Uncertain Expenses and the Short-Run Transmission of Monetary Policy*

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Abstract

In this paper, I study the importance of uncertain expenses for households' savings and the short-run response to monetary policy. Using data from the Consumer Expenditure Survey (CEX), I classify a group of uncertain expenditure items representing 14.5% of total expenses and document that these uncertain expenses drive 41.8% of the short-run consumption response to monetary policy shocks. I develop a heterogeneous-agent incomplete markets model with two assets, money and bonds, where households use the two assets to self-insure against income and expenditure uncertainty. A timing friction in the portfolio choice problem and frictions in the goods market lead households to hold extra liquidity relative to their total consumption level. 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 policy rate. In addition, the model generates concentration in the distribution of money holdings consistent with the data, a feature hard to reconcile with traditional transaction motives for money demand.

JEL codes: D52, E21, E41, E52

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1 Introduction

Household portfolio liquidity is key to understanding the transmission of monetary policy to consumption, as it is an important determinant of households' marginal propensities to consume (Kaplan, Moll, and Violante, 2018) and is crucial for households' responses to unexpected events. Recent literature has shown that incorporating household heterogeneity into standard monetary models provides new and important insights on this transmission.[1] In particular, a growing strand of this literature has focused on studying the consequences of a liquidity-insurance role for monetary policy, which operates when households use government-provided liquidity to insure idiosyncratic income risk (Bilbiie and Ragot, 2021). But less attention has been given to studying the implications of expenditure risk.

I study the quantitative importance of uncertain expenses for households' savings, especially for portfolio choice among assets with different liquidity, and the implications for monetary policy. I deem as "uncertain" those expenses for which the exact timing is difficult to predict, for example, car and home repairs or out-of-pocket medical expenses.[2] 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.

There are two main contributions of this paper. First, I document facts on uncertain expenses at the household level and show that they drive 41.8% of the short-run consumption adjustment by households in response to monetary policy shocks. Second, I develop a model in which self-insurance against expenditure risk is a significant driver of money demand and show that household portfolio rebalancing is an important mechanism for understanding this short-run

[1] Transmission channels have been broadly divided into *direct* (or partial-equilibrium), such as inter-temporal substitution. While *indirect* channels operate through the general-equilibrium response of labor income and housing assets (Kaplan, Moll, and Violante, 2018; Slacalek, Tristani, and Violante, 2020).

[2] Similar to Chase, Gjertson, and Collins (2011) and Collins (2015).

transmission. 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 reconcile with traditional transaction motives for money demand.[3]

I characterize uncertain expenses using consumption micro-data from the Consumer Expenditure Survey (CEX). I classify uncertain items as those infrequently purchased non-durable and non-*memorable* goods. In particular, I use a volatility-based approach as in Telyukova (2013) to determine infrequent items and exclude anticipated lumpy expenses on durable and memorable goods as defined by Hai, Krueger, and Postlewaite (2020). The resulting set of uncertain items represents 14.5% of total expenses for a typical household in the U.S., and includes items such as auto and home repairs, medical services, prescription drugs, and education services. Memorable and durable expenses represent 24% of total expenses and include items such as house furnishings and equipment, apparel, and entertainment. Last, certain expenses represent 61.5% of total expenses, and include items such as food at home, housing, gasoline, and insurance plans.

I measure the sensitivity of these broad expenditure categories to changes in the central bank's policy rate using pseudo-panels from the CEX, as in Cloyne, Ferreira, and Surico (2019). In particular, I use a local projection to construct impulse response functions of these components to monetary policy shocks following the narrative approach by Romer and Romer (2004). I show that 41.8% of the short-run consumption response is driven by the uncertain component of expenses, while the certain component is not sensitive to changes in the policy rate. Comparing the response of uncertain expenses to the response of memorable and durable expenses, I find that the peak in the response of uncertain expenses (5 quarters after the shock) occurs much earlier than for memorable and durable expenses (12 quarters after the shock), and also tends to dissipate sooner.[4]

[3]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.

[4]This is consistent with what is commonly found in the literature for the response of durable expenses (Cloyne,

To understand the mechanism responsible for this short-run transmission of monetary policy to consumption, I develop a dynamic quantitative model with income and expenditure risk, where household portfolio rebalancing can explain the shape of the response in uncertain expenses. The model features heterogeneous agents with incomplete markets, as in Aiyagari (1994), Bewley (1983), and Huggett (1993), with two assets, a low-return/ liquid asset that I will call money and a high-return/illiquid asset that I will call bonds. Households can use these assets to self-insure idiosyncratic risk on 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 the empirical section. 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.

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 that requires 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, capturing the necessity of planning for uncertain expenses.

This generates a micro-founded and tractable money-demand relationship consistent with the novel facts I establish in the data. In particular, this relationship includes 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 and generates inequality

Ferreira, and Surico, 2019; McKay and Wieland, 2021; Sterk and Tenreyro, 2018) in money holdings.[5] I use the CEX 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 against 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.[6] 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 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, Krusell, and Mitman (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

[5]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.

[6]Berentsen, Huber, and Marchesiani (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.

take longer to materialize (through adjustments in labor income or housing assets, for example).[7] This fast consumption response is explained by a relatively quick portfolio adjustment by households after changes in the nominal interest rate.[8]

I discipline the liquidity-accumulation mechanism in the model by matching two key empirical facts about certain and uncertain expenses. First, uncertain expenses are four times more volatile than certain expenses for all household groups. This means that, although expenditures for wealthier households tend to be less volatile overall, the volatility-based classification captures uncertainties that are present at all wealth levels. Second, the share of uncertain expenses (with respect to total expenditures) increases along with wealth. I capture these features by introducing a random preference for consuming uncertain goods and by allowing for a non-homothetic utility function between the two goods in the model.

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 paper contributes to overall wealth concentration.

Related literature. This paper contributes to a large literature that studies 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 response (Eichenbaum,

[7] See the evidence provided by Cloyne, Ferreira, and Surico (2019).

[8] See Drechsler, Savov, and Schnabl (2017) for evidence at the aggregate level, and Luetticke (2020a) for evidence at the household level.

Rebelo, and Wong, 2022; Kaplan, Moll, and Violante, 2018; Luetticke, 2020a; Nakamura, 2019; Slacalek, Tristani, and Violante, 2020; Wong, 2021) or on the response in durable expenses (Cloyne, Ferreira, and Surico, 2019; McKay and Wieland, 2021; Sterk and Tenreyro, 2018). Other papers have studied the implications of idiosyncratic income risk for monetary policy (Bayer, Luetticke, Pham-Dao, and Tjaden, 2019; Bilbiie and Ragot, 2021); this paper is the first to analyze idiosyncratic expenditure risk.

This paper also contributes to the literature on the determinants of money demand in models with heterogeneous agents and incomplete markets. Early papers 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 paper.

The liquidity-accumulation mechanism studied in this paper 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 paper is closer to that found in Allais, Algan, Challe, and Ragot (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 paper 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 paper.

Last, this paper contributes to the literature showing that medical expense risk drives savings behavior. For example, De Nardi, French, and Jones (2010) and De Nardi, French, Jones, and McGee (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.

Consumption or expenditure risk has been widely studied (Gorbachev, 2011; Miranda-Pinto, Murphy, Walsh, and Young, 2020). The household finance literature (Chase, Gjertson, and Collins, 2011; Collins, 2015) has generalized the concept of uncertain expenses to "contingencies" rather than only "emergencies" since a lack of *available* resources set aside to manage them may result in household instability or even leave households unable to take advantage of opportunities for upward economic mobility, such as job training or enrichment activities for children. To my knowledge, this paper 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 Uncertain Expenses

In this section, I document descriptive statistics, using the Consumer Expenditure Survey (CEX), for expenditures on a detailed set of items and discuss the criteria for classifying these items as uncertain expenses. I document that these uncertain expenses represent 14.5% of total expenditures for a typical household and display significantly larger fluctuations than certain expenses.

I further show that 41.8% of the short-run consumption response to monetary policy shocks, at the household level, is driven by uncertain expenses.

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).[9] 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.[10]

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

[9] See Table 6, in Appendix A, for this mapping.

[10] 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.

inconsistent information on major characteristics (age, sex, or race) of the reference person is reported at any interview.

2.1 A volatility-based approach

My main interest is to capture possible uncertainties in expenses that households face when making portfolio decisions. In general, I distinguish between two broad types of expenditures: (i) spending 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, Krueger, and Postlewaite (2020).

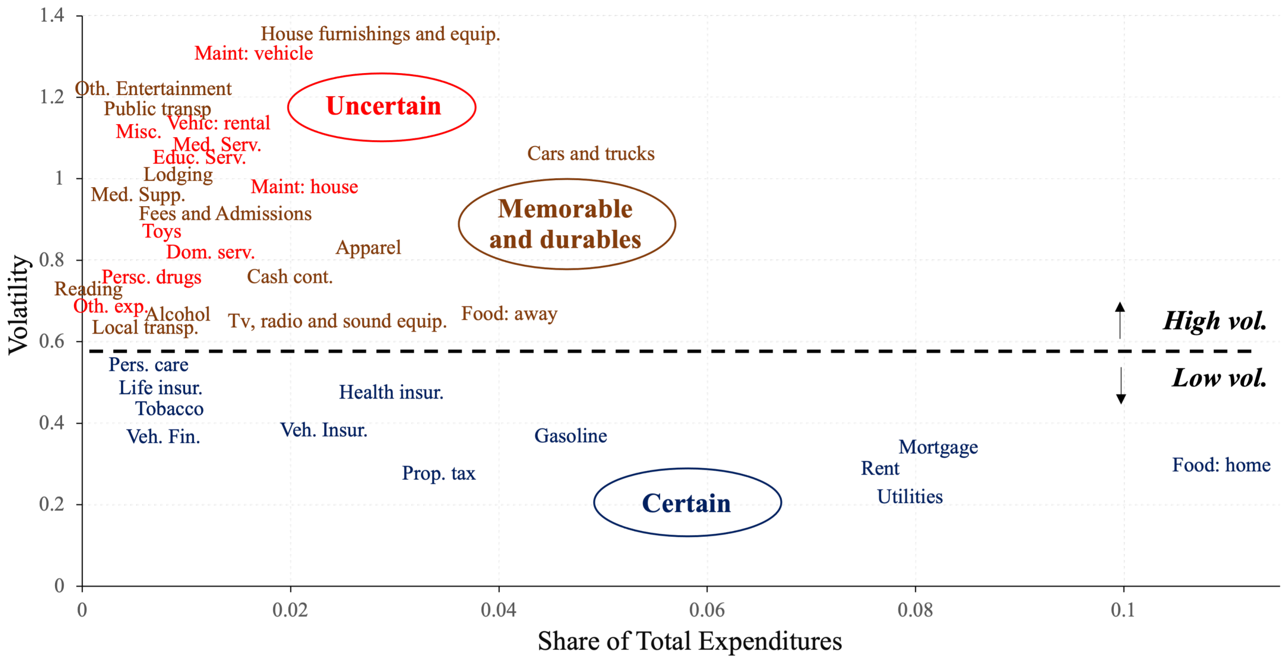
As a broad approach to assess possible expenditure risk, I use a volatility measure for a detailed set of expenditure categories $\{exp^j\}_{j=1}^J$. Raw volatility in expenditures might not be fully informative about uncertainty, as it could reflect predictable variation, or seasonal volatility. Following a similar approach to Telyukova (2013) and Telyukova and Visschers (2013), I filter out the predictable component of expenditures by estimating the following model for each expenditure item:[11]

$$\begin{aligned} \log(exp_{i,t}) &= \alpha_i + \delta_t + \gamma X_{i,t} + \varepsilon_{i,t} \\ \varepsilon_{i,t} &= \rho\varepsilon_{i,t-1} + \eta_{i,t}, \end{aligned} \tag{2.1}$$

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).

[11] 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: 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 (2.1), where the set $\{exp\}$ are all those expenditure items that add up to nondurables and services, as defined in the NIPA aggregates (See Table 6 for this mapping).

Figure 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 a lower share of total expenditures. The dotted line represents a weighted average volatility of all expenditure items ($\overline{\sigma^\eta}$).[12] 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, Krueger, and Postlewaite (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

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

total expenses and include items such as: Trips and vacations; Entertainment; Food and alcohol out; Photographic services and rental; Charitable giving; 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 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 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 paper 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.

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 wether the expenditure patterns, as shown in Figure 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 (2.1) 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, uncertain expenses are around four times more volatile than certain expenses for all three household

Table 1: Expenditure Risk by Household Groups
(based on income)

	(A) **Certain**		(B) **Uncertain**		(C) **Memorable and durables**			
I. Volatility							*Relative*	
							(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).

groups, since their relative volatility is constant.[13] This suggests that uncertainties in expenses that households face when making portfolio decisions are present for all household groups. The fact that volatility for all categories is decreasing in 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 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.

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

2.2 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.[14] 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.[15] 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.[16] 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, Ferreira, and Surico (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.[17]

Empirical specification. I follow the empirical specification from CFS. The expenditure item is regressed on a distributed lag of the monetary policy shocks, while also controlling for the lagged

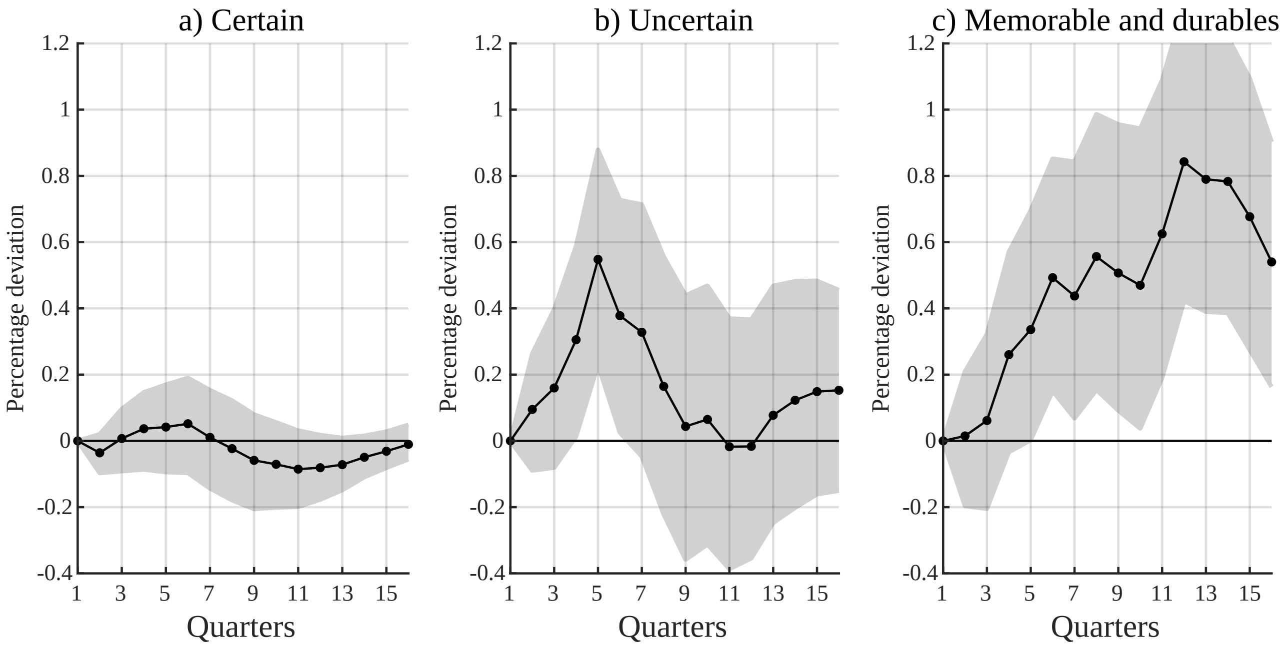
[14] The response of durable goods has been widely studied in the literature (Cloyne, Ferreira, and Surico, 2019; McKay and Wieland, 2021; Sterk and Tenreyro, 2018)

[15] 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.

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

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

Figure 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 2.1, 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.

endogenous variable. In particular, I estimate the following equation:

$$X_{j,t} = \alpha_0^j + \alpha_1^j trend + B^j(L)X_{j,t-1} + C^j(L)S_{t-1} + \sum_{q=2}^{4} D_q^j Z_q + u_{j,t}, \tag{2.2}$$

where X is an expenditure item (certain, uncertain, or memorable and durables), S is the monetary policy shock, Z is a vector of quarterly dummies, j is a particular household group ($j \in$ {Renters and Mortgagors}) and the α's represent a linear time trend.

Figure 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 of uncertain expenses comes much earlier, at around 5 quarters after the shock, and dissipates sooner.[18]

In Table 4??, 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.

In the next section, I develop a dynamic quantitative model with expenditure risk, in which household portfolio rebalancing is an important mechanism that explains the shape of the response in uncertain expenses documented in Figure 2 and Table 4??.

3 Model

In this section, I develop a heterogeneous-agent incomplete markets model 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.

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

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.

3.1 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:

$$E_0 \sum_{t=0}^{\infty} \beta^t [u(c_{i,t}, q_{i,t}; \vartheta_{i,t}) \equiv \xi \frac{c_{i,t}^{1-\sigma}}{1-\sigma} + (1-\xi) \frac{\vartheta_{i,t} q_{i,t}{}^{(1-\theta)}}{1-\theta}], \tag{3.1}$$

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 (3.1), subject to the following budget constraint:

$$\overbrace{c_{i,t} + \underbrace{q_{i,t}}_{exp.\ risk}}^{C_{i,t}} + m_{i,t+1} + b_{i,t+1} = \underbrace{y_{i,t}}_{inc.\ risk} + \frac{m_{i,t}}{1+\pi_t} + (1+r_t)b_{i,t}, \tag{3.2}$$

where $(C_{i,t})$ 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.

3.2 Frictions

Goods Market (ϕ). I assume that financial markets close before the goods market, so households must hold money before consuming as in Lucas (1982). This means that goods must be purchased with money according to the following reduced-form transactions constraint:

$$\phi[\underbrace{c_{i,t} + q_{i,t}}_{C_{i,t}}] \leq m_{i,t+1}, \tag{3.3}$$

where ϕ represents real transaction costs, so the cost of consuming one unit of C is given by $(1 + \phi)$. This specification leads to an equivalent money demand relation as in models with a Cash-in-Advance constraint, as discussed in Section 5.2.

Timing in portfolio (ν). The timing friction in financial markets is meant to capture that money is more liquid than bonds as in Aiyagari and Williamson (2000) and Akyol (2004). 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 (3.2) and (3.3)

$$\phi C_{i,t} \leq m_{i,t+1} = \underbrace{y_{i,t} + \frac{m_{i,t}}{1+\pi_t} + (1+r_t)b_{i,t}}_{Y_{i,t}} - b_{i,t+1} - C_{i,t}, \tag{3.4}$$

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

$$(1+\phi)[\underbrace{c+q}_{C}] + b \leq Y. \tag{3.5}$$

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:

$$\underbrace{\phi c + \underbrace{(\phi+\nu)q}_{\tilde{m}}}_{m^d} + \underbrace{b + (1-\nu)q}_{\tilde{b}} = Y - c, \tag{3.6}$$

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.

3.3 Idiosyncratic Risk

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

$$\begin{aligned} \log y_{i,t} &= z_{i,t} + \varepsilon_{i,t} \\ z_{i,t} &= \rho z_{i,t-1} + \eta_{i,t} \end{aligned}, \tag{3.7}$$

where ε and η are persistent and transitory shocks.

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

$$\log \vartheta_{i,t} \sim i.i.d\ N(0, \sigma_\vartheta^2), \tag{3.8}$$

where σ_ϑ is the standard deviation of the preference shock.

3.4 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 3), 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.[19]

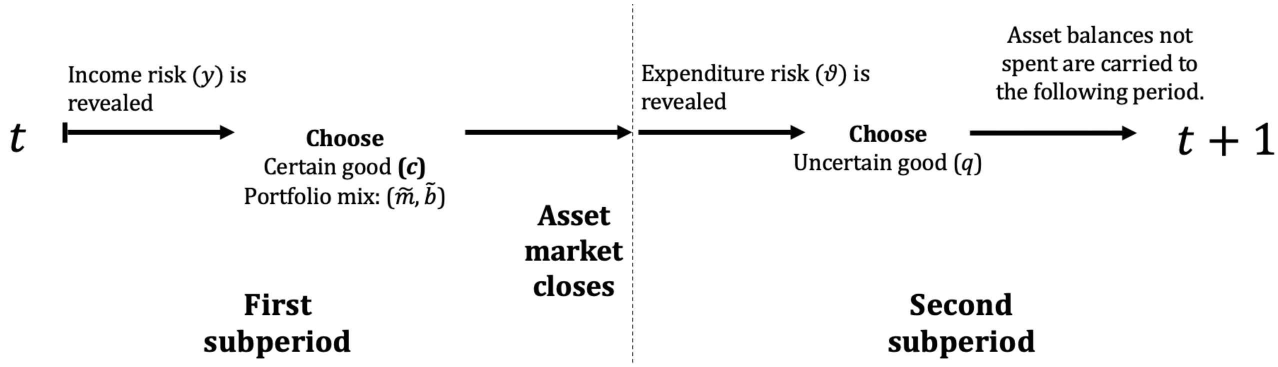
First sub-period: Each household knows their income realization y, chooses their consumption of the certain good (c) and decides its portfolio allocation between money ($\tilde{m}$) and bonds ($\tilde{b}$)

$$V^1(m, b, z, \varepsilon) = \max_{c, \tilde{m}, \tilde{b}} \left\{ E_\vartheta \left[V^2(c, \tilde{m}, \tilde{b}, z, \vartheta) \right] \right\} \tag{3.9}$$

$$s.t. \qquad (1+\phi)c + \tilde{m} + \tilde{b} = \underbrace{z + \varepsilon}_{y} + \frac{m}{1+\pi} + (1+r)b, \tag{3.10}$$

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

Figure 3: Timing of events



the expectation operator is taken over the preference shock (ϑ), which is unknown at this stage. According to the intuition developed in expression (3.6), money demand (m^d) for each household is given by:

$$m^d = \phi c + \tilde{m}. \tag{3.11}$$

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

$$V^2(c, \tilde{m}, \tilde{b}, z, \vartheta) = \max_q \left\{ u(c, q; \vartheta) + \beta \left[E_{\varepsilon'} E_{z'|z} \{ V^1(m', b', z', \varepsilon') \} \right] \right\} \tag{3.12}$$

$$s.t. \qquad 0 < q \leq \min \left\{ \frac{\tilde{m}}{(\nu + \phi)}, \frac{\tilde{b} - \underline{b}}{(1 - \nu)} \right\}, \tag{3.13}$$

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

$$m' = \tilde{m} - (\nu + \phi) q \geq 0; \quad and, \quad b' = \tilde{b} - (1 - \nu) q \geq \underline{b}. \tag{3.14}$$

3.5 Solution

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 E.

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:

$$x' = \frac{m'}{1+\pi} + (1+r)b', \tag{3.15}$$

where m' and b' are defined as in (3.14). 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 C.

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 E.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 E.2 for more details.

4 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 (3.7) 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:

$$\eta_{i,t} \begin{cases} 0 & 1-\lambda_\eta \\ N(0,\sigma_\eta^2) & \lambda_\eta \end{cases} ; \qquad \varepsilon_{i,t} \begin{cases} 0 & 1-\lambda_\varepsilon \\ N(0,\sigma_\varepsilon^2) & \lambda_\varepsilon \end{cases} , \tag{4.1}$$

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, Kaplan, and Zafar (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: 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, Kaplan, and Zafar (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

4.1 *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, Kaplan, and Zafar (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 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

Table 3: 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

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 3 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.

5 Results

There are two main results in this paper. 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.

5.1 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, Krusell, and Mitman, 2018). To assess the importance of this channel, I evaluate how much of the response in the data, as shown in Section 2.2, 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, Tristani, and Violante, 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 $\boldsymbol{\epsilon}$, so we can find an explicit expression in terms of the policy instrument $R(\epsilon)$ by rewriting the evolution of savings (3.15) as:

$$\overline{x}' \equiv (1+r)\left[\frac{m'}{(1+R(\epsilon))} + b'\right], \tag{5.1}$$

where $(1 + R) = (1 + r)(1 + \pi)$ and the relative price between money and bonds is given by ${}^{1}/_{(1+R)}$, 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 2.2 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 Section 2.2), while holding constant the real interest rate r.[20] Then, following a similar approach as in Nakamura (2019) and 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 2.2. I estimate equation (2.2) with the 3-month treasury bill rate as the dependent variable, and compute the local projection to a monetary policy shock (ϵ). See Appendix G for the trajectory.

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

$$\left\{V_t^1, V_t^2, c_t, q_t, \tilde{m}_t, \tilde{b}_t, \bar{x}_t; \{R_{t'}\}_{t'=t}^{T})\right\}_{t=o}^{T}, \tag{5.2}$$

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:

$$\{\Gamma_t; \{R_{t'}\}_{t'=t}^{T}\}_{t=o}^{t=T}. \tag{5.3}$$

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 ($\mathcal{Q}$):

$$\mathcal{Q}_t(\{R_{t'}\}_{t'=t}^{T}) = \int q_t d\vartheta d\Gamma_t, \quad for \quad t = 1, ..., T, \tag{5.4}$$

[20] 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.

Table 4: Average Cumulative Consumption Response
(in 2000 US dollars, per household)

Time after the shock *(in quarters)*	**Certain** Data	**Certain** Model	**Uncertain** Data	**Uncertain** Model	**Memorable and durables** 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.

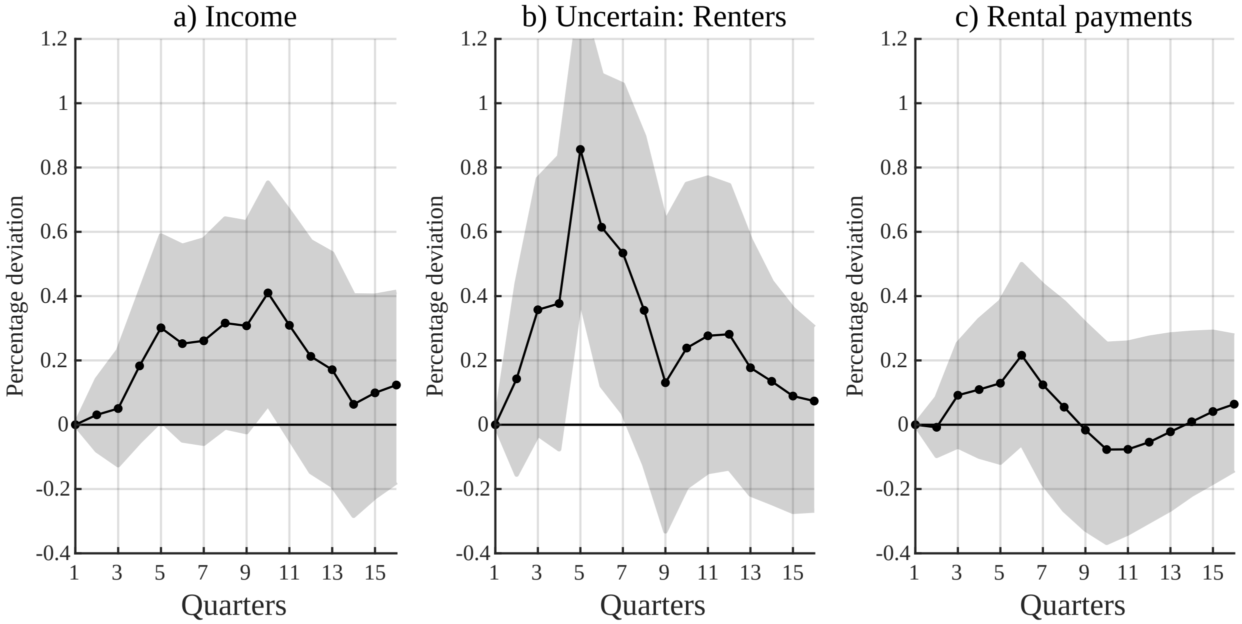
that can be directly compared to the response of uncertain expenses in Figure (2). Note that this sequence for average uncertain expenses only considers a path for the change in the relative price of money and bonds ($^1/_{(1+R)}$) and does not take into account any other potential transmission channels.

Table 4 compares the average cumulative consumption response (converted into 2000 US dollars) generated in the model, according to expression 5.4, to the consumption response in the data, as shown in Figure 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.

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

Figure 4: Dynamic effects of a 25 bp unanticipated interest rate cut



Note: Gray areas are bootstrapped 90% confidence bands.

general-equilibrium forces) rather than on *direct* (or, partial-equilibrium) effects.[21] 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 4.a, I report the point estimates and confidence bands for the response of household income 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.

[21] Cloyne, Ferreira, and Surico (2019), Kaplan, Moll, and Violante (2018), and Slacalek, Tristani, and Violante (2020)

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, Duarte, and Mann, 2018). Second, mortgage refinancing decisions are an important determinant of household consumption response to monetary policy (Wong, 2021). In Figure 4.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 4.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.

5.2 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).[22] As shown in Table 5, money is much more unequally distributed than consumption in the data, instead resembling inequality in financial wealth.[23] For example, the *Gini* coefficient for money and bonds is around 0.80, while for consumption it is 0.29.

[22] Most of the literature has used a similar approach (Allais, Algan, Challe, and Ragot, 2020; Aoki, Michaelides, and Nikolov, 2021; Aruoba, Waller, and Wright, 2011; Doepke and Schneider, 2006; Erosa and Ventura, 2002; Gottlieb, 2015; Ragot, 2014).

[23] 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 5: 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.

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:

$$\mathcal{M} \;\equiv\; \frac{m_i^d(X)}{C_i(X)} - \frac{m_j^d(Y)}{C_j(Y)} \;>\; 0 \qquad \underline{\text{in data}}. \tag{5.5}$$

No uncertain expenses. Suppose that $\vartheta = \overline{\vartheta}$, then constraint (3.3) is binding whenever $(1 + r) > {}^1\!/_{(1+\pi)}$, so that money holdings of household i are proportional to their total consumption level.

$$m_i^d = \phi C_i, \tag{5.6}$$

since money holdings are proportional to C, any properties from this distribution will be mapped into the distribution of money holdings. In addition, liquidity accumulation, as defined in (5.5), is:

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

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

$$m_i^d = \underbrace{\phi c_i^*}_{certain} + \underbrace{(\nu + \phi) q_i^*(\vartheta^h)}_{\tilde{m}_i}, \tag{5.7}$$

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

$$\mathcal{M} = \underbrace{\nu}_{\substack{\text{Timing} \\ \text{friction}}} \Delta(\text{Share of q}) + \underbrace{\phi}_{\substack{\text{Goods mkt.} \\ \text{friction}}} \Delta(\text{Dispersion of q}) \tag{5.8}$$

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.

Inequality measures in the distribution of assets

Table 5 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 studied in this paper contributes to explain overall wealth concentration as in De Nardi, French, Jones, and McGee (2021).

6 Conclusion

This paper presents a quantitative evaluation of uncertain expenses on household's savings and the transmission of monetary policy to consumption. In particular, in the portfolio choice among assets with different liquidity. Using consumption micro-data from the Consumer Expenditure Survey (CEX), I categorize expenditure items into certain and uncertain expenses. I document the following three facts of uncertain expenses. First, uncertain expenses represent 14.5% of total expenses. Second, expenditure risk is present at all levels of income. Third, uncertain expenses represent a larger share of total expenses for high-income households, than for low-income households. In addition, I show that uncertain expenses are an important driver of the short-run consumption response to monetary policy shocks.

Household portfolio rebalancing is an important mechanism that explains the shape of the response in uncertain expenses and, hence, helps us understand the short-run transmission of monetary policy to consumption. The liquidity-accumulation mechanism studied in this paper, based on expenditure risk, can generate concentration in the distribution of money holdings consistent with the data. In addition, expenditure risk contributes to our understanding of overall wealth concentration.

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A Mapping of CEX to NIPA

Table 6: 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

B 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 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

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

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 $\Psi(\nu; R)$ accounts for the assets used to purchase it.

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

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

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

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

ii) **Second sub-period:**

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

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

First Order Condition:

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

B.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

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

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

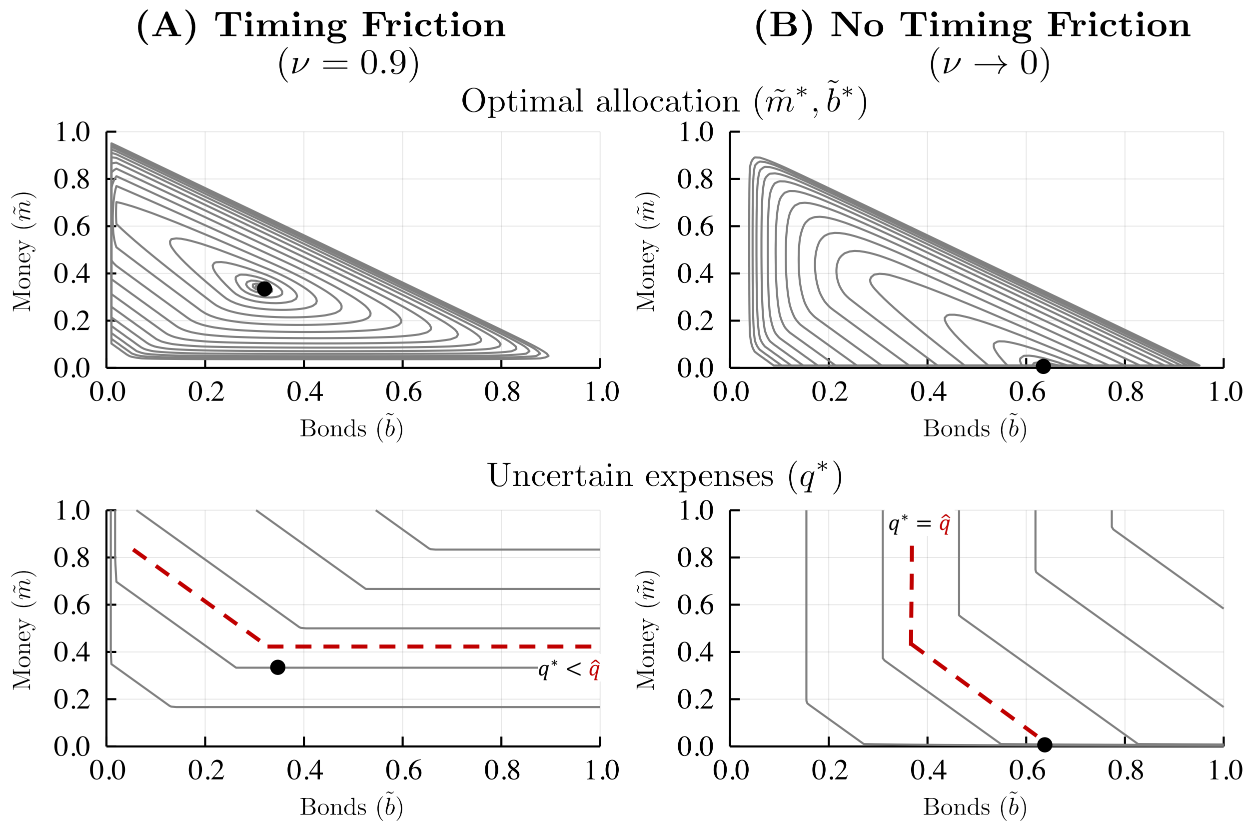
and define the optimal policies as $\tilde{m}^*(y;R)$, $\tilde{b}^*(y;R)$, then consumption is given by

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

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

Figure 5 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 5: Portfolio Allocation



B.3 Sensitivity to the nominal interest rate (R)

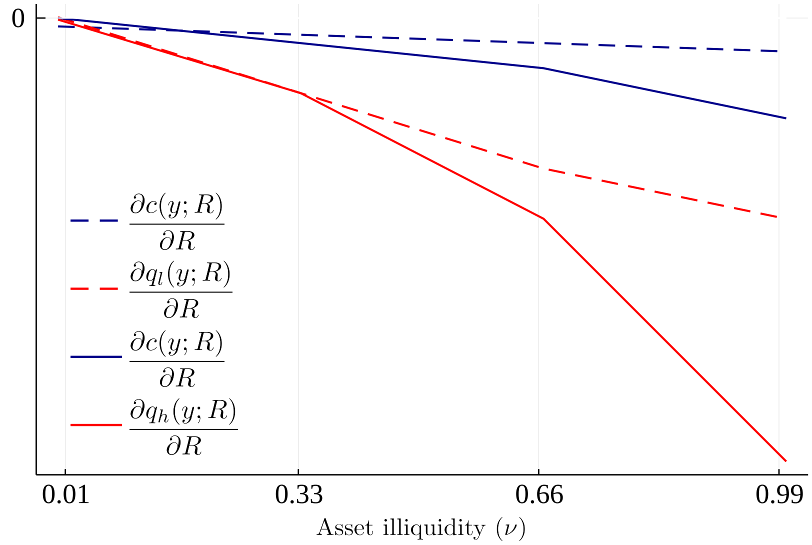
Approximate the derivatives for "x" with the forward difference expression

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

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 6: 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 $\hat{q} = {}^{\tilde{m}^*}/_{\nu}$

C Transformed Household's Problem

i) **First sub-period:**

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

$$s.t. \qquad (1+\phi)c + \tilde{m} + \tilde{b} = \hat{x} + z \tag{C.2}$$

ii) **Second sub-period:**

$$V^2(\tilde{m}, \tilde{b}, z, \vartheta) = \max_{q_{\vartheta}} \left\{ \frac{\vartheta q^{\theta(1-\sigma)}}{1-\sigma} + \beta\left[E_{\lambda} E_{\varepsilon'} E_{z'|z}\{V^1(x'(\vartheta) + \varepsilon', z')\}\right] \right\} \tag{C.3}$$

$$s.t. \qquad 0 < q_{\vartheta} \leq \min\left\{ \frac{\tilde{m}}{(\nu+\phi)}, \frac{\tilde{b} - \underline{b}}{(1-\nu)} \right\} \tag{C.4}$$

where

$$x'(\vartheta) = \frac{m'(\vartheta)}{1+\pi} + (1+r)b'(\vartheta) \tag{C.5}$$

and

$$m'(\vartheta) = \tilde{m} - (\nu + \phi)q_\vartheta \geq 0; \quad \textit{and}, \quad b'(\vartheta) = \tilde{b} - (1-\nu)q_\vartheta \geq \underline{b} \tag{C.6}$$

D Optimality Conditions

- First order conditions

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

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

$$\tilde{b}: \qquad E_\vartheta V_b^2(c, \tilde{m}, \tilde{b}, z, \vartheta) - \lambda^c = 0 \tag{D.3}$$

$$q_\vartheta: \qquad \vartheta\theta q^{\theta(1-\rho)-1} - \left(\mu_\vartheta + \frac{\beta}{1+\pi} E_{\varepsilon'} E_{z'|z} V_x^1(x'(\vartheta), z', \varepsilon')\right) = 0 \tag{D.4}$$

- Envelope conditions

$$V_c^2(c, \tilde{m}, \tilde{b}, z, \vartheta) = c^{-\sigma} \tag{D.5}$$

$$V_m^2(c, m, b, z, \vartheta) = \frac{\beta}{1+\pi'} \phi E_{\varepsilon'} E_{z'|z} V_x^1(x'(\vartheta), z', \varepsilon') + \mu_\vartheta \tag{D.6}$$

$$V_b^2(c, m, b, z, \vartheta) = \frac{\beta}{1+\pi'}(1+i)\phi E_{\varepsilon'} E_{z'|z} V_x^1(x'(\vartheta), z', \varepsilon') \tag{D.7}$$

$$V_x^1(x'(\vartheta), z', \varepsilon') = \lambda' \tag{D.8}$$

- Combining (D.1) and (D.2)

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

and using (D.5), (D.6) and (D.4)

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

E Computational Algorithm

E.1 Decision rules

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

i) 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 (D.8)

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

this pins down the desired portfolio level $P(\hat{x}, z)$, from the household's budget constraint (C.2)

$$(\tilde{m} + \tilde{b}) = z + \hat{x} - (1+\phi)c(\hat{x}, z) \equiv P(\hat{x}, z) \tag{E.2}$$

ii) 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:

$$\tilde{m}(\tilde{b}) = P(\hat{x}, z) - \tilde{b} \tag{E.3}$$

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

$$b^{max} = P(\hat{x}, z); \qquad b_{min} = \max\left\{P(\hat{x}, z) - \hat{x}^{max}, \underline{b}\right\} \tag{E.4}$$

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

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

$$V^2(\tilde{m}(\tilde{b}^j), \tilde{b}^j, z, \vartheta^k) = \max_{q_{\vartheta^k} \in (0, \min\{\frac{\tilde{m}(\tilde{b}^j)}{(\nu+\phi)}, \frac{\tilde{b}^j - \underline{b}}{(1-\nu)}\}]} \{ \frac{\vartheta^k q_{\vartheta^k}^{\theta(1-\sigma)}}{1-\sigma} + \beta E_\lambda E_{\varepsilon'} E_{z'|z} V^1 (\frac{\tilde{m}(\tilde{b}^j) - (\nu+\phi) q_{\vartheta^k}}{1+\pi} + (1+r)[\tilde{b}^j - (1-\nu) q_{\vartheta^k}] + \varepsilon', \tag{E.5}$$

and define

$$V^2_{aux}(\tilde{b}^j, z) = E_\vartheta V^2(\tilde{m}(\tilde{b}^j), \tilde{b}^j, z, \vartheta) = \sum_k p^{\vartheta^k} V^2(\tilde{m}(\tilde{b}^j), \tilde{b}^j, z, \vartheta^k) \tag{E.6}$$

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

$$j^* = arg \max\{V^2_{aux}(\tilde{b}^j, z)\}_{j=1}^{n_j}; \qquad and \qquad V^2(\hat{x}, z) = \max\{V^2_{aux}(\tilde{b}^j, z)\}_{j=1}^{n_j} \tag{E.7}$$

and define the policy functions as

$$\tilde{b}^*(\hat{x}, z) = \tilde{b}^{j^*}; \quad \tilde{m}^*(\hat{x}, z) = P(\hat{x}, z) - \tilde{b}^*; \quad q^*(\hat{x}, z, \vartheta) = arg \max\{V^2(\tilde{m}^*, \tilde{b}^*, z, \vartheta)\} \tag{E.8}$$

v) Update V^1

$$V^1(\hat{x}, z) = \frac{c(\hat{x}, z)^{1-\sigma}}{1-\sigma} + V^2(\hat{x}, z) \tag{E.9}$$

- Iterate until convergence in V^1

E.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:

$$(\hat{x}, z, \vartheta, \varepsilon') \to (\hat{x}') \tag{E.10}$$

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

$$H(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}) = grid_{\hat{x}}^{-1}(\hat{x}') \tag{E.11}$$

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

$$w(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}) = \frac{\hat{x}' - grid_{\hat{x}'}(H(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}))}{grid_{\hat{x}'}(H(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}) + 1) - grid_{\hat{x}'}(H(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}))} \tag{E.12}$$

***Updating the distribution* Γ.**

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

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

ii) 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:

$$\begin{aligned}\Gamma'(H(i_{\hat{x}}, i_z, i_\vartheta, i_\varepsilon), i_{z'}) &= \Gamma'(H(i_{\hat{x}}, i_z, i_\vartheta, i_\varepsilon), i_{z'}) + \\ & w(i_{\hat{x}}, i_z, i_\vartheta, i_\varepsilon) p(i_\vartheta) \left[(\lambda_\varepsilon p(i_\varepsilon) + (1 - \lambda_\varepsilon) \mathbb{I}_{\{i_\varepsilon = i_{\varepsilon 0}\}})(\lambda_\eta \Pi(i_z, i_{z'}) + (1 - \lambda_\eta) \mathbb{I}_{\{i_z = i_{z'}\}}) \right] \Gamma(i_{\hat{x}}, i_z)\end{aligned} \tag{E.13}$$

$$\begin{aligned}\Gamma'(H(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}) + 1, i_{z'}) &= \Gamma'(H(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'}) + 1, i_{z'}) + \\ & (1 - w(i_{\hat{x}}, i_z, i_\vartheta, i_{\varepsilon'})) p(i_\vartheta) \left[(\lambda_\varepsilon p(i_{\varepsilon'}) + (1 - \lambda_\varepsilon) \mathbb{I}_{\{i_{\varepsilon'} = i_{\varepsilon 0}\}})(\lambda_\eta \Pi(i_z, i_{z'}) + (1 - \lambda_\eta) \mathbb{I}_{\{i_z = i_{z'}\}}) \right] \Gamma(i_{\hat{x}}, i_z)\end{aligned} \tag{E.14}$$

calculate

$$dist = |\Gamma' - \Gamma| \tag{E.15}$$

and set

$$\Gamma' = \Gamma \tag{E.16}$$

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

F Proofs

Proof. [sketch] Combining (5.7) and (5.8), 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 (C) and consider two wealth levels $x > y$, what needs to be shown is that

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

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

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

using that

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

then

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

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 (**??**)

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

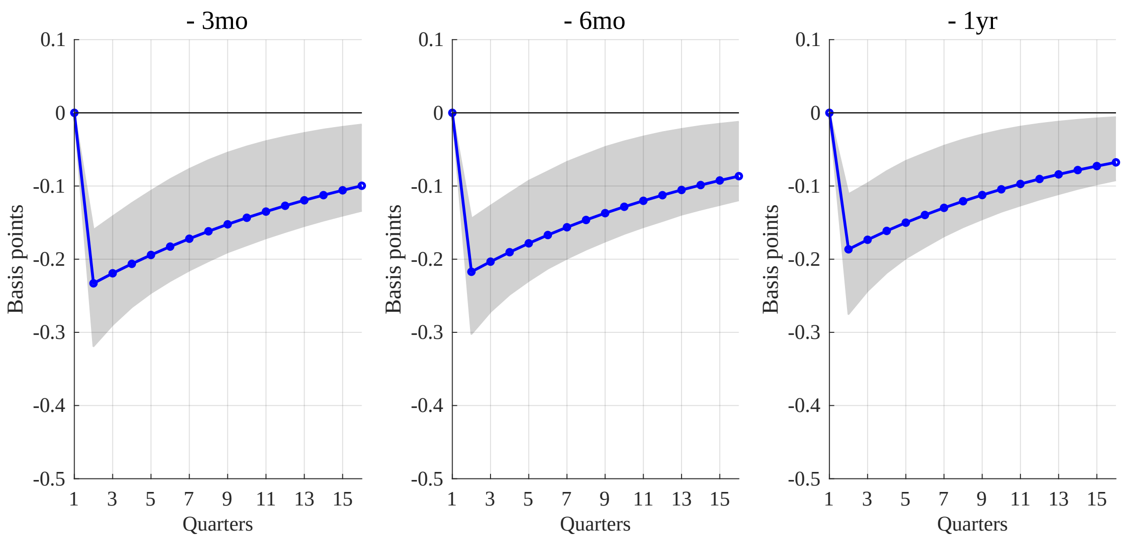
and using (5.8), $(B) > 0$ if

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

□

G Path for $\{R_t\}_{t=1}^{T}$

Figure 7: Dynamic effects of a 25 bp unanticipated interest rate cut



Note: Gray areas are bootstrapped 90% confidence bands.