Inflation, Demand for Liquidity and Welfare*

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Abstract

Money holding differs significantly over household consumption and age. Liquidity demand for money (i.e., money holding per dollar of consumption) decreases as household consumption increases. It also increases with household age conditional on the level of consumption. This paper quantifies welfare gains of reducing the long-run inflation rate, taking into account these money-holding patterns. We calibrate a life-cycle model of money holding and find that inflation has significantly different impacts across household groups due to their heterogeneity in money holding. Under a tax-revenue-neutral scenario where a loss in the seigniorage revenue is compensated by a tax hike, poorer households gain while their rich peers lose from lower inflation rates.

Keywords: Welfare cost, inflation, demand for money.

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1 Introduction

Understanding welfare cost of inflation is crucial for a discussion of monetary policy frameworks such as a target rate of inflation under the inflation-targeting monetary policy regime. One channel through which inflation affects welfare is money holding by households as inflation is an implicit tax that reduces the real value of money. Since money holding differs across households, a distribution of welfare costs also vary. In this paper, we first document stylized facts regarding money holding across households, using the Canadian micro data. We show that money holding by households differs significantly over age. Poorer and older households hold more money relative to their consumption. This heterogeneity suggests that a distribution of welfare cost due to inflation will be non-degenerate and dispersed. When ignoring this heterogeneity in money holding, the aggregate welfare cost of inflation is likely to be different from those that take into account heterogeneity. Second, a simple life-cycle model with money and costly credit transaction is calibrated to match these facts. Using the calibrated model, we calculate the welfare cost of long-run inflation at the aggregate level and across households.

In the data, we find the following stylized facts:

- Money-consumption ratio (i.e., money holding per dollar of consumption) decreases with consumption.
- Money-consumption ratio increases with household age. Specifically, the money holding of the households aged 75 to 85 is three times higher than that of the households aged 35 or younger.
- Differences in money-consumption ratios between the young and the old households shrink as consumption increases.

In order to incorporate these stylized facts, we extend Erosa and Ventura (2002) and develop a life-cycle model of money holding with a cash-in-advance constraint and transaction cost of using credit to purchase consumption. The main trade-off between the use of money and that of credit is their respective cost. On one hand, money is subject to inflation tax and hence costly to hold. One the other hand, use of credit involves direct transaction costs. We assume credit transaction technology, and hence the cost to vary across age, which allows our model to replicate the stylized facts on money holding across age groups.

We calibrate the model to the Canadian household data, including the stylized facts listed above. Using the calibrated model, we conduct a tax-revenue-neutral experiment where a loss in the seigniorage revenue from lower inflation is compensated by higher tax on labour endowment. When inflation is reduced from 2% (i.e., the long-run target rate of inflation in Canada) to 0%, we find that poor households (i.e., those in the lowest income quintile) gain 0.6% of their consumption while their rich peers (i.e., the highest quintile) lose 0.14%. Aggregate welfare improves by 0.01% of consumption.

The gain comes in two layers: a lower cost of holding money and a resulting lower total cost from credit transactions due to a compositional shift from use of credit to money in purchasing consumption. The loss, on the other hand, is from a higher tax rate on labour endowment. The gain outweighs the loss for the poor households since they hold a higher fraction of money in their portfolio and use less credit to purchase consumption than do the rich. In contrast, the rich do not reap much benefit due to their low money holding, and the loss from higher tax on labour endowment overturns the benefit.

There is a long list of previous studies measuring the welfare cost of inflation. Lucas (2000) finds that when the annual inflation rate is reduced from 10 per cent to 0 per cent, the gain is slightly less than 1 per cent of real income. However, Lucas points out that "...Using aggregate evidence only, it may not be possible to estimate reliably the gains from reducing inflation further, ...". That is, in order to accurately and reliably assess the cost of inflation, one needs to look into the cross-section evidence on the demand for money. Mulligan and Sala-i Martin (2000) document that 59 per cent of the U.S. households hold cash and checking accounts, and do not hold interest-bearing financial assets. This fact is interpreted as the existence of fixed cost for financial transactions. The fixed cost is one form of dead weight loss in models of money demand. As the inflation rate decreases, households will hold more cash, and avoid paying the fixed cost of financial transactions. The aggregate dead weight loss is not necessarily equal to the area under the inverse aggregate money demand curve, except in extreme cases. Ignoring the fixed (adoption) costs will underestimate the welfare cost of higher inflation. Attanasio, Guiso, and Jappelli (2002) use a household level data set with much richer information on cash holding, cash transactions, and usage of ATM cards. They estimate the demand for cash and for interest-bearing assets, and find that the welfare cost of inflation varies considerably within the population but is small (0.1 per cent of consumption or less).

One important contribution to measuring the welfare cost of inflation is given by Erosa and Ventura (2002). They extend the Aiyagari model to include the cash-in-advance constraint and study the welfare distribution of changing inflation rates. On the other hand, Chiu and Molico (2010) calibrate a search-theoretical model of demand for money, and find that the welfare cost of inflation is 40 per cent smaller than that in complete market representative-agent models, such as Lucas (2000).

However, the existing studies ignore the age profile of money holding. Our evidence from the Canadian household data shows that older households hold more money relative to their consumption. This fact suggests that credit transaction cost may vary with age due to age-related factors that affect the ability of using credit. It is necessary to take into account this fact in order to give a more reliable assessment of the welfare cost of inflation.

Finally, our focus on the demand for money differs from that of the literature on cash inventory management, e.g., Baumol (1952) and Tobin (1956). While the literature on cash inventory management considers fixed costs of transferring non-cash assets to cash as a source of friction giving rise to cash-noncash portfolios, our paper assumes fixed costs associated with credit (i.e., non-cash) transactions as the source, following Dotsey and Ireland (1996) and Erosa and Ventura (2002). This assumption better suits our objective since we focus on the cost of holding money in the long run with agents making decisions at a lower frequency than that in cash inventory management models.

In the next section, we use the Canadian data and document how money holding varies with age and consumption. A life-cycle model of demand for money is developed in Section 3, and Section 4 discuss the model calibration. In Section 5, we evaluate welfare from changing inflation. Finally, Section 6 concludes the paper.

2 Money holding in Canadian households

We use the Canadian Financial Monitor (CFM) 1999-2010. The CFM surveys about 1,000 households each month on the household's financial activities including banking, borrowing, and investing. Since we focus on money holding for consumption purpose, we need consumption data. The CFM provides information on household consumption over the period of 2008-2010, which is what we use for the paper.

We define money as the household's monthly balances in checking accounts and saving accounts with zero or very low interest rates. We consider these balances mostly as liquidity buffers for consumption purposes. This definition of money is broader than "cash" and differs in focus from that of cash-inventory management models, e.g., the Baumol-Tobin model. We define consumption as the household's sum of gross monthly spending on non-durable goods, services, and durable goods. Excluded from this consumption definition are the property tax and housing services from owned and rented residential properties. Some durable spending is at the annual frequency, including the purchase of a vehicle, home appliances and electronics, home furnishings, vacation trips, home renovation. We divide them by twelve to obtain the monthly average spending on these goods and services.

2.1 Money holding by age

In order to observe money-consumption ratios over age, we group households by the age of the household head into six categories: less than or equal to 35 years old, 36-45 years old, 46-55 years old, 56-65 years old, 66-75 years old, and 76-85 years old. Given an age group, we further make five sub-groups based on consumption quintile. Money-consumption ratios are calculated by taking the ratio of the average money holding and the average consumption of a given group. Figure 1 displays the three stylized facts regarding money-consumption ratios, where the values on the horizontal axis are relative to the overall average consumption. We observe that (1) money holding per dollar of consumption (i.e., money-consumption ratio) decreases with consumption; (2) money-consumption ratio increases with age conditional on consumption; and (3) age differences in money-consumption ratio shrink as consumption increases.

The first fact has been documented in previous studies (see Erosa and Ventura (2002)). It suggests that, as household consumption increases, a fraction of consumption purchased with money becomes smaller, implying non-cash payment methods become more important as consumption increases.[1] What has not been studied previously is the age aspect of money holding, i.e., the second and the third stylized facts.

3 Model

In this section, we present a simple over-lapping generation model of money holding. There is no uncertainty. There is a continuum of households in the economy. Each household lives for J periods and belong to one of the I income classes, where j indexes the age and

[1] Erosa and Ventura (2002) replicate this fact by assuming that the transaction cost of using credit displays economies of scale as in Dotsey and Ireland (1996).

i their class. They are endowed with z_{ij} units of exogenous working hours. Households retire at age J_r and receive retirement benefits until death. In each period, households use money and credit to purchase consumption good.[2] A fraction of consumption purchased with money is subject to a cash-in-advance constraint. In purchasing by credit, households pay a transaction cost.

A trade-off between the use of money and credit in the following. Holding money is subject to inflation tax as inflation reduces the real value of money. Using credit, on the other hand, involves a direct cost. Following Dotsey and Ireland (1996) and Erosa and Ventura (2002), the credit transaction technology is a function of the fraction of consumption purchased with credit, s:

$$\gamma_j(s) = \int_0^s \gamma_j \cdot \left(\frac{x}{1-x}\right)^{\theta_j} dx, \tag{1}$$

where $\gamma_j > 0$ and $\theta_j > 0$. This function is convex and strictly increasing in s for all $s \in [0, 1)$. It is independent of the level of consumption. Thus, the credit technology exhibits increasing returns to scale: the credit transaction cost per unit of consumption decreases with consumption. The higher the consumption, the cheaper it is to use credit. This assumption helps generate the first stylized fact: money-consumption ratio decreases with consumption. We allow both γ and θ to vary with age. The empirical evidence shown in the previous section suggests that the demand for money is higher for the older households than for the younger ones. One possible reason is that old households face more difficulty and hence more costly to process complex financial information and use the credit technology.[3]

Let c_{ij} be consumption, a_{ij} be the real asset, and m_{ij} be real money holding of the agent

[2]There is only one type of good which can be purchased by money or credit.

[3]In cash-inventory management literature, empirical evidence shows that older households pay fewer visits to bank branches than younger households. See Mulligan and Sala-i Martin (2000).

with age j and labor endowment z_{ij}. The agent's optimization problem is given by:

$$\max_{\{c_{ij}, s_{ij}, a_{i,j+1}, m_{i,j+1}\}} \sum_{j=1}^{J} \beta_{ij} \frac{c_{ij}^{1-\sigma} - 1}{1-\sigma} \tag{2}$$

$$subject \ \ to \tag{3}$$

$$c_{ij}(1 - s_{ij}) \leq m_{ij}, \tag{4}$$

$$c_{ij} + q\gamma(s_{ij}) + a_{i,j+1} + (1+\pi)m_{i,j+1} \leq [1 + r(1-\tau_a)]a_{ij} + m_{ij} + (1-\tau_z)wz_{ij}, \tag{5}$$

where q is the price per unit of credit-transaction service, w the wage rate, r the interest rate, τ_a the tax rate on non-money asset income, and τ_z the tax rate on wage income.

Condition (4) is the cash-in-advance constraint. Given the current money holding, the household chooses consumption and a fraction of credit transaction. Given no uncertainty, the cash-in-advance constraint holds with equality. If the household only uses money for transactions, consumption is constrained by the current amount of money. Consumption can increase if the household uses credit. We assume that discount factors differ by age and income type, which may reflect changes in family size and costs related to labor force participation.

From the household's first-order necessary condition, we can obtain the optimal money consumption ratio as follows:

$$\frac{m_{ij}}{c_{ij}} = 1 - s_{ij} = \frac{1}{1 + \left[\widetilde{R} c_{ij}/(q\gamma)\right]^{1/\theta}}, \tag{6}$$

where $\widetilde{R}$ is the after-tax nominal interest rate, $\widetilde{R} = (1+\pi)[1 + r(1-\tau_a)] - 1$, where π is the inflation rate. Clearly, the demand for money increases as consumption increases, but at a decreasing rate, hence the money-consumption ratio declines as consumption rises. Parameter θ represents the interest rate elasticity of demand for money, as the interest rate elasticity of money demand is $-\frac{1}{\theta}\cdot\left[1+\left(\frac{g\gamma}{\tilde{R}c_{ij}}\right)^{1/\theta}\right]^{-1}$. The interest elasticity increases with consumption, meaning the demand for money is more elastic as the consumption becomes larger.

The government has an exogenous spending G_t, which is financed by revenue from inflation tax, capital income tax and labour income tax, as follows

$$G_t = \pi_t M_t + \tau_a r A_t + \tau_z w Z_t,$$

where M_t is the total money supply, B_t is total asset of all households and Z_t is the total labour supply at time t. A fraction of G_t is used for retirement benefits. The equilibrium aggregate variables are defined as:

$$M_t = \sum_{i=1}^{I}\sum_{j=1}^{J} m_{ij},$$
$$A_t = \sum_{i=1}^{I}\sum_{j=1}^{J} a_{ij},$$
$$Z_t = \sum_{i=1}^{I}\sum_{j=1}^{J} z_{ij}.$$

Finally, a Cobb-Douglas production technology exists and produces a good for consumption and investment. The production inputs include capital and labour and have constant elasticity of substitution. The real interest rate is exogenously determined in the global capital market. Labour is assumed to be non-tradable and only domestically supplied.

4 Calibration

To match the data moments shown in Figure 1, we assume that credit cost parameters γ and θ vary with age. Without age-specific cost parameters, our model is able to replicate the downward slope of money-consumption ratio over consumption, as in Erosa and Ventura

(2002), but is unable to match levels and slopes of money-consumption ratios by age groups. Further, we assume that the discount factor β_{ij} varies with both age and household type. Age-specific discount factors allow us to capture hump-shaped consumption profiles over life cycle. Such consumption profiles can be attributable to changes in household size and in costs of participating in the labour force. In addition, heterogeneous discount factor across income types is necessary for the model to match the consumption dispersion within age group.

Household parameters. We set $J = 7$ (7 age groups) and $I = 5$ (5 classes). In the CFM data, for each age group, households are sub-grouped by consumption quintile. z_{ij} is calibrated to be the average income of the households in the ij group. We match data moments on money and consumption for all groups except for the first age group. The first age group is assumed to be born without non-money asset and a minimal amount of money holding. We choose the age-specific cost parameters γ_j to match the mean value of money-consumption ratio for each age, and θ_j to match the mean slope of money-consumption ratio over consumption for each age. We calibrate the discount factor for each age and income group to match the household consumption for each age-income group. The discount factors for the first age group in the model is normalized to be 1.

Other parameters. Some parameters are chosen without using the CFM data. We assume that Canada is a small open economy. We set the annual real interest rate to be 4 per cent, and the capital depreciation rate to be 7 per cent. The share of labour in the aggregate production is 0.65. With these parameters and the Cob-Douglas production technology, we can obtain the annual wage rate. Government spending is 21 per cent of total output, and the capital income tax rate is 30 per cent. The household's inter-temporal elasticity of substitution parameter σ is set to 2. Inflation in the baseline calibration is 2 per cent.

In the calibration as well as in our inflation experiments, the government's budget is always balanced by setting the labor income tax rate. We also examine the case where labor income tax is unchanged when the inflation rate changes.

4.1 Baseline results

In the baseline model, the target moments are the average money-consumption ratio of each age group (6 moments), the average slope of the money-consumption ratio over consumption for each age group (6 moments), and the relative consumption of each age-consumption group (30 moments). We have 42 moments to match by calibrating the same number of parameters. Table 1 and Figure 3 show the parameter values for γ_j's and θ_j's, and β_{ij}'s, respectively. The mean values for the discount factor by ages are respectively, from young to old, 1.372, 1.346, 1.041, 0.686, 0.441, and 0.252. The mean values for the discount factor by income classes are respectively, from low income to high income, 0.048, 0.079, 0.124, 0.240, and 3.790.

Figure 2 visually shows that the model fairly captures the money-consumption ratios by age-consumption groups observed in the data. The average credit-transaction cost is 2 per cent of consumption.

Table 1: Calibration: age-specific γ and θ

Targets	Data	Model	Parameter values
m/c age 1	0.145	0.152	γ_1=0.000008
m/c age 2	0.169	0.174	γ_2=0.000113
m/c age 3	0.224	0.228	γ_3=0.000381
m/c age 4	0.275	0.275	γ_4=0.000625
m/c age 5	0.385	0.381	γ_5=0.002795
m/c age 6	0.543	0.543	γ_6=0.005353
$\Delta\frac{m}{c}/\Delta c$ age 1	-0.087	-0.070	θ_1=2.543
$\Delta\frac{m}{c}/\Delta c$ age 2	-0.100	-0.093	θ_2=2.000
$\Delta\frac{m}{c}/\Delta c$ age 3	-0.154	-0.148	θ_3=1.817
$\Delta\frac{m}{c}/\Delta c$ age 4	-0.201	-0.200	θ_4=1.762
$\Delta\frac{m}{c}/\Delta c$ age 5	-0.370	-0.374	θ_5=1.451
$\Delta\frac{m}{c}/\Delta c$ age 6	-0.671	-0.672	θ_6=1.357

5 Welfare cost of inflation

We calculate the welfare and its distribution when inflation deviates from the baseline 2 per cent. Welfare is measured as the consumption equivalent variation (CEV). Let λ_i^c be the consumption equivalent variation for income group i. Let V_i^0 be the life time utility of the households for household income group i,

$$V_i^0 = \sum_{j=1}^{J} \beta_{ij} u(c_{ij}^0),$$

where c_{ij}^0 is the consumption under 2 per cent inflation, and β_{ij} is the discount factor at age j for income type i. The welfare measure for income group i is obtained from the following equation,

$$\sum_{j=1}^{J} \beta_{ij} u(c_{ij} + \lambda_i) = V_i^0,$$

where c_{ij} is the consumption of income group i at the age j under the new inflation rates.

The welfare measure is then calculated as

$$W_i = \frac{6\lambda_i}{\sum_{j=1}^{6} c_{ij}^0} \times 100\%.$$

The aggregate welfare measure is obtained from aggregating the welfare measure of income groups as follows

$$W = \frac{6(\sum_{i=1}^{5} \lambda_i)}{\sum_{i=1}^{5} \sum_{j=1}^{6} c_{ij}^0} \times 100\%.$$

We compare the steady-state welfare changes for inflation rates of -2 per cent, 0 per cent, 5 per cent, and 10 per cent, all compared against the baseline model with 2 per cent inflation.

The welfare calculation is done in two cases. In the first case, when inflation changes, the government budget is balanced by adjusting the labour tax rate, τ_z (i.e., tax neutrality); while in the second case, the labor tax remains unchanged (i.e., tax non-neutrality).

5.1 Aggregate welfare

Table 2 shows the aggregate welfare numbers for different cases. Negative values suggest a welfare gain.

Table 2: Aggregate welfare (in per cent)

Inflation	-2 %	0%	5%	10%
tax neutrality				
	0.288	-0.095	0.294	0.780
tax non-neutrality				
	-1.528	-0.616	0.810	1.973

When inflation changes under tax neutrality, welfare changes show a U-shape due to a trade-off between inflation tax and labour income tax. As inflation lowers from 2% to 0%, the benefits of lower inflation tax outweigh the costs of increasing labour income tax, a net gain of 0.01% of consumption. As inflation lowers further to -2%, the burden of labour income tax overshadows the benefits of lower inflation tax, a net loss of 0.29% (relative to the baseline of 2% inflation). Under tax non-neutrality, this trade-off does not exist and welfare improves monotonically as inflation lowers.

5.2 Welfare distribution

We first document the steady-state distribution of welfare over income groups, then show how the welfare differs across age groups.

Table 3 summarizes the welfare by income groups in the steady state. The low-income households are more sensitive to inflation. Their CEV values vary more than those in high-income households. The low-income households hold more money than their peers as they face high average credit-transaction costs due to their low consumption level. The high-income households can better afford credit-transaction costs as their high consumption lowers its average costs, and hence do not hold much money. Changes in inflation thus have smaller effects on the high-income households. However, the high-income households tend to suffer from low inflation rates because a large part of government spending is now financed by their labour income tax. As inflation decreases and labour tax increases, government spending is financed more by labour tax revenues than those from inflation tax. Since the rich households pay more labor tax and less inflation tax than their peers, their shares of government spending finance increase. As inflation decreases from 2% to 0%, the low-income households gain 0.6% of their consumption while the high-income lose 0.14%, highly heterogeneous across households.

Table 3: Welfare by income group (in per cent): tax neutrality

Inflation	-2 %	0 %	5 %	10 %
Low income	-0.936	-0.614	0.896	2.302
Low-middle	-0.226	-0.335	0.722	1.568
Middle	0.061	-0.125	0.416	1.129
Middle-high	0.509	-0.061	0.219	0.654
High	0.812	0.140	-0.068	-0.074

Table 4: Welfare by income group: tax non-neutrality

Inflation	-2 %	0 %	5 %	10 %
Low income	-2.715	-1.116	1.391	3.432
Low-middle	-2.113	-0.870	1.249	2.782
Middle	-1.956	-0.694	0.981	2.428
Middle-high	-1.578	-0.675	0.827	2.058
High	-0.686	-0.287	0.359	0.923

Table 4 shows the welfare results under tax non-neutrality. The effects are larger compared to those in Table 3 due to the fact that labor income tax does not counter the changes in inflation tax.

6 Conclusions

The paper documents money holding heterogeneity over age and consumption levels, and finds that older households hold more money conditional on consumption. An over-lapping generation model is developed and calibrated to match the observed heterogeneity in money holding. We use the calibrated model to conduct welfare analysis for the aggregate economy as well as for the welfare distribution across households. We find large differences in welfare cost of inflation across households. These differences partly reflect non-linearity generated by the increasing-returns-to-scale credit-transaction technology as well as its age-specific parameters.

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Figures

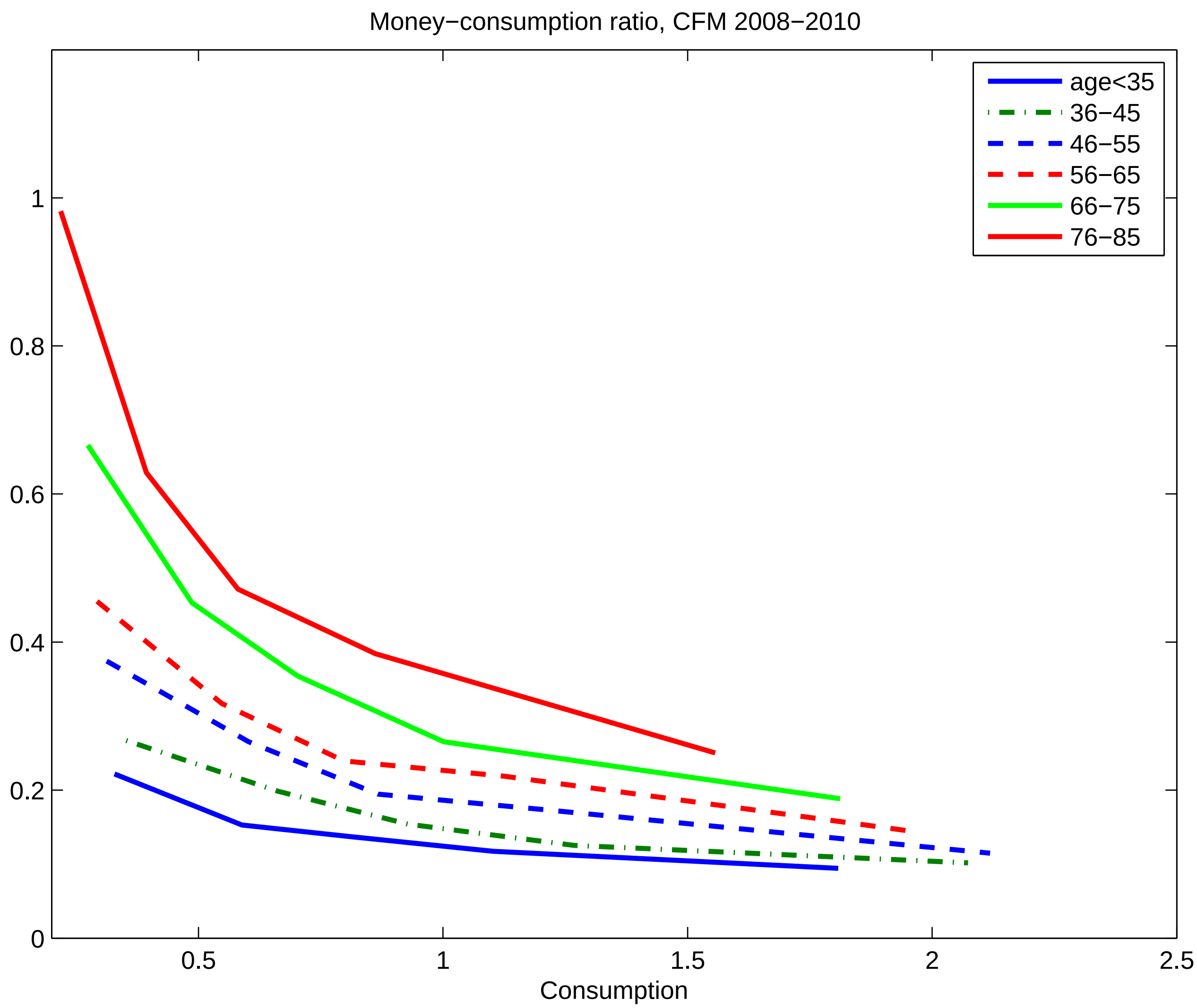

Figure 1: Money-consumption ratio by age (Data source: CFM 2008-2010)

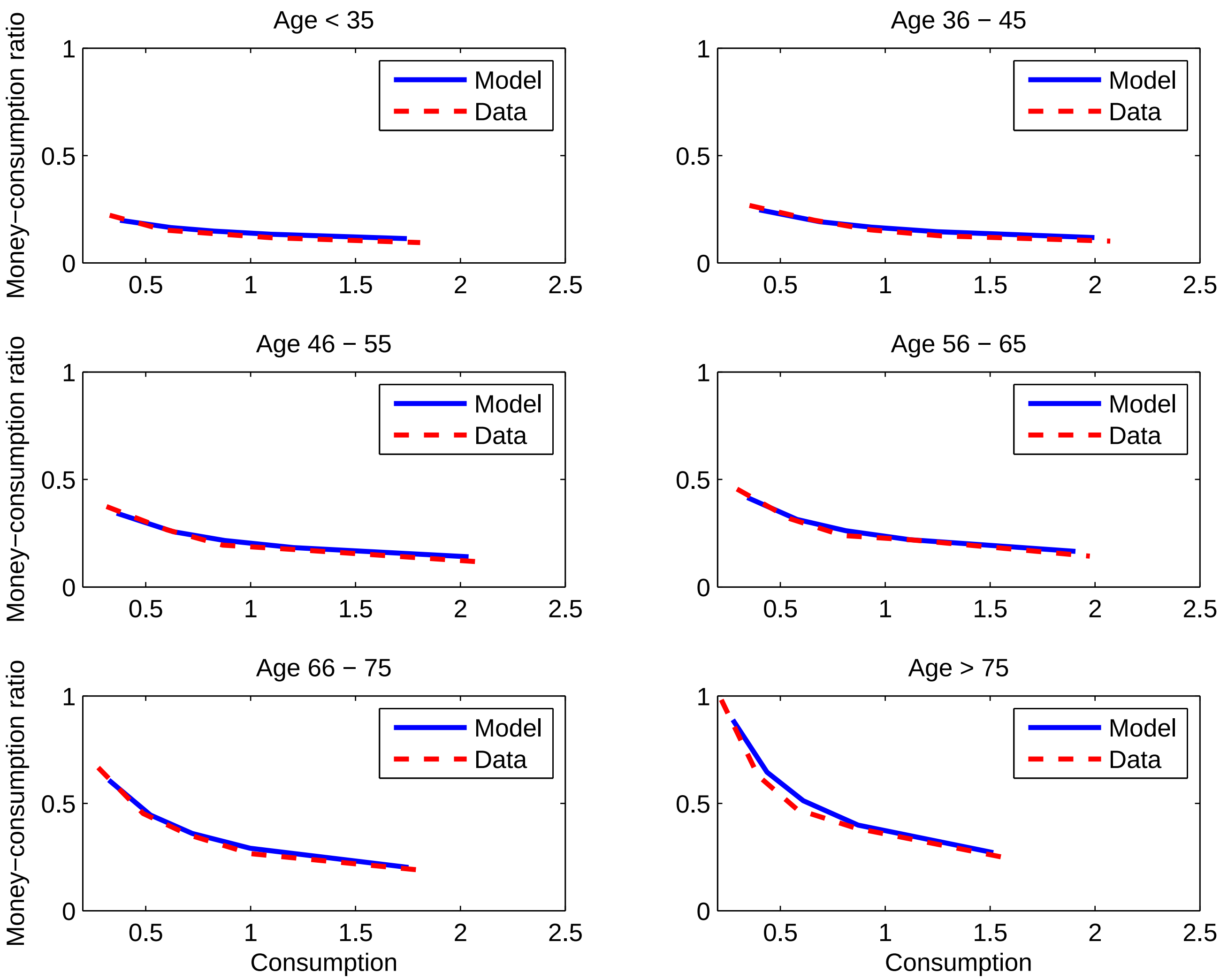

Figure 2: Calibration: age-specific γ and θ

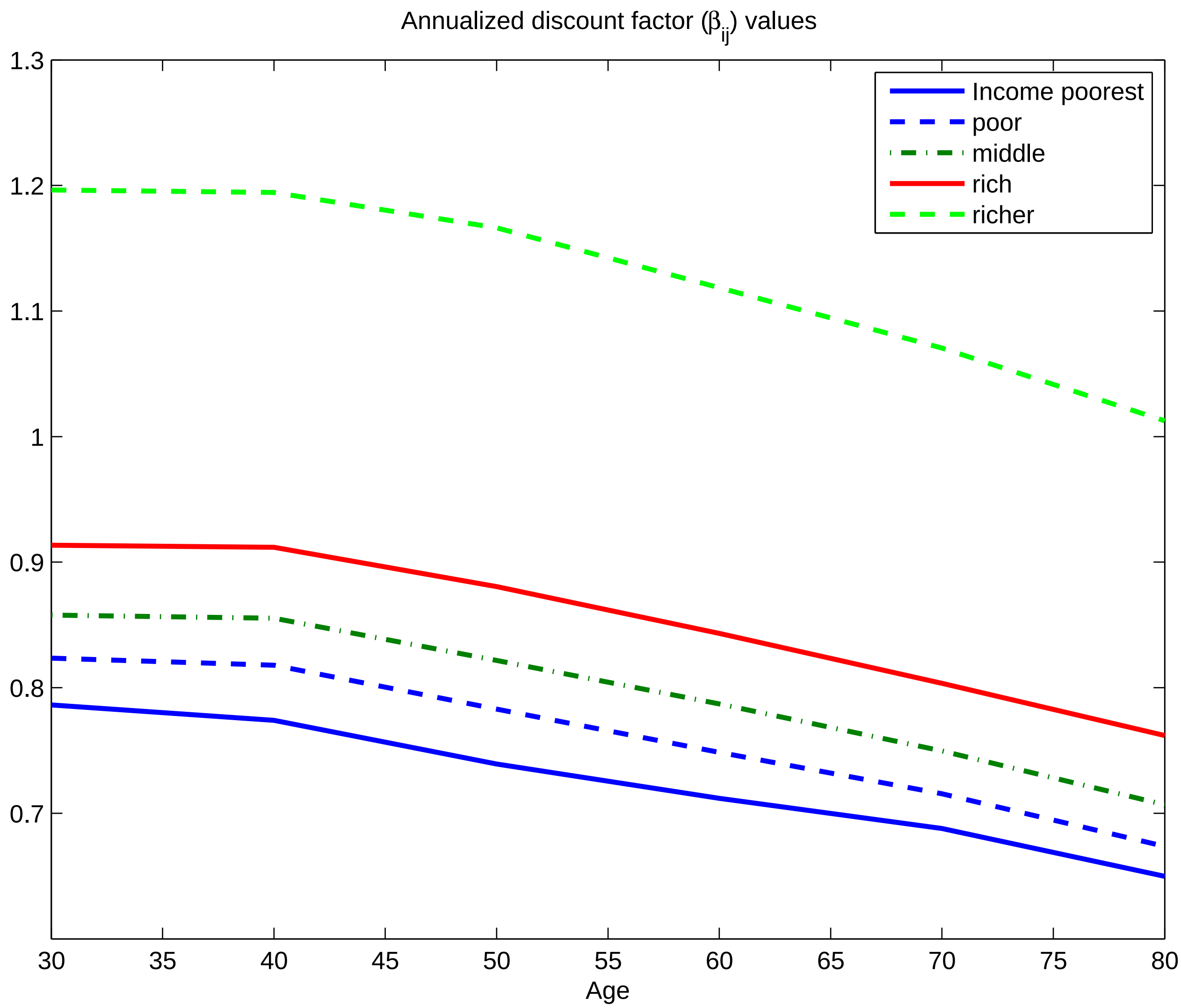

Figure 3: Calibration: discount factor