ONLINE APPENDIX: CONSUMER CREDIT WITH OVER-OPTIMISTIC BORROWERS

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Abstract
This online appendix provides additional details on the calibration of over-optimism and the income process in Exler et al. (2024). In addition, the Appendix reports results for robustness experiments related to the fraction of behavioural borrowers, the degree of over-optimism about income, and the policy experiments. Additional details on the specification of the borrowing limit regulation as well as the ergodic distribution of type scores are also reported. (JEL: E21, E49, G18, K35)

Keywords: Consumer Credit, Over-Optimism, Financial Mistakes, Bankruptcy, Default, Financial Literacy, Financial Regulation, Type Score, Cross-Subsidization.

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Appendix A: Calibration

A.1. Over-optimism and Transitory Income Risk

To measure financial literacy and the relative frequency of low transitory income realizations, we use data from the 2016 and 2019 SCF. The 2016 wave added a set of questions on the financial literacy of households. We use the number of correct answers to three questions on the topics of risk diversification, interest rate compounding, and inflation (X7558 to X7560) as a measure of financial literacy. Table A.1 shows that 85% of college educated respondents correctly answered 2 or 3 questions. Only 69% of high school educated respondents achieved the same. The number of correctly answered questions is also highly positively correlated with income (see final column in Table A.1).

As discussed in Section 4 of Exler et al. (2024), we proxy behavioralism by low financial literacy. We designate repondents with at most one correct question as having low financial literacy. As presented in Table A.1, this results in a share of $\lambda_N = 31\%$ behavioral amongst non-college households and a share of $\lambda_C = 15\%$ behavioral amongst college educated households.

The SCF contains a question (X7650) asking whether respondents' total income in the previous year was unusually low, normal, or unusually high compared to their expectation during a "normal" year. Table A.1 reports that measure by education group and high vs. low financial literacy scores. For the non-college educated, we find that among those who answered at most 1 literacy question correctly, 22% experienced unusually low income, compared to 17% among households that answered two or three correctly. For college educated respondents, 18% of low financial literacy respondents see unusually low income compared to 14% amongst those with high financial literacy. We define the degree of over-optimism by the spread in downside income risk and calculate very similar values of $\psi_N = \text{Prob}_N^B(\eta_1)/\text{Prob}_N^R(\eta_1) = 22/17 = 1.28$ for non-college and $\psi_C = \text{Prob}_C^B(\eta_1)/\text{Prob}_C^R(\eta_1) = 18/14 = 1.29$ for college. As discussed in Section 4 of Exler et al. (2024), we choose $\psi = 1.285$ for both groups. We use the *ratio* of the probabilities of adverse shocks across borrowers (and not the levels) to map the single-year observations from the SCF into our triennial model.

Given the overall probabilities of the transitory shock $\text{Prob}(\eta) = [0.1, 0.8, 0.1]$, the degree of over-optimism $\psi = 1.285$ and the shares $\lambda_N = 31\%$ and $\lambda_S = 15\%$ uniquely determine the transitory income probabilities for both, rational and behavioral, agents in the two education groups. To see how, note that by definition $\text{Prob}_e(\eta_1) = (1-\lambda_e)\text{Prob}_e^R(\eta_1) + \lambda_e \text{Prob}_e^B(\eta_1)$. Given the definition of ψ, this is $\text{Prob}_e(\eta_1) = (1-\lambda_e)\text{Prob}_e^R(\eta_1) + \lambda_e \psi \text{Prob}_e^R(\eta_1)$. Hence, $\text{Prob}_e^R(\eta_1) = \text{Prob}_e(\eta_1)(1-\lambda_e+\lambda_e\psi)^{-1}$ and $\text{Prob}_e^B(\eta_1) = \text{Prob}_e(\eta_1) \times \psi/(1-\lambda_e+\lambda_e\psi)$ for both education groups $e \in \{N, C\}$. Finally, $\text{Prob}_e^T(\eta_3) = 1 - \text{Prob}_e^T(\eta_2) - \text{Prob}_e^T(\eta_1)$ for $T \in \{B, R\}$ and $e \in \{N, C\}$. See Table 1 in Exler et al. (2024) for the resulting values.

TABLE A.1. Unusual income and financial literacy

# Correct questions	Share	Fraction with income unusually low	normal	high	Total Income
No college degree					
0 or 1	0.31	0.22	0.69	0.09	49,583
2 or 3	0.69	0.17	0.72	0.11	66,766
Ratio (0 or 1) / (2 or 3)		1.28	0.96	0.86	
With college degree					
0 or 1	0.15	0.18	0.74	0.08	72,271
2 or 3	0.85	0.14	0.76	0.10	157,450
Ratio (0 or 1) / (2 or 3)		1.29	0.98	0.78	

Note: Results for pooled SCF 2016 and 2019 for 25-55 years olds. With college degree are households that report at least a first college degree for the household head (x5931). Total income is the total received income of the household from all sources before taxes and deductions (x5729).

A.2. Life-Cycle Dynamics of Income

To construct the life-cycle component h_j in Equation (3) in Exler et al. (2024), we calculate a vector of earning multipliers consistent with the estimates in Hubbard et al. (1994, Table A.2). The authors estimate a third degree polynomial in age to represent average life-cycle effects. The resulting multipliers, normalizing aggregate economy-wide income to one, are depicted in Figure A.1.

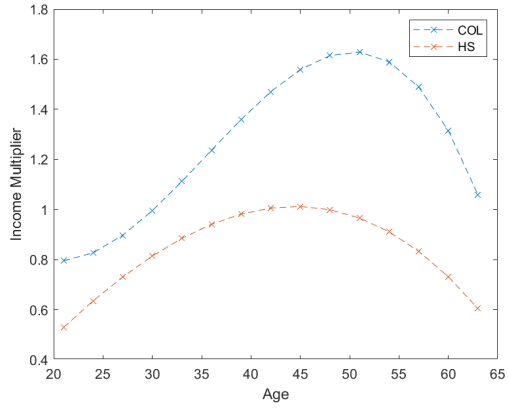

FIGURE A.1. Life-Cycle Earning Multipliers

Appendix B: Robustness

Our calibration strategy yields an estimate of the fraction of behavioral consumers and their degree of over-optimism. Yet, given the limited data and lack of consensus in the

literature we view it as a suggestive rather than a definitive estimate. In Appendix B.1, we investigate the effect of changing the fraction of behavioral consumers, λ, and the degree of over-optimism, ψ. When comparing economies with different λ or ψ, we hold fixed all other parameters.[1] In Appendix B.2, we assess the robustness of Section 6's policy experiments with respect to λ and ψ.

B.1. Varying Over-optimism

Table B.1 reports aggregate and type-specific outcomes as the fraction of behaviorals in the economy is varied from zero to one. As the fraction of behavioral borrowers rises, both average debt-to-income and default rise while average borrowing interest rates remain roughly constant. These aggregates are driven by changes in the composition of borrowers and changes in individual behavior. The overall higher debt-to-income ratios and default rates of behavioral consumers directly account for the rise in average debt-to-income and bankruptcy filings as λ rises. This composition effect of more behavioral consumers is partially offset by a change in behavior: the amount borrowed and the frequency of bankruptcy filings by each type decline in λ. This reflects the cross-subsidization channel: more behaviorals means that for each rational borrower cross-subsidization payments rise, which makes borrowing more costly. Similarly, borrowing becomes more costly for behaviorals as the amount of cross-subsidization per each behavioral borrower declines. Thus, the amount of debt held by each type declines. Smaller debts are easier to repay and thus individual bankruptcies decline, too.

These patterns explain the small impact on average borrowing interest rates as the share of behavorials (λ) rises. Although behavioral agents pay higher interest rates for any given fraction λ, rational agents individually pay lower average rates as the fraction λ rises. On average, these effects roughly cancel out and interest rates remain rather stable.

Table B.2 reports the effects of changing the extent to which behavioral borrowers are over-optimistic. We vary the degree of over-optimism, ψ, between 1 (where the two types are identical and there is no over-optimism) and 2.[2] As behaviorals are convinced they face the same income process as rationals, higher ψ translates into a higher degree of over-optimism. This drives the rise in debt-to-income of behavioral agents, as over-borrowing rises while income falls. Although defaults by over-optimists also rise, they rise by (proportionately) less than debt-to-income due to an increase in filing too late. The larger rise in debt than bankruptcies slightly pushes down average behavioral equilibrium borrowing rates (which does not contradict higher interest rate *schedules*). Being pooled with increasingly behavioral consumers

1. Since we do not re-calibrate, this implies a change in aggregate earnings dynamics as the fraction of risky people changes.

2. Recall that ψ denotes the ratio of the probability of a low transitory income realization of the two types of agents: $\text{Prob}^B(\eta_1)/\text{Prob}^R(\eta_1)$. This means that the expected income of the behavioral income process declines as ψ increases.

TABLE B.1. Varying the Fraction of Behavioral Agents

	Fraction of behavioral borrowers λ				
	0	0.12	0.25†	0.5	1
Debt-to-income					
Rational	6.39%	6.29%	6.18%	6.05%	
Behavioral		7.85%	7.73%	7.58%	7.43%
Average	6.39%	6.47%	6.54%	6.76%	7.43%
Bankruptcy filings					
Rational	0.54%	0.52%	0.50%	0.43%	
Behavioral		0.74%	0.73%	0.72%	0.60%
Average	0.54%	0.55%	0.56%	0.57%	0.60%
Average interest rates					
Rational	10.32%	10.26%	10.20%	9.89%	
Behavioral		10.88%	10.93%	10.91%	10.38%
Average	10.32%	10.35%	10.40%	10.43%	10.38%

† In the benchmark, 31% of non-college and 15% of college educated are behavioral. That results in an economy-wide fraction of $\lambda = 0.25 \approx 0.62 \times 0.31 + 0.38 \times 0.15$ behavioral consumers. Besides setting this fraction to 0 and 1, we halve and double the benchmark fraction within each education group for a total fraction of $\lambda = 0.12$ and $\lambda = 0.5$.

TABLE B.2. Varying the Degree of Over-Optimism

	Degree of Over-Optimism ψ			
	1.00	1.10	1.285†	2.00
Debt-to-income				
Rational	6.31%	6.25%	6.18%	5.92%
Behavioral	6.45%	6.88%	7.73%	10.62%
Average	6.35%	6.40%	6.54%	6.95%
Bankruptcy filings				
Rational	0.52%	0.51%	0.50%	0.46%
Behavioral	0.66%	0.69%	0.73%	0.88%
Average	0.55%	0.55%	0.56%	0.56%
Average interest rates				
Rational	10.28%	10.26%	10.20%	10.06%
Behavioral	10.95%	10.94%	10.93%	10.80%
Average	10.44%	10.43%	10.40%	10.31%

† The benchmark economy is calibrated to $\psi = 1.285$.

means rational borrowers are pooled with an increasingly risky pool of borrowers. More risky pools are reflected in rising interest rate *schedules*, which drive rationals to borrow less and consequently default less. This results in lower average interest rates for the rational.

These effects show up in the aggregates, albeit more muted. As the degree of over-optimism increases from one to two, borrowing by behaviorals increases by

more than 60%, while the economy-wide debt-to-income ratio rises by less than 10%. Even though bankruptcy filings of behavioral consumers increase by more than 30%, average filings remain roughly constant.

These experiments highlight the importance of dis-aggregated data to provide direct evidence on the degree and incidence of over-optimism. Aggregate data provides limited insights especially in the degree of over-optimism. As we vary the extent of over-optimism, there is remarkably little variation in the debt-to-income ratio and virtually none in the average filing rate and interest rate. Thus, a strategy of calibrating the model to aggregate data only would impose little discipline on the parameters related to over-optimism. Instead, additional dis-aggregated data is needed to calibrate the degree and size of over-optimism, corresponding to our strategy outlined in Section 4 of Exler et al. (2024).

B.2. Robustness of Policy Experiments

The following experiments show that the effects of consumer protection policies discussed in Section 6 of Exler et al. (2024)are largely robust to changing the fraction and degree of overoptimism as discussed in Section B.1. Table B.3 reports the effects of consumer protection policies in an economy where the share of behavioral agents is double: 62% of non-college, 30% of college, and 50% on average. Table B.4 reports the same policy experiments in an economy with a higher degree of over-optimism ($\psi = 2$).[3]

Table B.3 shows very similar policy effects in an economy with a higher fraction of behavioral consumers. Welfare effects remain qualitatively identical and quantitatively very similar. This is mainly due to the observations described in Section B.1: while averages are significantly affected through a composition effect, changing the fraction of behavioral consumers has little impact on the agents' individual behavior. Consequently, introducing different forms of consumer protection policies has comparable effects on both types of agents. There are two exceptions: First, when default costs are lowered (cf. column (3)), overborrowing *increases* for non-college agents, while in our baseline policy experiment in Table Table 7 of Exler et al. (2024), lower default costs decrease these mistakes. With more behavioral borrowers in the economy, their per capita cross-subsidization decreases. When default costs are lowered, both rational and behavioral borrowers default much more often and hold less debt. In response, interest rate schedules deteriorate, but overoptimists do not lower their debts enough and consequently overborrow more. Nevertheless, committing more financial mistakes does not change the welfare implications of this reform.

Second, contrary to our benchmark policy experiment in Table 7 of Exler et al. (2024),introducing a DTI limit only for agents with a type score below 0.65 does affect college educated households. This effect is of a technical nature: since there are 30% overoptimists among the college educated, lenders have a type-score prior of

3. Table 7 of 4 of Exler et al. (2024) presents our benchmark results, where $\lambda = 0.25$ and $\psi = 1.285$

TABLE B.3. Policy Experiments with 50% Behavioral Agents

Parameter	(1) BM with $\lambda = 0.5$	(2) Borrow Cost ↑ $\tau = 7.9\%$	(3) Default Cost ↓ $\gamma = 50\%$	(4) Debt-to-income $\leq 100\%$	(5) Debt-to-income $\leq 100\%$ if $s < 0.65$
Debt-to-income					
Rational, non-college	6.25%	5.36%	4.65%	5.70%	5.71%
Behavioral, non-college	7.60%	6.53%	5.70%	6.90%	6.90%
Rational, college	5.93%	4.65%	4.32%	3.98%	5.34%
Behavioral, college	7.55%	5.99%	5.40%	5.09%	6.55%
Bankruptcy filings					
Rational, non-college	0.77%	0.77%	1.86%	0.75%	0.75%
Behavioral, non-college	0.89%	0.89%	2.13%	0.87%	0.87%
Rational, college	0.13%	0.12%	0.46%	0.13%	0.14%
Behavioral, college	0.16%	0.15%	0.56%	0.16%	0.18%
Average interest rates					
Rational, non-college	11.69%	12.88%	21.86%	11.36%	11.36%
Behavioral, non-college	11.81%	13.01%	22.85%	11.44%	11.44%
Rational, college	8.72%	9.72%	10.79%	8.60%	8.95%
Behavioral, college	8.77%	9.76%	11.31%	8.59%	8.95%
Paternalistic Welfare					
Rational, non-college		-0.19%	0.64%	-0.06%	-0.06%
Behavioral, non-college		-0.21%	0.65%	-0.08%	-0.08%
Rational, college		-0.21%	0.23%	-0.25%	-0.12%
Behavioral, college		-0.22%	0.25%	-0.26%	-0.15%
Financial Mistakes					
Filing too late, non-college	0.05%	0.22%	0.05%	0.01%	0.01%
Filing too late, college	0.09%	0.05%	0.14%	0.01%	0.03%
Overborrowing, non-college	6.36%	8.80%	7.30%	6.23%	6.23%
Overborrowing, college	9.71%	9.39%	10.37%	8.62%	8.62%

Note: Welfare expressed as consumption equivalence variation (CEV) relative to the benchmark.

0.7. This prior implies that some bad income shocks are already enough for college educated agents to be subject to the DTI limit that binds for type scores below 0.65. In the benchmark economy, the college prior was 0.85 and hence the threshold was virtually non-binding.

In Table B.4, the same policies apply to an economy with behaviorals that are more over-optimistic (and face more downside income risk). Relative to our benchmark calibration, the effects of consumer protection policies remain qualitatively the same and quantitatively quite similar. However, there are two exceptions: First, when default costs are lowered (cf. column (3)), overborrowing *increases* for non-college agents contrary to our baseline policy experiment. With $\psi = 2$, behavioral borrowers

TABLE B.4. Policy Experiments with a Higher Degree of Over-Optimism ($\psi = 2$)

Parameter	(1) BM with $\psi = 2$	(2) Borrow Cost $\uparrow$ $\tau = 7.9\%$	(3) Default Cost $\downarrow$ $\gamma = 50\%$	(4) Debt-to-income $\leq 100\%$	(5) Debt-to-income $\leq 100\%$ if $s < 0.65$
Debt-to-income					
Rational, non-college	5.93%	5.04%	4.41%	5.43%	5.70%
Behavioral, non-college	10.09%	8.71%	7.60%	9.13%	9.36%
Rational, college	5.90%	4.51%	4.20%	3.91%	5.46%
Behavioral, college	11.85%	9.54%	8.12%	8.09%	9.90%
Bankruptcy filings					
Rational, non-college	0.71%	0.71%	1.69%	0.69%	0.70%
Behavioral, non-college	1.06%	1.05%	2.42%	1.03%	1.04%
Rational, college	0.13%	0.12%	0.43%	0.13%	0.14%
Behavioral, college	0.25%	0.23%	0.76%	0.23%	0.28%
Average interest rates					
Rational, non-college	11.45%	12.59%	18.97%	11.11%	11.18%
Behavioral, non-college	11.73%	12.84%	20.09%	11.24%	11.29%
Rational, college	8.76%	9.71%	10.32%	8.61%	8.93%
Behavioral, college	8.89%	9.86%	11.04%	8.59%	8.96%
Paternalistic Welfare					
Rational, non-college		-0.19%	0.63%	-0.06%	-0.04%
Behavioral, non-college		-0.22%	0.68%	-0.10%	-0.09%
Rational, college		-0.21%	0.22%	-0.24%	-0.08%
Behavioral, college		-0.22%	0.35%	-0.24%	-0.16%
Financial Mistakes					
Filing too late, non-college	0.24%	0.28%	0.19%	0.05%	0.12%
Filing too late, college	0.20%	0.17%	0.48%	0.03%	0.09%
Overborrowing, non-college	18.43%	20.16%	19.10%	16.21%	17.46%
Overborrowing, college	22.20%	23.08%	26.43%	22.67%	21.04%

overestimate their future ability to repay by more. They roll over too much debt and default too late relative to their informed selves. This effect is more pronounced in a regime where default costs are low. However, committing more financial mistakes does not change the welfare implications of this reform. Both types would happily trade higher equilibrium interest rates for a cheaper option of default and gaining access to better insurance.

Second, similar to the previous robustness exercise, there is a mechanical effect when analyzing DTI limits for type scores below 0.65. When the degree of over-optimism is larger, there are more negative shocks that provide information on the fundamental type of a borrower. Thus, banks can learn faster and update type scores more quickly. Consequently, there are some college educated consumers with type scores below 0.65 that are affected by the policy in column (5).

Appendix C: Details of Borrowing Limit Regulation

Here we provide the equations behind the policies considered in Sections 6.4 and 7 of Exler et al. (2024).*Debt-to-income limits* are implemented by restricting the bond price of too large loans:

$$q_e^b(d',z,j,s) = \begin{cases} q_e^{ub}(d',z,j,s) & \text{if } q_e^{ub}(\cdot)d'/(h^e z^e) \leq B(s) \\ 0 & \text{otherwise.} \end{cases} \tag{C.1}$$

Here, q_e^{ub} is the unrestricted borrowing bond price. Putting a limit on DTI means that as soon as a loan $q_e^{ub}d'$ is too high relative to income (defined as hz), borrowing is no longer possible. The effective bond price q_e^b is set to zero in such a case. We define the debt-to-income limit by using hz as a proxy for income. The reason is that banks typically define such limits by using the predicted future income rather than the income in the period when the loan is taken out. Since the transitory income shock has no impact on the ability to repay in the next period, we define the debt-to-income limits using the permanent and persistent income components only.

For a general debt-to-income limit, as in Section 6.4 of Exler et al. (2024), $B(s) = B$ is independent of the type score. For type-score dependent policies discussed in Section 7, $B(s)$ depends on the score. In our policy experiments, we set one limit for all scores below a threshold, $s < \bar{s}$, while consumers above the threshold face no limit. In other words, we set

$$B(s) = \begin{cases} \overline{B} & \text{if } s < \bar{s} \\ \infty & \text{if } s \geq \bar{s}. \end{cases} \tag{C.2}$$

The limit, $\overline{B}$, applies to the amount of debt a person aims to incur in that period. Recall that in our notation, d' is the promised repayment including the interest rate (rather than a conventional measure of debt).

Appendix D: Ergodic Distribution of Type Scores

TABLE D.1. Type-Score Distribution Across Types (CDF)

	Non-College		College		Full Population		
Score	Realist	Behavioral	Realist	Behavioral	Realist	Behavioral	All Types
0.10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.15	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.25	0.00%	0.01%	0.00%	0.00%	0.00%	0.01%	0.00%
0.30	0.01%	0.05%	0.00%	0.00%	0.01%	0.04%	0.01%
0.35	0.05%	0.17%	0.00%	0.00%	0.03%	0.13%	0.06%
0.40	0.19%	0.54%	0.00%	0.00%	0.11%	0.42%	0.19%
0.45	0.61%	1.50%	0.00%	0.01%	0.35%	1.16%	0.55%
0.50	1.80%	3.83%	0.01%	0.02%	1.03%	2.96%	1.51%
0.55	4.89%	9.02%	0.02%	0.09%	2.80%	6.97%	3.84%
0.60	12.71%	20.12%	0.09%	0.29%	7.28%	15.58%	9.35%
0.65	31.54%	42.23%	0.33%	0.96%	18.12%	32.79%	21.77%
0.70	69.50%	79.35%	1.56%	3.54%	40.27%	62.01%	45.69%
0.75	87.92%	93.29%	6.08%	10.95%	52.71%	74.46%	58.13%
0.80	96.78%	98.60%	21.85%	31.06%	64.54%	83.15%	69.18%
0.85	99.42%	99.80%	72.30%	80.99%	87.75%	95.50%	89.68%
0.90	99.94%	99.98%	93.95%	96.81%	97.36%	99.26%	97.83%
0.95	100.00%	100.00%	99.42%	99.77%	99.75%	99.95%	99.80%
1.00	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Overall Population Shares							
	42.78%	19.22%	32.3%	5.7%	75.08%	24.92%	

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