0; \xi) = 0$ and $M(1, \theta; \xi) \leq 1$ *for all* θ. Also that $\lim_{\theta\to\infty} M(\theta^{-1}, 1; \xi) = 0$ and $\lim_{\theta\to 0} M(\theta^{-1}, 1; \xi) = \infty$.

[9] The buyer can post $1/f$ additional orders, knowing that only a fraction f will be matched.

3.2.3.2 The Bargaining Problem

Once sell and buy orders have been matched, intermediaries bargain on behalf of buyers and sellers over a transaction price q_t^o. Following a similar concept in the labour-search literature, the transaction price is determined as bargaining at the margin, that is, over an incremental asset transaction in a successful match (see Cui and Radde, 2019). The settlement price q_t^* is the solution to the following Nash bargaining problem

$$\max_{q_t^o} \left[v^{h'}\left(q_t^o\right)\right]^{1-\omega} \left[v^{l'}\left(q_t^o\right)\right]^{\omega},$$

where $\omega \in (0,1)$ is the bargaining weight assigned to the seller; and $v^{h'}(q_t^o)$ and $v^{l'}(q_t^o)$ are the marginal transaction surplus for each agent. This represents the value that each agent assigns to purchasing/selling an additional unit of the asset at a given price of q_t^o. The first order condition for this problem is:

$$(1-\omega)\frac{v^{h''}\left(q_t^*\right)}{v^{h'}\left(q_t^*\right)} + \omega\frac{v^{l''}\left(q_t^*\right)}{v^{l'}\left(q_t^*\right)} = 0, \tag{3.16}$$

in order to determine q^*, the next step is to compute the individual marginal valuations $v^{h'}(q_t^*)$ and $v^{l'}(q_t^*)$. After establishing these two objects, I derive expressions for the prices q_t^*, q_t^{buy} and q_t^{sell} in section (3.2.3.3).

Consider the problem for an agent who has the opportunity to purchase an incremental amount of assets $\varepsilon > 0$, at an arbitrary price q_t^o

$$v^h\left(q_t^o, \varepsilon\right) = u(c_t^h) + \beta v(s_{t+1} + \varepsilon)$$

$$s.t.\ c_t^h + q_t\left[s_{t+1} - (1-\delta)\,s_t\right] + q_t^o\varepsilon = z_t^h + rs_t,$$

where the asset stock for the household in the next period would be $(s_{t+1} + \varepsilon)$; differentiating with respect to ε and evaluating it at $\varepsilon = 0$,

$$v^{h'}(q_t^o) = -u'(c_t^h)q_t^o + \beta v'(s_{t+1}). \tag{3.17}$$

In a similar way, for an agent selling an incremental unit $\varepsilon > 0$ of the asset at an arbitrary price q_t^o, we get

$$v^l(q_t^o, \varepsilon) = u(c_t^l) + \beta v(s_{t+1} - \varepsilon)$$

$$s.t.\ c_t^l = z_t^l + rs_t + \phi q_t^{sell} s_t + q_t^o \varepsilon,$$

and, differentiating and evaluating at $\varepsilon = 0$ gives

$$v^{l'}(q_t^o) = u'(c_t^l)q_t^o - \beta v^{'}(s_{t+1}).$$

This expression can be written in terms of the consumption wedge φ_t, using the optimality condition (3.11)

$$v^{l'}(q_t^o) = (1 + \varphi_t)u'(c^h)q_t^o - \beta v'(s_{t+1}), \tag{3.18}$$

the marginal transaction surplus for the low endowment members is increasing in φ_t; this is, the benefit of liquidating the asset is increasing in terms of the consumption wedge.

3.2.3.3 Asset Prices

For a seller, the probability of a successful match with a buy order is ϕ as given by (3.13), in which case, the asset is sold at the price

$$q_t^{sell} = q_t^* - {}^{\kappa}/_{\phi}, \tag{3.19}$$

where q_t^* is the settlement price that results from the bargaining problem derived earlier; and ${}^{\kappa}/_{\phi}$ is the fee charged by the financial intermediary, since not all orders are matched, they need to process ${}^{1}/_{\phi}$ sell orders.

For a buyer, the probability of a successful match is f, as given by (3.14), and the asset is purchased at

$$q_t^{buy} = q_t^* + {}^{\kappa}/_{f} \tag{3.20}$$

where ${}^{\kappa}/_{f}$ is the fee charged by the intermediary.

Then, the spread between the purchase price and the sell price covers intermediation costs of processing orders

$$q_t^{buy} - q_t^{sell} = \kappa\left(\frac{1}{\phi} + \frac{1}{f}\right) \tag{3.21}$$

which is a free entry condition in the financial market.

Having derived the expressions for the marginal transaction surplus for buyers and sellers, in the previous subsection, I can establish the following result that relates the settlement price to the consumption wedge.

Lemma 1. *Given some bargaining weight ω, the settlement price q_t^* can be expressed as a function of the consumption wedge φ_t and the purchase price q_t^{buy}, with the following form*

$$q_t^* = \Lambda(\varphi_t, \omega) q_t^{buy} \tag{3.22}$$

and the following properties for the coefficient $\Lambda(\cdot)$ hold:

1. $0 < \Lambda(\varphi_t, \omega) \leq 1$

2. $\Lambda(\varphi_t, \omega)$ *is decreasing in* φ_t*, and*

3. $\Lambda(\varphi_t, \omega) \to 1$ *when* $\varphi_t \to 0$

Proof. (sketch) Plugging (3.17) and (3.18) into equation (3.16), using (C.3), and solving for q_t^*, leads to the following expression

$$q_t^* = \frac{1 + \omega\varphi_t}{1 + \varphi_t} q_t^{buy} \tag{3.23}$$

where $\Lambda(\varphi_t, \omega) \equiv \frac{1+\omega\varphi_t}{1+\varphi_t} \in (\omega, 1]$; $\frac{\partial}{\partial\varphi_t}\frac{1+\omega\varphi_t}{1+\varphi_t} < 0$; and $\lim_{\varphi_t \to 0} \frac{1+\omega\varphi_t}{1+\varphi_t} = 1$. □

This lemma states that a higher consumption wedge φ_t worsens the bargaining position of the party liquidating the asset. This highlights part of the main channel at work in the model. However, the buy price q_t^{buy} also depends on the consumption wedge φ_t

Corollary 2. *Given asset market conditions* $(\phi, f, \kappa, \omega)$ *the buy and sell prices* (q_t^{buy}, q_t^{sell}) *can be expressed as functions of* $\Lambda(\varphi_t, \omega)$*.*

Proof. (sketch) Plugging (3.22) into equations (3.19) and (3.20), leads to the following expression for the prices

$$q_t^{sell} = \kappa \left[\frac{\Lambda(\varphi_t, \omega)}{1 - \Lambda(\varphi_t, \omega)} \frac{1}{f} - \frac{1}{\phi} \right] \quad \textit{and} \quad q_t^{buy} = \frac{1}{1 - \Lambda(\varphi_t, \omega)} \frac{\kappa}{f} \tag{3.24}$$

□

Having established these relationships for asset prices, the next step is to determine how the asset market conditions $(\phi, f, \kappa, \omega)$ affect the consumption wedge φ_t. The main idea is to determine φ_t endogenously and analyze its relationship to asset market illiquidity ϕ.

3.3 Equilibrium Characterization

In this section, I establish the relation between the consumption wedge φ and asset illiquidity ϕ.

3.3.1 Preliminaries

Asset Market

Given the assumption of a fixed asset supply, the asset stock is constant $s_{t+1} = s_t = \bar{s} > 0$, then asset market tightness as defined in expression (3.15) simplifies to

$$\theta = \frac{\phi}{f} = \overline{K} \tag{3.25}$$

where $\overline{K}$ is a constant given that the fractions γ and $1 - \gamma$ are fixed. For simplicity, let $\overline{K} = 1$ and that the matching technology is determined by the Cobb-Douglas function

$$M(N^{sell}, N^{buy}; \xi) = \xi \left(N^{sell}\right)^{\eta} \left(N^{buy}\right)^{1-\eta}, \tag{3.26}$$

where η is the matching elasticity and ξ is the matching efficiency.

Remark 3. Given the matching technology in (3.26), asset illiquidity ϕ is determined by the matching efficiency ξ, this is

$$\phi = \xi\theta^{1-\eta} = \xi, \tag{3.27}$$

where ξ is an exogenous parameter.

Preferences

Each household member's utility function is specified as a standard CRRA utility function

$$u(c^j) = \frac{\left(c^j\right)^{1-\sigma}}{1-\sigma}, \tag{3.28}$$

where σ is the relative risk aversion parameter. It is simple, and will be useful, to express consumption of the high endowment members c^h in terms of the aggregate consumption c, by using (3.5) and the first order condition (3.11)

$$c^h = \left[\frac{1}{\gamma/(1+\varphi_t)^{1/\sigma} + (1-\gamma)}\right] c. \tag{3.29}$$

Market Clearing

Finally, the market clearing condition is:

$$c + q^{buy} - q^{sell} = \overline{Y},$$

where $\overline{Y} = z^h + z^l$. Using the free entry condition (3.21), aggregate consumption can be expressed as a function of liquidity ϕ

$$c(\phi) = \bar{Y} - \frac{2\kappa}{\phi}, \tag{3.30}$$

and so aggregate consumption is increasing in ϕ.

3.3.2 Characterization

Notice from the analysis developed throughout the paper that once establishing a function $\varphi(\phi)$, the rest of the relevant variables c^h, c^l and prices q^{buy} and q^{sell} can be pinned down.

Proposition 4. *Given asset market features (r, κ, ω) and the fraction of low endowment members γ, there exists a function $\varphi(\phi)$ such that*

1. $\varphi(\phi) > 0$ *for all* $\phi \in (0, 1)$
2. $\varphi(\phi)$ *is decreasing*

Proof. (Sketch) Using the Euler equation for assets (3.12) expressed in the steady state form, plugging in (3.24) and rearranging terms, it can be expressed as the following quadratic equation

$$A(\boldsymbol{\phi})\boldsymbol{\varphi}^2 + B(\boldsymbol{\phi})\boldsymbol{\varphi} - C = 0 \tag{3.31}$$

with coefficients given by $A(\boldsymbol{\phi}) = \left(\frac{\beta}{1-\beta}\boldsymbol{\phi}\gamma(r + \kappa\bar{\omega})\right)$, $B(\boldsymbol{\phi}) = \left(\frac{\beta}{1-\beta}\boldsymbol{\phi}(r + \gamma\kappa\bar{\omega}) - \frac{\kappa}{1-\omega}\right)$ and $C = \frac{\kappa}{1-\omega}$.

Since (3.31) is quadratic, in general, there are two solutions to this equation. For a range of parameters $(\beta, r, \gamma, \kappa, \omega)$, for any given $\overline{\phi} \in (0, 1)$, the two solutions to equation (3.31) are $\varphi_1^*(\overline{\phi}) \in (0, 1)$ and $\varphi_2^*(\overline{\phi}) < 0$. The negative solution can be ruled out since φ is the Lagrange multiplier for the household's problem, which cannot be negative. Consider the solution $\varphi_1^*(\overline{\phi}) \in (0, 1)$ and define the function $\varphi : (0, 1) \to \mathbb{R}^{++}$ as $\varphi(\phi) = \varphi_1^*(\phi)$ for all $\phi \in (0, 1)$. □

The results from Proposition 1 show how asset illiquidity tightens the constraint for the low endowment members. As assets become less easy to sell, due to a lower matching efficiency in the market, the household finds it more costly to equalize consumption across its members.

When the matching efficiency is such that there are no frictions for exchanging the asset, then there is perfect risk sharing for household members, and their consumption is equalized.[10]

Remark 5. There is imperfect risk sharing within the household when $\phi < 1$.

Once this relationship between ϕ and φ, and its implications for consumption within the household are established, the other relevant variables of the model can be pinned down. In particular, rearranging the Euler equation for assets leads to the following expression for the purchase price

$$q^{buy} = \underbrace{\frac{\beta}{1-\beta} r}_{fundamental} + \underbrace{\frac{\beta}{1-\beta}\{\gamma[\varphi(\phi)(r + \kappa\bar{\omega}) + \kappa\bar{\omega}]\}}_{premium:\ Q_{q^{buy}}} \tag{3.32}$$

where $\bar{\omega} = {}^{(2\omega-1)}/_{(1-\omega)}$. Assets are priced above their fundamental value, and the premium $Q_{q^{buy}}$ is decreasing in ϕ. Using (3.24), the resell price is

$$q^{sell} = \frac{\kappa}{\phi}\left[\frac{1}{(1-\omega)\varphi(\phi)} + \overline{\omega}\right] \tag{3.33}$$

so in order to analyze how the sell price is related to asset illiquidity, it is necessary to take into account $\varphi(\phi)$. The following lemma formalizes the response of asset prices to asset liquidity

Lemma 6. *The purchase price q^{buy} is decreasing in ϕ; while the sell price q^{sell} is increasing in ϕ.*

Proof. (Sketch) Calculating

$$\frac{dq^{buy}}{d\phi} = \frac{\beta}{1-\beta}\gamma(r + \kappa\bar{\omega})[\varphi'(\phi)] < 0 \quad since \quad \varphi'(\phi) < 0$$

[10]Due to the intermediation cost of κ, even in the limiting case when $\phi = 1$, $\varphi(1) > 0$ but "close" to zero. "Perfect risk sharing" in this context is up to the intermediation costs.

and

$$\frac{dq^{sell}}{d\phi} = -\frac{\kappa}{(1-\omega)}[\frac{\phi\varphi'(\phi)+\varphi(\phi)}{\phi^2\varphi(\phi)^2}] > 0 \;\; if \quad -\varphi'(\phi) > \frac{\varphi(\phi)}{\phi}$$

In general, as I explain in the following example, the sell price is increasing in the level of asset liquidity. □

Summarizing the response of asset prices to lower asset market liquidity, I conclude the following. On the one hand, lower liquidity increases the consumption wedge and pushes up the premium on the purchase price for assets. On the other hand, the agent liquidating the asset is willing to accept a lower price in exchange for the asset, which lowers the sell price. This differentiated response captures two distinct channels at work in the model. The first, is a precautionary motive for holding assets as a buffer to smooth consumption in the future when receiving a low endowment shock. The second, captures a deterioration in the bargaining position for the agent liquidating the asset to finance current consumption.

3.4 Quantitative analysis

In this section, I provide a quantitative example that shows the relation between asset liquidity, prices, and consumption within the household. For this example, I compute the function $\varphi(\phi)$ as defined in Proposition (4) for a given set of parameter values for $(\beta, r, \gamma, \kappa, \omega)$. I use standard parameters from the literature. The discount factor $\beta = 0.98$. The financial market parameters (r, κ) were chosen so that the spread in asset prices $(q^{buy} - q^{sell})$ is on average around 6%, in line with the evidence provided by Cui and Radde (2019). The bargaining weight is assumed to be equal for buyers and sellers $\omega = 1/2$, so changes in the bargaining position reflect only changes in φ. And last, the fraction of members who receive the low endowment $\gamma = 0.25$, in line with the fraction of wealthy hand-to-mouth in the US as documented in Kaplan et al. (2014).

Figure 3.1: Steady states for different liquidity values ϕ

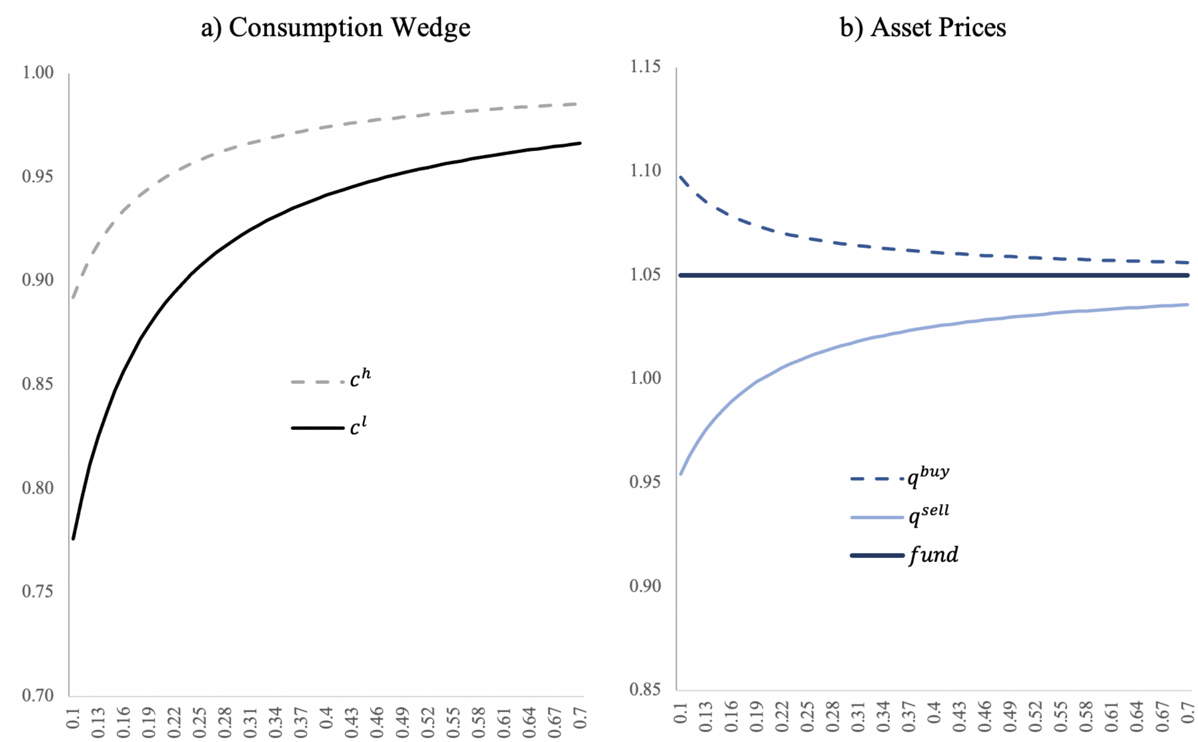


Figure (3.1) shows the steady state of the model as a function of ϕ.[11] Panel a) shows the negative relationship between ϕ and φ, higher asset illiquidity tightens the constraint for those members that receive the low endowment shock, who are unable to smooth consumption, note that $c^l \to c^h$ as $\phi \to 1$; when assets are liquid, there is perfect risk sharing within the household. Panel b) contains the differentiated response for asset prices.

3.5 Empirical analysis

From the analysis in the previous section, an interpretation of the results from the model is that given some level of asset illiquidity $\phi^* < 1$, there is a consumption wedge ($\varphi^* > 0$) between those agents that hold illiquid assets and receive a negative income shock, and those that do not

[11] Changes in liquidity are determined by the matching efficiency ξ.

receive a negative shock. The limiting case when assets are fully liquid ($\phi \to 1$) implies that the consumption wedge decreases (a case close to perfect risk-sharing), so that there should not be large differences in consumption among asset-holders.

Following the interpretation found in Gorton and Metrick (2009, 2012), the Great Recession episode was one such that liquidity in asset markets was less than normal, or: $\phi^{GR} < \phi^*$, in terms of the model. In this case, the model predicts an increase in the consumption wedge $\varphi^{GR} > \varphi^*$ for asset holders. This could be accounted for by comparing the drop in consumption for those that hold illiquid assets and receive negative income shocks, to those that do not receive a negative income shock. In this section, I use data from the Consumer Expenditure Survey (CEX) to explore these consumption patterns during the Great Recession.

Data. The CEX is a rotating panel that gathers detailed information on consumption expenditures for households in the US (or consumer units). Each consumer unit is interviewed for up to four times during a 12-month period and is asked to report consumption patterns for the preceding three months. After completing the four interviews, each consumer unit is replaced. In addition to consumption data, the survey offers comprehensive information on socioeconomic characteristics of the household.

The consumption measure used for this analysis is household expenditures on nondurable goods. I build the consumption measure by mapping the consumption categories in the CEX to each one of the corresponding nondurable categories from the NIPA Tables line 70 (food, clothing, gas and energy, and other nondurables). The monthly timing of the interviews generates staggered consumption periods for each consumer unit, that do not always coincide with calendar quarters. Each one of the consumption categories is deflated using the corresponding 3-month price index for Personal Consumption Expenditures (PCE). For each consumer unit, I build the quarterly change in consumption by calculating $\Delta \log c_{t,i} = \log c_{t,i} - \log c_{t-1,i}$. There are up to three observations for each household.

To measure illiquid assets, I add the value of all securities directly held by the household (comprising stocks, mutual funds and non U.S. savings bonds) to owned property value. To build a measure of net-worth (NW), I subtract the outstanding value of the household's mortgage on these properties. Since the information on asset holdings is only available for the last interview, I cannot observe the change in net-worth during the period for which the consumption is reported. Instead, I build an indicator of whether the household has net-worth above the median value of all the other households in the same year ($NW_i^{high} = 1$). In addition, since income information is reported only on the first and last interviews, I calculate an indicator of whether the household reported a drop in income from wages and salaries ($\Delta Y_i < 0$). These indicators categorize households into those that had a drop in wages and those that hold high net-worth in illiquid assets. Last, I define an indicator variable (rec_t) for the periods of the Great Recession (Jan 2008 to June 2009). The sample is from 1996 to 2009.

The empirical specification follows Parker et al. (2013), who model consumption growth as a function of time effects and individual controls meant to identify exogenous changes in income growth. In particular, I run the following regression

$$\Delta \log c_{t,i} = \sum_m \delta_m M + \beta X_{t,i} + \alpha rec_t + \rho NW_i^{high} + \theta(NW_i^{high} \times rec_t) + \varepsilon_{t,i} \tag{3.34}$$

where M denotes a complete set of indicator variables for months $m = 1, 2, ..., 12$, to control for seasonal expenditure patterns unrelated to the Great Recession; and, X_t is a set of household characteristics: family size; race; education; urban or rural; single; and a third-order polynomial on age.

The parameter of interest in equation (3.34) is the one for the interaction term θ, which measures the drop in consumption for households with sizable illiquid assets during the Great Recession, relative to those households with lower wealth in illiquid assets. The buffer-stock literature suggests that households liquidate part of their asset holdings to smooth consumption. So, the

Table 3.1: Consumption during the Great Recession

	(1) All sample	(2) $\Delta Y < 0$	(3) $\Delta Y \geq 0$
NW_high	0.00257	0.00538	0.00146
	(0.00200)	(0.00339)	(0.00248)
rec	-0.02491***	-0.02416***	-0.02591***
	(0.00460)	(0.00661)	(0.00646)
NW_high × rec	-0.01470**	-0.02742***	-0.00395
	(0.00614)	(0.00873)	(0.00874)
N	148078	48171	99907
N_clust	63719	19163	44556

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < .01$

drop in consumption for households that receive negative income shocks should be similar to those who do not receive a negative shock.

Table 3.1 shows the estimation results for equation (3.34). The first column presents the results for the complete sample, while the second column is restricting the sample to those households who reported an income drop ($\Delta Y_i < 0$); the third column is for those who reported an increase in income ($\Delta Y_i > 0$). The evidence presented in this table suggests that consumption smoothing during this period was not homogeneous across households. The first thing to note is that there was an overall consumption drop of around 2.5%, compared to other periods. From column (1), those households with high net worth observed an additional 1.47% drop in consumption during this period. Now focusing on those who report an income drop in column (2), they observed an additional 2.74% consumption decrease; which reflects a lower ability to smooth negative income shocks. Finally, for those that did not have an income reduction in column (3), there is no evidence of a particular change in consumption during this period.

3.6 Conclusion

In this chapter, I study how asset market illiquidity affects risk-sharing among asset holders. I build a model where households receive idiosyncratic endowments and self-insure using one asset. Following the interpretation of Kiyotaki and Moore where some fraction of the asset stock cannot be resold, I use search and matching frictions to endogenize the notion of asset liquidity. Those agents that receive a low endowment participate in the market as sellers of the asset, while those who receive a high endowment are buyers. I use the solution to the bargaining problem between buyers and sellers to characterize the buy and sell price of the asset. In particular, I show that the sell price is a decreasing function of illiquidity. So higher illiquidity restricts those agents that receive the low endowment. Therefore, the consumption wedge between buyers and sellers increases.

I provide evidence that search frictions in asset markets are important in explaining the increase in the cross-sectional dispersion of consumption within the group of asset holders during the Great Recession, driven by a reduction in their ability to smooth negative income shocks.

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Appendix A

Appendices to Chapter 1

A.1 Mapping of CEX to NIPA

Table A.1: Mapping of expenditure items in the CEX to NIPA

CEX	NIPA	Line	Type
Food at home	Food and nonalcoholic beverages purchased for off-premises	72	n
Food away from home	Food services	233	s
Alcoholic beverages	Alcoholic beverages purchased for off-premises consumption	97	n
Mortgage interest	Rental of tenant-occupied nonfarm housing	152	s
Property taxes	Rental of tenant-occupied nonfarm housing	152	s
Maintenance, repairs, insurance, and other expenses	Household maintenance	325	s
Rented dwelling	Rental of tenant-occupied nonfarm housing	152	s
Other lodging	Accommodations	247	s
Utilities, fuels and public services	Household utilities	163	s
Domestic services	Domestic services	326	s
Other household expenses	Household supplies	129	n
House furnishings and equipment	Furnishings and durable household equipment	21	d
Apparel and services	Clothing and footwear	102	n
Cars and trucks, new (net outlay)	New motor vehicles	5	d
Cars and trucks, used (net outlay)	Net purchases of used motor vehicles	10	d
Other vehicles	Sports and recreational vehicles	51	d
Gasoline and motor oil	Gasoline and other energy goods	111	n
Vehicle finance charges	Financial services	251	s
Maintenance and repairs	Motor vehicle maintenance and repair	190	s
Vehicle insurance	Net motor vehicle and other transportation insurance	277	s
Vehicle rental, leases, licenses, and other charges	Other motor vehicle services	191	s
Public and other transportation on trips	Public transportation	197	s
Local public transportation, excluding on trips	Public transportation	197	s
Health insurance	Net health insurance	273	s
Medical services	Health care	170	s
Prescription drugs	Pharmaceutical and other medical products	119	n
Medical supplies	Therapeutic appliances and equipment	64	d
Fees and admissions	Membership clubs, sports centers, parks, theaters, and museums	208	s
Televisions, radios, and sound equipment	Video, audio, photographic, and information processing equipment	37	d
Pets, toys, and playground equipment	Recreational items	124	n
Other entertainment	Other recreational services	228	s
Personal care	Personal care products	135	n
Reading	Educational books	67	d
Education	Education services	288	s
Tobacco and smoking supplies	Tobacco	139	n
Life and other personal insurance	Life insurance	269	s
Miscellaneous expenditures	Other services	278	s
Cash contributions	Social services and religious activities	313	s
Retirement, pensions, Social Security	Financial services furnished without payment	252	s

Appendix B

Appendices to Chapter 2

B.1 A two period model of precautionary money demand

In this section, I build a simple two period model to illustrate the main mechanism and the portfolio rebalancing channel of Monetary Policy that operates in this model.

B.1.1 Setup

Agents live for two periods ($t = 1, 2$) and receive an endowment (y) at the beginning of the first period. They use this endowment to consume during the first period ($C_1 = c + q$), where the consumption basket is divided into a certain (c) and an uncertain (q) component; and the remaining portion of the endowment is used for consumption during the second period (C_2). Agents have preferences given by

$$v(C_1) + \beta u(C_2) \tag{B.1}$$

where $v(C_1 = c + q) \equiv u(c) + \vartheta u(q)$ with a random parameter ϑ that captures some degree of uncertainty for consumption of q; $u(\cdot)$ satisfies the usual properties; and β is the discount factor. Then the household's problem is to choose a portfolio P in order to maximize expression (B.1).

Timing friction in portfolio choice problem (ν). At the start of the first period, after receiving the endowment (y) but before knowing the realization of ϑ, agents decide how to allocate their portfolio between two assets: money (m) that can be used to purchase q, but has a return of $^1/_{(1+\pi)}$ in the second period, where $\pi > 0$ represents the inflation rate; and bonds (b) that pay a real return of $(1 + r)$ in the second period, but can only finance a fraction $(1 - \nu)$ of q.

Denote as $(\tilde{m}, \tilde{b})$ the portfolio allocation over money or bonds for each household at the beginning of the first period, At the time when households decide the portfolio allocation over money or bonds, they consider the uncertainty in consuming q such that

$$\underbrace{c + \underbrace{\nu q}_{\tilde{m}}}_{m} + \underbrace{b + (1-\nu)q}_{\tilde{b}} = y - c \tag{B.2}$$

note that money demand is given by $m = c + \tilde{m}$; and denote end of period balances carried over to the second period as (m', b'), where

$$\begin{aligned} m' &= \tilde{m} - \nu q \geq 0 \\ b' &= \tilde{b} - (1-\nu)q \geq \underline{b} \end{aligned} \tag{B.3}$$

where $\underline{b} < 0$ is an exogenous debt limit.Then, consumption during the second period is equal to the sum of balances carried over (W), at market prices (π, r)

$$C_2 = W = \frac{m'}{(1+\pi)} + (1+r)b' = (1+r)\{\underbrace{\frac{\tilde{m}}{(1+R)} + \tilde{b}}_{\mathbb{P}(\tilde{m},\tilde{b};R)} - \underbrace{\left[\frac{\nu}{(1+R)} + (1-\nu)\right]}_{\Psi(\nu;R)} q\} \tag{B.4}$$

where $(1 + R) = (1 + r)(1 + \pi)$ is the nominal interest rate and consider the normalization $\hat{W} = {}^{W}/_{(1+r)}$, so that the relative return between the two assets is the important object for the household. Expression(B.4) states that consumption in the second period is the difference between the initial portfolio allocation valued at the relevant market price $\mathbb{P}(\tilde{m}, \tilde{b}; R)$, less consumption of q; and $\Psi(v; R)$ accounts for the assets used to purchase it.

The household's problem during the first period can be separated into two subperiods:

1. **First sub-period:** The portfolio choice between $(\tilde{m}, \tilde{b})$ in the first period is made considering the uncertainty in q

$$V_1^1(y; R) = \max_{c,\tilde{m},\tilde{b}} \left\{ E_\vartheta \left[V_1^2(c, \tilde{m}, \tilde{b}, \vartheta; R) \right] \right\} \tag{B.5}$$

$$s.t. \qquad c + \tilde{m} + \tilde{b} = y \tag{B.6}$$

2. **Second sub-period:**

$$V_1^2(c, \tilde{m}, \tilde{b}, \vartheta; R) = \max_q \left\{ v(\underbrace{c + q}_{C_1}) + \beta u(\underbrace{\mathbb{P}(\tilde{m}, \tilde{b}; R) - \Psi(v, R)q}_{C_2 = \hat{W}}) \right\} \tag{B.7}$$

$$s.t. \qquad 0 < q \leq \min \left\{ \frac{\tilde{m}}{v}, \frac{\tilde{b} - \underline{b}}{(1 - v)} \right\} \tag{B.8}$$

First Order Condition:

$$q_\vartheta : \quad \frac{\vartheta}{\Psi(v, R)} u'(q_\vartheta) \geq \beta u'(C_2)$$

B.1.2 Characterization

Suppose that $u(c) = {}^{c^{1-\sigma}}/_{(1-\sigma)}$, then an interior solution for the problem in the second subperiod is given by

$$\hat{q}_k = \underbrace{\left(\frac{1}{\left(\beta\Psi(\nu,R)/\vartheta^k\right)^{1/\sigma} + \Psi(\nu,R)}\right)}_{\Lambda(\vartheta,\nu,R)} \mathbb{P}(\tilde{m},\tilde{b},R); \qquad for\ k = 1, ..., n \tag{B.9}$$

then

$$V_1^1(y;R) = \max_{\tilde{m},\tilde{b}} \left\{ \frac{[y-(\tilde{m}+\tilde{b})]^{1-\sigma}}{1-\sigma} + \sum_k p^k \left(\frac{\vartheta^k (q_k^*)^{(1-\sigma)}}{1-\sigma} + \beta \frac{\left[\mathbb{P}(\tilde{m},\tilde{b},R) - \Psi(\nu,R) q_k^*\right]^{1-\sigma}}{1-\sigma} \right) \right\} \tag{B.10}$$

$$with \qquad q_k^* = \min\left\{\hat{q}_k, \frac{\tilde{m}}{\nu}\right\} \tag{B.11}$$

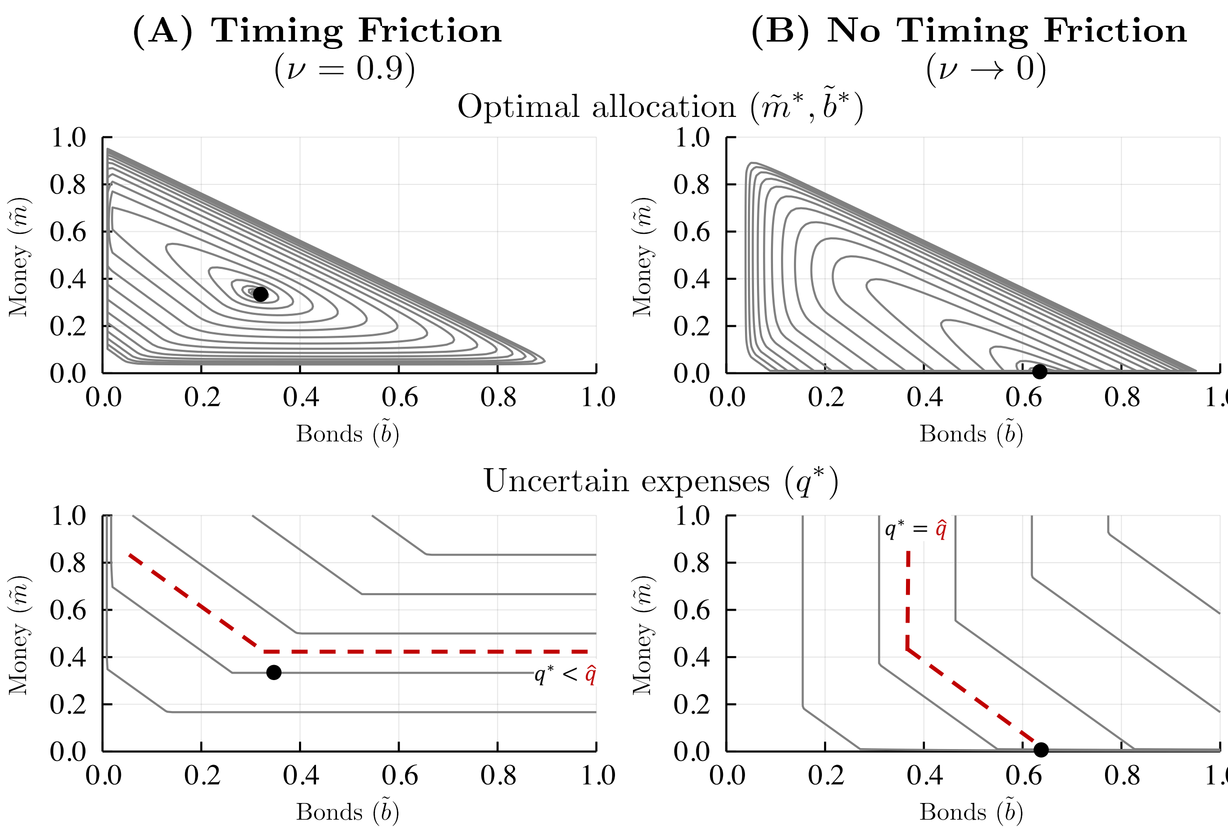
and define the optimal policies as $\tilde{m}^*(y;R)$, $\tilde{b}^*(y;R)$, then consumption is given by

$$c(y;R) = y - [\tilde{m}^*(y;R) + \tilde{b}^*(y;R)] \tag{B.12}$$

$$q_k^*(y;R) = \min\left\{\hat{q}_k(y;R), \frac{\tilde{m}^*(y;R)}{\nu}\right\} \tag{B.13}$$

Figure B.1 shows a special case with two realizations of the expenditure shock $\vartheta = \{\underline{\vartheta} \to 0, \overline{\vartheta}\}$, where $\hat{q}_{\underline{\vartheta}} \to 0 < \frac{\tilde{m}}{\nu}$ and $\hat{q}_{\overline{\vartheta}} > \frac{\tilde{m}}{\nu}$.

Figure B.1: Portfolio Allocation



B.1.3 Sensitivity to the nominal interest rate (R)

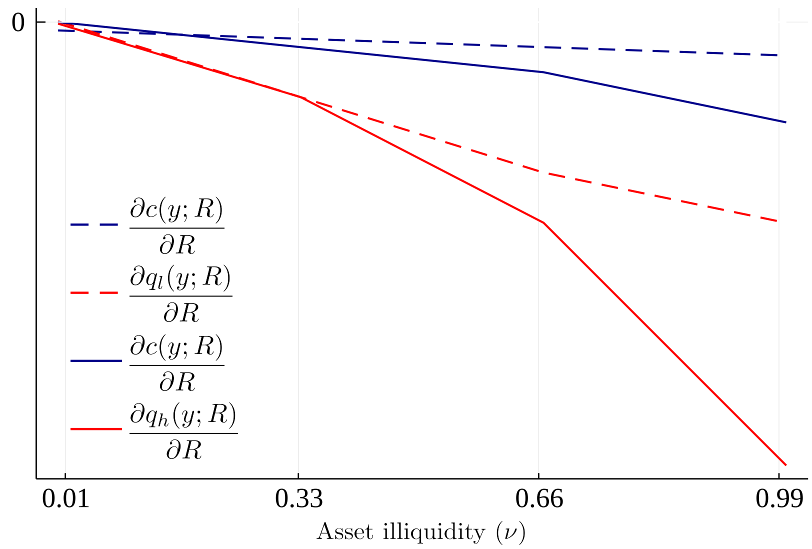
Approximate the derivatives for "x" with the forward difference expression

$$\frac{\partial x(y;R)}{\partial R} = \frac{x(y;R+h) - x(y;R)}{h} \tag{B.14}$$

for h small enough.

Showing two cases $\vartheta = \{\underline{\vartheta} \to 0, \vartheta_l\}$ (dash) and $\vartheta = \{\underline{\vartheta} \to 0, \vartheta_h\}$ (solid)

Figure B.2: Consumption response to R



The key in the consumption response is that $\hat{q} > \tilde{m}^*/\nu$ if there was no uncertainty, households would choose money balances such that $\hat{q} = \tilde{m}^*/\nu$

B.2 Transformed Household's Problem

1. **First sub-period:**

$$V^1(\hat{x}, z) = \max_{c, \tilde{m}, \tilde{b}} \left\{ \frac{c^{1-\sigma}}{1-\sigma} + E_\vartheta \left[V^2(\tilde{m}, \tilde{b}, z, \vartheta) \right] \right\} \tag{B.15}$$

$$s.t. \qquad (1+\phi)c + \tilde{m} + \tilde{b} = \hat{x} + z \tag{B.16}$$

2. **Second sub-period:**

$$V^2(\tilde{m}, \tilde{b}, z, \vartheta) = \max_{q_\vartheta} \left\{ \frac{\vartheta q^{\theta(1-\sigma)}}{1-\sigma} + \beta \left[E_\lambda E_{\varepsilon'} E_{z'|z} \{ V^1(x'(\vartheta) + \varepsilon', z') \} \right] \right\} \tag{B.17}$$

$$s.t. \qquad 0 < q_\vartheta \leq \min\left\{\frac{\tilde{m}}{(\nu+\phi)}, \frac{\tilde{b}-\underline{b}}{(1-\nu)}\right\} \tag{B.18}$$

where

$$x'(\vartheta) = \frac{m'(\vartheta)}{1+\pi} + (1+r)b'(\vartheta) \tag{B.19}$$

and

$$m'(\vartheta) = \tilde{m} - (\nu+\phi)q_\vartheta \geq 0; \quad and, \quad b'(\vartheta) = \tilde{b} - (1-\nu)q_\vartheta \geq \underline{b} \tag{B.20}$$

B.3 Optimality Conditions

- First order conditions

$$c: \qquad E_\vartheta V_c^2(c, \tilde{m}, \tilde{b}, z, \vartheta) - \lambda^c(1+\phi) = 0 \tag{B.21}$$

$$\tilde{m}: \qquad E_\vartheta V_{\tilde{m}}^2(c, \tilde{m}, \tilde{b}, z, \vartheta) - \lambda^c = 0 \tag{B.22}$$

$$\tilde{b}: \qquad E_\vartheta V_b^2(c, \tilde{m}, \tilde{b}, z, \vartheta) - \lambda^c = 0 \tag{B.23}$$

$$q_\vartheta: \qquad \vartheta\theta q^{\theta(1-\rho)-1} - \left(\mu_\vartheta + \frac{\beta}{1+\pi}E_{\varepsilon'}E_{z'|z}V_x^1(x'(\vartheta), z', \varepsilon')\right) = 0 \tag{B.24}$$

- Envelope conditions

$$V_c^2(c, \tilde{m}, \tilde{b}, z, \vartheta) = c^{-\sigma} \tag{B.25}$$

$$V_m^2(c, m, b, z, \vartheta) = \frac{\beta}{1+\pi'}\phi E_{\varepsilon'}E_{z'|z}V_x^1(x'(\vartheta), z', \varepsilon') + \mu_\vartheta \tag{B.26}$$

$$V_b^2(c, m, b, z, \vartheta) = \frac{\beta}{1+\pi'}(1+i)\phi E_{\varepsilon'} E_{z'|z} V_x^1(x'(\vartheta), z', \varepsilon') \tag{B.27}$$

$$V_x^1(x'(\vartheta), z', \varepsilon') = \lambda' \tag{B.28}$$

- Combining (B.21) and (B.22)

$$\phi E_\vartheta V_c^2(c, m, b, z, \vartheta) = E_\vartheta V_m^2(c, m, b, z, \vartheta)$$

  and using (B.25), (B.26) and (B.24)

$$\phi c^{-\sigma} = E_\vartheta\{\vartheta \theta q^{\theta(1-\sigma)-1}\}$$

B.4 Computational Algorithm

B.4.1 Decision rules

Adapting the Envelope Condition Method (ECM) as described in Maliar and Maliar (2013)

1. Given an initial guess for $V^1(\hat{x}, z)$, compute $V_x^1(\hat{x}, z)$ and obtain current consumption using the envelope condition (B.28)

$$c(\hat{x}, z) = \left[\frac{V_x^1(\hat{x}, z)}{(1+\phi)}\right]^{-\frac{1}{\sigma}} \tag{B.29}$$

   this pins down the desired portfolio level $P(\hat{x}, z)$, from the household's budget constraint (B.16)

$$(\tilde{m} + \tilde{b}) = z + \hat{x} - (1+\phi)c(\hat{x}, z) \equiv P(\hat{x}, z) \tag{B.30}$$

2. Now, the objective is to find the optimal combination for $(\tilde{m}, \tilde{b})$, given $P(\hat{x}, z)$. Define money holdings as a function of $\tilde{b}$ as:

$$\tilde{m}(\tilde{b}) = P(\hat{x}, z) - \tilde{b} \tag{B.31}$$

then define a grid of size n_j for $\tilde{b}$ in the interval (b_{min}, b^{max}), with:

$$b^{max} = P(\hat{x}, z); \qquad b_{min} = \max\left\{P(\hat{x}, z) - \hat{x}^{max}, \underline{b}\right\} \tag{B.32}$$

where these boundaries are such that $0 < \tilde{m} < \hat{x}^{max}$

3. Given $\{\hat{x}, z, \tilde{b}^j\}$, for all $\tilde{b}^j \in (b_{min}, b^{max})$ and for ϑ^k

$$V^2(\tilde{m}(\tilde{b}^j), \tilde{b}^j, z, \vartheta^k) = \max_{q_{\vartheta^k} \in (0, \min\{\frac{\tilde{m}(\tilde{b}^j)}{(\nu+\phi)}, \frac{\tilde{b}^j - \underline{b}}{(1-\nu)}\}]} \{\frac{\vartheta^k q_{\vartheta^k}^{\theta(1-\sigma)}}{1-\sigma} + \beta E_\lambda E_{\varepsilon'} E_{z'|z} V^1(\frac{\tilde{m}(\tilde{b}^j) - (\nu+\phi) q_{\vartheta^k}}{1+\pi} + (1+r)[\tilde{b}^j - (1-\nu) q_{\vartheta^k}] + \varepsilon', z')\} \tag{B.33}$$

and define

$$V^2_{aux}(\tilde{b}^j, z) = E_\vartheta V^2(\tilde{m}(\tilde{b}^j), \tilde{b}^j, z, \vartheta) = \sum_k p^{\vartheta^k} V^2(\tilde{m}(\tilde{b}^j), \tilde{b}^j, z, \vartheta^k) \tag{B.34}$$

4. Create a vector of $\{V^2_{aux}(\tilde{b}^j, z)\}_{j=1}^{n_j}$, and find the optimal combination of assets as:

$$j^* = arg \max\{V^2_{aux}(\tilde{b}^j, z)\}_{j=1}^{n_j}; \quad and \quad V^2(\hat{x}, z) = \max\{V^2_{aux}(\tilde{b}^j, z)\}_{j=1}^{n_j} \tag{B.35}$$

and define the policy functions as

$$\tilde{b}^*(\hat{x}, z) = \tilde{b}^{j^*}; \quad \tilde{m}^*(\hat{x}, z) = P(\hat{x}, z) - \tilde{b}^*; \quad q^*(\hat{x}, z, \vartheta) = arg \max\{V^2(\tilde{m}^*, \tilde{b}^*, z, \vartheta)\} \tag{B.36}$$

5. Update V^1

$$V^1(\hat{x}, z) = \frac{c(\hat{x}, z)^{1-\sigma}}{1-\sigma} + V^2(\hat{x}, z) \tag{B.37}$$

- Iterate until convergence in V^1

B.4.2 Stationary Distribution $\Gamma(\hat{x}, z)$

Define the transition matrix (H).

The policy functions define a mapping from states $(\hat{x}, z)$, the preference shock (ϑ), and the next-period transitory income shock (ε') to future asset holdings $(\hat{x}')$ as:

$$(\hat{x}, z, \vartheta, \varepsilon') \to (\hat{x}') \tag{B.38}$$

then, we can define the function $H : (i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}) \to i_{\hat{x}'}$, that maps the corresponding indices by inverting the grid for $\hat{x}$ as:

$$H(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}) = grid_{\hat{x}}^{-1}(\hat{x}') \tag{B.39}$$

and the weighting function (w) for two adjacent points in the grid as:

$$w(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}) = \frac{\hat{x}' - grid_{\hat{x}'}(H(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}))}{grid_{\hat{x}'}(H(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}) + 1) - grid_{\hat{x}'}(H(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}))} \tag{B.40}$$

Updating the distribution **Γ.**

Adapting the histogram-method as described in Young (2010) (iterating over Γ)

1. Start with some given density $\Gamma(\cdot) = [1/n_{\hat{x}} * n_z]$, and with $\Gamma'(\cdot) = [\mathbf{0}]$.

2. For $i_z = 1 : n_z$ (current persistent shock); $i_{\hat{x}} = 1 : n_{\hat{x}}$ (asset holdings); $i_\vartheta = 1 : n_\vartheta$ (preference shock); $i_{\varepsilon'} = 1 : n_{\varepsilon'}$ (next-period transitory shock); $i_{z'} = 1 : n_z$ (next-period persistent shock), compute:

$$\begin{aligned}\Gamma'(H(i_{\hat{x}}, i_z, i_\vartheta, i_\varepsilon), i_{z'}) &= \Gamma'(H(i_{\hat{x}}, i_z, i_\vartheta, i_\varepsilon), i_{z'}) + \\ &w(i_{\hat{x}}, i_z, i_\vartheta, i_\varepsilon)p(i_\vartheta)\left[(\lambda_\varepsilon p(i_\varepsilon) + (1-\lambda_\varepsilon)\mathbb{I}_{\{i_\varepsilon = i_{\varepsilon 0}\}})(\lambda_\eta \Pi(i_z, i_{z'}) + (1-\lambda_\eta)\mathbb{I}_{\{i_z = i_{z'}\}})\right]\Gamma(i_{\hat{x}}, i_z)\end{aligned} \tag{B.41}$$

$$\begin{aligned}\Gamma'(H(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}) + 1, i_{z'}) &= \Gamma'(H(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}) + 1, i_{z'}) + \\ &(1 - w(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}))p(i_\vartheta)\left[(\lambda_\varepsilon p(i_{\varepsilon'}) + (1-\lambda_\varepsilon)\mathbb{I}_{\{i_{\varepsilon'} = i_{\varepsilon 0}\}})(\lambda_\eta \Pi(i_z, i_{z'}) + (1-\lambda_\eta)\mathbb{I}_{\{i_z = i_{z'}\}})\right]\Gamma(i_{\hat{x}}, i_z)\end{aligned} \tag{B.42}$$

calculate

$$dist = |\Gamma' - \Gamma| \tag{B.43}$$

and set

$$\Gamma' = \Gamma \tag{B.44}$$

3. If $dist > tol$, go back to step 2. Otherwise stop iteration.

B.5 Proofs

Proof. [sketch] Combining (2.23) and (2.24), money demand, at wealth level (x), is given by

$$m(x) = \phi c(x) + (\nu + \phi)[q(x) + \chi(x)]$$

Normalize money demand (m) by total consumption ($\mathbb{C}$) and consider two wealth levels $x > y$, what needs to be shown is that

$$\frac{m(x)}{\mathbb{C}(x)} - \frac{m(y)}{\mathbb{C}(y)} > 0,$$

so define the difference in money demand in the two wealth levels $x > y$, as:

$$\frac{m(x)}{\mathbb{C}(x)} - \frac{m(y)}{\mathbb{C}(y)} = \phi\left[\frac{c(x)}{\mathbb{C}(x)} - \frac{c(y)}{\mathbb{C}(y)}\right] + (\nu + \phi)\left[\frac{q(x)}{\mathbb{C}(x)} - \frac{q(y)}{\mathbb{C}(y)} + \frac{\chi(x)}{\mathbb{C}(x)} - \frac{\chi(y)}{\mathbb{C}(y)}\right]$$

using that

$$\frac{c(x)}{\mathbb{C}(x)} - \frac{c(y)}{\mathbb{C}(y)} = -\left[\frac{q(x)}{\mathbb{C}(x)} - \frac{q(y)}{\mathbb{C}(y)}\right]$$

then

$$\frac{m(x)}{\mathbb{C}(x)} - \frac{m(y)}{\mathbb{C}(y)} = \nu \underbrace{\frac{q(x)}{\mathbb{C}(x)} - \frac{q(y)}{\mathbb{C}(y)}}_{(A)} + (\nu + \phi)[\underbrace{\frac{\chi(x)}{\mathbb{C}(x)} - \frac{\chi(y)}{\mathbb{C}(y)}}_{(B)}]$$

i) $(A) > 0$ when the share of the uncertain component increases in wealth

ii) $(B) > 0$ requires additional steps:

consider two realizations of $\vartheta = \{\vartheta^l, \vartheta^h\}$ such that $\chi(x)_{\vartheta^h} = \chi(y)_{\vartheta^h} = 0$, then from expression (**??**)

$$\frac{\tilde{m}(x)}{(1+\phi)} = q(x)_{\vartheta^h}, \quad and \quad \frac{\tilde{m}(y)}{(1+\phi)} = q(y)_{\vartheta^h}$$

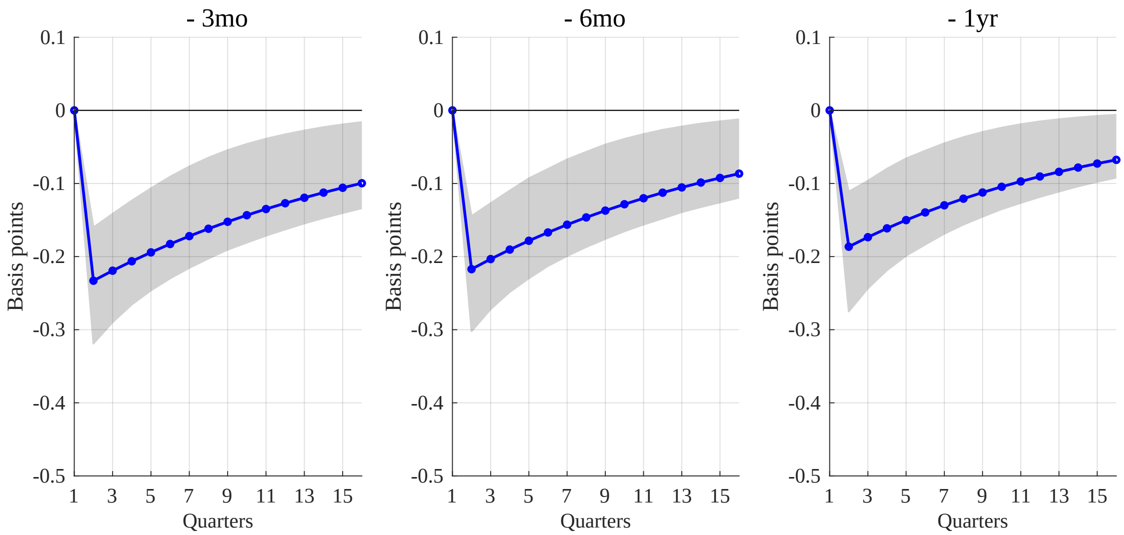
and using (2.24), $(B) > 0$ if

$$\frac{\chi(x)}{\mathbb{C}(x)} = \frac{q(x)_{\vartheta^h} - q(x)_{\vartheta^l}}{\mathbb{C}(x)} > \frac{q(y)_{\vartheta^h} - q(y)_{\vartheta^l}}{\mathbb{C}(y)} = \frac{\chi(y)}{\mathbb{C}(y)}$$

□

B.6 Path for $\{R_t\}_{t=1}^{T}$

Figure B.3: Dynamic effects of a 25 bp unanticipated interest rate cut (nominal rates)



Note: Gray areas are bootstrapped 90% confidence bands.

Appendix C

Appendices to Chapter 3

C.1 First Order Conditions

Let λ be the Lagrange multiplier for the household's aggregate budget constraint (3.8) and φ^* some re-scaled Lagrange multiplier for the constraint in (3.9), then the first order conditions for this problem are given by

$$c_t^l : \ \gamma u'(c_t^l) - \lambda_t \gamma - \varphi_t^* = 0 \tag{C.1}$$

$$c_t^h : \ (1-\gamma)u'(c_t^h) - \lambda_t(1-\gamma) = 0 \implies \lambda_t = u'(c_t^h) \tag{C.2}$$

$$s_{t+1} : \ -\lambda_t q_t^{buy} + \beta v'(s_{t+1}) = 0 \tag{C.3}$$

and the envelope condition

$$v'(s_{t+1}) = \lambda_{t+1}\{r + [q_{t+1}^{buy} - \gamma\phi(q_{t+1}^{buy} - q_{t+1}^{sell})]\} + \varphi_{t+1}^*\{r + \phi q_{t+1}^{sell}\} \tag{C.4}$$

last, define φ^* as the scaled multiplier $\varphi_t^* \equiv \gamma u'(c_t^h)\varphi_t$.

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