The Portfolio Choice Channel of Wealth Inequality

Mauricio Calani
Banco Central de Chile

Lucas Rosso
Universidad de Chile

MMF 2021 - Cambridge, UK
September, 2021

Motivation

Motivation

- What is the role of households portfolio choice in wealth inequality?

- Recent evidence suggests that return to savings is highly increasing in wealth Bach et al. (2020); Fagereng et al. (2020)
  - *scale* dependent returns
  - results hold even within narrow asset classes!

- Portfolio choice and *scale* dependence usually abscent in workhorse models of wealth accumulation (e.g. Aiyagari, 1994)
  - hard to get large top wealth shares
  - unrealistic participation rates and risky shares

This Paper

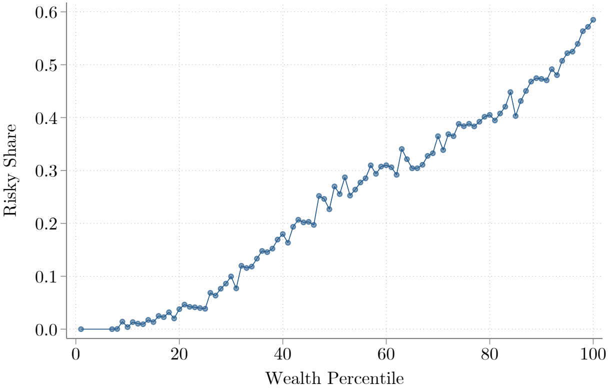
- Proposes a model that explicitly incorporates households portfolio decisions.

- Model provides better fit than workhorse model of wealth accumulation
  $\longrightarrow$ and adds more realism to households balance sheets.

- Intends to shed light on the effect of portfolio adjustment frictions in wealth inequality
  $\longrightarrow$ adjustment cost amplifies precautionary channel.

Stylized Facts ▸ Robustness

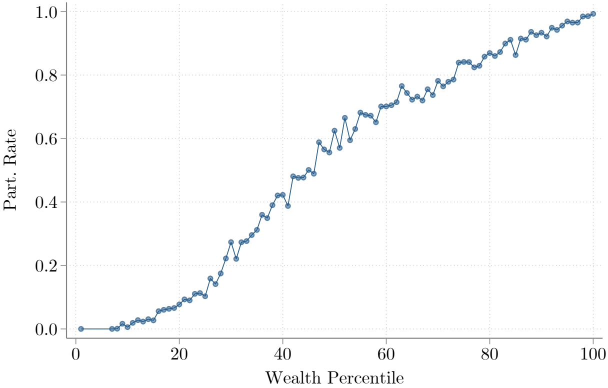
Risky asset share steeply increasing across wealth distribution!



Notes: Data from the Survey of Consumer Finances (SCF) for the period 1998-2019. Risky assets defined as in Chang et al. (2018) but without including non-actively managed business in Financial Wealth definition. ▸ Detail

Stylized Facts

Extensive margin matters for portfolio choice



Notes: Data from the Survey of Consumer Finances (SCF) for the period 1998-2019. Risky assets defined as in Chang et al. (2018) but without including non-actively managed business in Financial Wealth definition. Participation rate defined as $\mathbf{1}\{R > 0\}$

Related Literature

Combine two workhorse macro models + adjustment frictions

- Portfolio choice models Merton (1969); Samuelson (1969)
- Bewley models Bewley (1986); Huggett (1993); Aiyagari (1994)
- Non-convex (fixed) adjustment costs Kaplan and Violante (2014)

Related Work:

1. **Empirical evidence of portfolio heterogeneity**

   Vissing-Jorgensen (2002); Kuhn et al. (2020); Bach et al. (2020); Fagereng et al. (2020); Martínez-Toledano (2020)

2. **Models of wealth inequality with idiosyncratic returns to wealth**

   Benhabib et al. (2011, 2015); Gabaix et al. (2016); Gomez (2018); Hubmer et al. (2020); Xavier (2020)

3. **Continuous time HA models**

   Achdou et al. (2017); Kaplan et al. (2018)

Model

Setup ▸ Advantages

Continuous time, partial-equilibrium heterogeneous agent model with

1. Rich households balance sheets
   - safe and risky assets
   - "hard" and "soft" borrowing constraints
   - fixed adjustment cost in risky asset

2. Uninsurable labor income risk.

Problem consists of solving a system of two PDEs

- Hamilton-Jacobi-Bellman (HJB) equation for individual choices

- Kolmogorov Forward (KF) equation for evolution of distribution

Household Balance Sheets

- Stochastic income follows a two-state Poisson process:

$$z_t \in \{z_L, z_H\}$$

- Safe wealth b_t, risky wealth a_t
- Changes in risky asset holdings entail a fixed adjustment cost κ
  $\Longrightarrow$ stopping-time element
- Stochastic return in risky asset:

$$\mathrm{d}r_t^a = \mu \, \mathrm{d}t + \sigma \, \mathrm{d}W_t$$

- Working assumption: Labor income independent from capital income
  $\longrightarrow$ second order in infinite-horizon settings (no life cycle)
  $\longrightarrow$ consistent with empirical literature Cocco et al. (2005); Fagereng et al. (2017)

Household's Problem

Households are heterogeneous in their wealth (a, b), income z, and the return on savings

$$\upsilon_k(a, b, z) = \max_{\{c_t\},\tau} \mathbb{E}_0 \int_0^\tau e^{-\rho t} u(c_t) + e^{-\rho\tau} \mathbb{E}_0 \, \upsilon_k^*(a_\tau + b_\tau, z)$$

$$\begin{aligned}
&\mathrm{d}a_t = \mathrm{d}r_t^a a_t; \\
&\mathrm{d}b_t = (z_t + r_t^b(b_t)b_t - c_t)\mathrm{d}t \\
&z_t \in \{z_L, z_H\} \text{ Poisson with intensities } \lambda_L, \lambda_H \\
&\mathrm{d}r_t^a = \mu \, \mathrm{d}t + \sigma \, \mathrm{d}W_t \\
&a \geq 0; \; b \geq \underline{b},
\end{aligned}$$

where

$$\upsilon_k^*(a + b, z) = \max_{a', b'} \upsilon_k(a', b', z) \;\; s.t. \; a' + b' = a + b - \kappa$$

HJB equation

$$\begin{aligned} \rho v(a,b,z) = \max_{c} \quad & u(c) + \\ \textit{Safe Asset}: \; & + \partial_b v(a,b,z)(z + r^b b - c) \\ \textit{Risky Asset}: \; & + \mu(r^a) a \partial_a v(a,b,z) + \frac{\sigma^2(r^a)a^2}{2} \partial_{aa} v(a,b,z) \\ \textit{Labor Income}: \; & + \sum_{z' \in Z} \lambda^{z \to z'} \left(v(a,b,z') - v(a,b,z) \right), \end{aligned}$$

with a state-constraint boundary condition

$$\partial_b v(a, \underline{b}) \geq u'(z + r^b \underline{b})$$

and a constraint that

$$v(a,b,z) \geq v^*(a+b,z) \; \forall \; a, b$$

HJB quasi-variational inequality ▸ Derivation

Suppressing dependence on (a, b, z), the HJBQVI can be written as

$$\min\Big\{\rho v - \max_c\{u(c) - \mu a\,\partial_a v - \frac{\sigma^2 a^2}{2}\partial_{aa} v - (z + r^b b - c)\,\partial_b v - \sum_{z' \in Z} \lambda^{z \to z'}\left(v(z') - v(z)\right), v - \mathcal{M}v\Big\} = 0,$$

where $v^* = \mathcal{M}v$, and $\mathcal{M}$ is known as the "intervention operator" (See e.g., Azimzadeh et al., 2018)

In matrix notation

$$\min\left\{\rho\mathbf{v} - u(\mathbf{v}) - \mathbf{A}(\mathbf{v})\,\mathbf{v}, \mathbf{v} - \mathbf{v}^*(\mathbf{v})\right\} = 0$$

Kolmogorov-Forward Equation

Without adjustment the KF equation is

$$0 = -\partial_a(\mu a g(a,b,z)) + \frac{1}{2}\partial_{aa}(\sigma^2 a^2 g(a,b,z)) - \partial_b[s^b(a,b,z)\, g(a,b,z)] \\ - \lambda^{z\to z'} g(a,b,z) + \lambda^{z'\to z} g(a,b,z'),$$

In matrix notation

$$0 = \mathbf{A}^T g$$

- Caveat: Mathematical formulation of the KF for impulse control problem is not straightforward!
- However, turns out to be significantly easier to deal once discretized

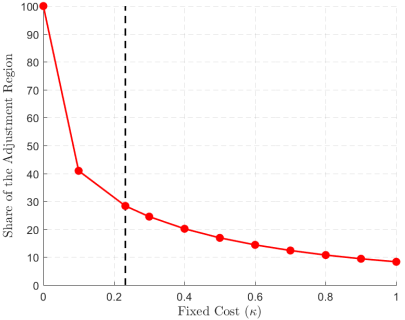
▸ Numerical Solution

Quantitative Analysis

Parametrization

Parameter	Description	Value	Source/Target
Households			
γ	Risk aversion	2	Standard
ρ	Subjective discount rate	0.053	Standard ($\beta = 0.95$)
Assets			
$\underline{b}$	Borrowing limit	-1	1 times avg. income
ϖ	Interest rate wedge	0.06	Kaplan et al. (2018)
r^b	Safe asset return	0.02	Gomes and Michaelides (2005)
μ	Risky asset drift	0.06	Gomes and Michaelides (2005)
σ	Risky asset volatility	0.18	Gomes and Michaelides (2005)
κ	Adjustment cost	0.23	Participation Rate
Income Process			
z_1, z_2	Income states	$0.79, 1.21$	$\sigma_z = 0.21$, $\varphi_z = 0.9$, $\mathbb{E}(z) = 1$
λ_1, λ_2	Income jumps	$0.25, 0.25$	Eq. (1)

The role of κ



Notes: Connected dots denote the size of the adjustment region out of the total state-space. Vertical line represents the calibrated value for κ

- Small frictions can generate large inaction ranges
- Calibrated κ represents only 0.75% of adjusting households stock.
- Inaction range highly increasing in κ
- Common interpretations: opp cost, processing cost, mental accounting.

"Fat-tail Aiyagari" as a useful benchmark

Measure	Data	Baseline Model	Fat-tail Aiyagari (1994)
Top 1%	37.5	22.2	11.5
Top 5%	64.6	49.6	35.2
Top 10%	77.8	66.1	52.6
Middle 40%	19.5	33.8	38.3
Bottom 50%	0.98	0.10	9.2

- When $\kappa = 0$, the model reduces to a combination of workhorse models of wealth accumulation (Aiyagari, 1994) + portfolio choice (Merton, 1969) $\longrightarrow$ "Fat-tail Aiyagari"
- Under the same calibration, the introduction of adj. friction (i.e. $\kappa > 0$) substantially improves the fit!
  $\longrightarrow$ adjustment cost narrows the gap in top shares to roughly half
- Still much to go (e.g., no *type* dependence)

The amplifying effect of κ

- Assume wealth inequality increases due to a permanent decrease in labor income risk (Why?)
- How does the adjustment cost affect wealth top shares?
- Turns out that κ amplifies top shares by a factor over 8!
  $\longrightarrow$ *scale* dependence feeds precautionary channel

	Baseline			Fat-tail Aiyagari (1994)		
	$\sigma_\nu = 0.20$	$\sigma_\nu = 0.18$	% change	$\sigma_\nu = 0.20$	$\sigma_\nu = 0.18$	% change
Top 1%	22.2	33.9	52.70	11.5	12.2	6.09
Top 5%	49.6	64.1	29.23	35.2	36.6	3.98
Top 10%	66.1	80.1	21.18	52.6	53.6	1.90

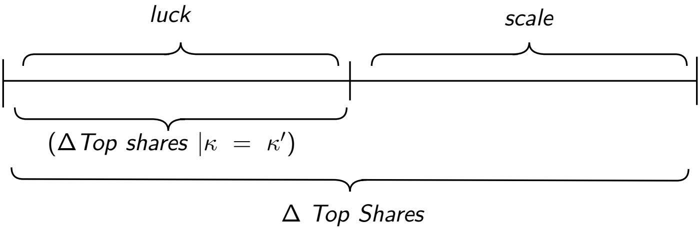
Decomposing top shares into *luck* and *scale*

In the lens of the model, differences in wealth accumulation are generated by

- *luck*: idiosyncratic shocks to income and returns
- *scale*: portfolio re-balancing entails an adjustment cost κ

However, *luck* depends on the participation decision and thus in the *scale component* $\Longrightarrow$ Effects are not additively separable

Our approach: re-calibrate κ after a permanent shock (e.g. to the income process) to create counterfactual with equal *scale* component



Decomposing top shares into *luck* and *scale*

	$\sigma_\nu = 0.20$	$\sigma_\nu = 0.18$	% change	% scale	% *luck*
Top 1%	22.2	33.9	52.7	88.0	12.0
Top 5%	49.6	64.1	29.2	88.3	11.7
Top 10%	66.1	80.1	21.2	89.3	10.7

- Roughly 90% of the change in top shares is explained by the *scale* component!
- Results consistent with the amplifying effect discussed earlier

Conclusion

Concluding Remarks

- Portfolio choice matters! $\longrightarrow$ risky share is steeply increasing across wealth distribution.
- Adjustment frictions amplify the effect of portfolio choice in inequality by introducing *scale* dependence.
- Portfolio choice + small Adjustment frictions narrow the gap in top wealth shares to $\approx$ half.

Thanks!

For questions feel free to reach out to lrosso@fen.uchile.cl

References I

ACHDOU, Y., J. HAN, J.-M. LASRY, P.-L. LIONS, AND B. MOLL (2017): "Income and wealth distribution in macroeconomics: A continuous-time approach," Technical report, National Bureau of Economic Research.

ACHURY, C., S. HUBAR, AND C. KOULOVATIANOS (2012): "Saving rates and portfolio choice with subsistence consumption," *Review of Economic Dynamics*, 15, 108–126.

AIYAGARI, S. R. (1994): "Uninsured idiosyncratic risk and aggregate saving," *The Quarterly Journal of Economics*, 109, 659–684.

AZIMZADEH, P., E. BAYRAKTAR, AND G. LABAHN (2018): "Convergence of Implicit Schemes for Hamilton–Jacobi–Bellman Quasi-Variational Inequalities," *SIAM Journal on Control and Optimization*, 56, 3994–4016.

BACH, L., L. E. CALVET, AND P. SODINI (2020): "Rich pickings? Risk, return, and skill in household wealth," *American Economic Review*.

BENHABIB, J., A. BISIN, AND S. ZHU (2011): "The distribution of wealth and fiscal policy in economies with finitely lived agents," *Econometrica*, 79, 123–157.

——— (2015): "The wealth distribution in Bewley economies with capital income risk," *Journal of Economic Theory*, 159, 489–515.

BEWLEY, T. (1986): "Stationary monetary equilibrium with a continuum of independently fluctuating consumers," *Contributions to mathematical economics in honor of Gérard Debreu*, 79.

CHANG, Y., J. H. HONG, AND M. KARABARBOUNIS (2018): "Labor market uncertainty and portfolio choice puzzles," *American Economic Journal: Macroeconomics*, 10, 222–62.

COCCO, J. F., F. J. GOMES, AND P. J. MAENHOUT (2005): "Consumption and portfolio choice over the life cycle," *The Review of Financial Studies*, 18, 491–533.

FAGERENG, A., C. GOTTLIEB, AND L. GUISO (2017): "Asset market participation and portfolio choice over the life-cycle," *The Journal of Finance*, 72, 705–750.

FAGERENG, A., L. GUISO, D. MALACRINO, AND L. PISTAFERRI (2020): "Heterogeneity and persistence in returns to wealth," *Econometrica*, 88, 115–170.

FAGERENG, A., M. B. HOLM, B. MOLL, AND G. NATVIK (2019): "Saving behavior across the wealth distribution: The importance of capital gains," Technical report, National Bureau of Economic Research.

GABAIX, X., J.-M. LASRY, P.-L. LIONS, AND B. MOLL (2016): "The dynamics of inequality," *Econometrica*, 84, 2071–2111.

GOMES, F., AND A. MICHAELIDES (2005): "Optimal life-cycle asset allocation: Understanding the empirical evidence," *The Journal of Finance*, 60, 869–904.

GOMEZ, M. (2018): "Asset prices and wealth inequality," *Working Paper, Columbia University*.

GUVENEN, F., G. KAMBOUROV, B. KURUSCU, S. OCAMPO, AND D. CHEN (2019): "Use it or lose it: Efficiency gains from wealth taxation," Technical report, Federal Reserve Bank of Minneapolis.

References II

HUBMER, J., P. KRUSELL, AND A. A. SMITH JR (2020): "Sources of US wealth inequality: Past, present, and future," in *NBER Macroeconomics Annual 2020, volume 35*: University of Chicago Press.

HUGGETT, M. (1993): "The risk-free rate in heterogeneous-agent incomplete-insurance economies," *Journal of economic Dynamics and Control*, 17, 953–969.

KAPLAN, G., B. MOLL, AND G. L. VIOLANTE (2018): "Monetary policy according to HANK," *American Economic Review*, 108, 697–743.

KAPLAN, G., AND G. L. VIOLANTE (2014): "A model of the consumption response to fiscal stimulus payments," *Econometrica*, 82, 1199–1239.

KUHN, M., M. SCHULARICK, AND U. I. STEINS (2020): "Income and wealth inequality in America, 1949–2016," *Journal of Political Economy*, 128, 000–000.

LAIBSON, D., P. MAXTED, AND B. MOLL (2020): "Present Bias Amplifies the Household Balance-Sheet Channels of Macroeconomic Policy," Technical report, Mimeo.

MARTÍNEZ-TOLEDANO, C. (2020): "House price cycles, wealth inequality and portfolio reshuffling," *WID. World Working Paper*.

MERTON, R. C. (1969): "Lifetime portfolio selection under uncertainty: The continuous-time case," *The review of Economics and Statistics*, 247–257.

SAMUELSON, P. A. (1969): "Lifetime portfolio selection by dynamic stochastic programming," *The review of economics and statistics*, 239–246.

VISSING-JORGENSEN, A. (2002): "Towards an explanation of household portfolio choice heterogeneity: Nonfinancial income and participation cost structures," Technical report, National Bureau of Economic Research.

XAVIER, I. (2020): "Wealth Inequality in the US: the Role of Heterogeneous Returns," *Working Paper*.

Q & A

Safe and Risky asset definitions

Return

I group assets into the following categories:

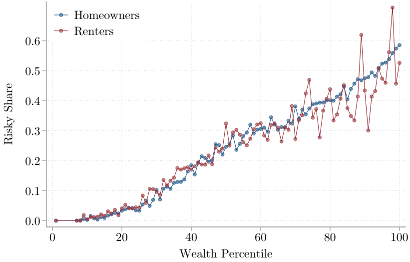
$$\begin{aligned} \textit{Safe Assets} &= \text{Checking Accounts} + \text{Money Market Accounts} + \text{Savings Accounts} \\ &+ \text{Certificates of Deposit} + \text{Safe Saving Bonds} + \text{Life Insurance} \\ &+ \text{Safe Trusts} + \text{Miscellaneous Assets} + \text{Safe Mutual Funds} \\ &+ \text{Safe Annuities} + \text{Safe IRA} + \text{Safe Pensions} \end{aligned}$$

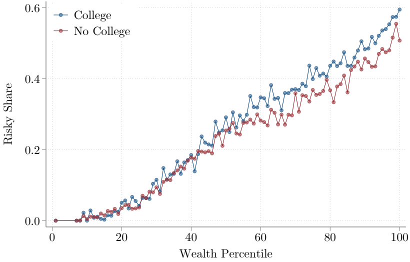
$$\begin{aligned} \textit{Risky Assets} &= \text{Risky Saving Bonds} + \text{Brokerage Accounts} + \text{Stocks} \\ &+ \text{Risky Mutual Funds} + \text{Risky Annuities} + \text{Risky Trusts} + \text{Risky IRA} \\ &+ \text{Risky Pensions} \end{aligned}$$

And the baseline definition

$$\omega = \frac{\textit{Risky Assets}}{\textit{Risky Assets} + \textit{Safe Assets}}$$

Robustness in Risky Share ◂ Return





Notes: Homeowners represent households with housing net worth different than 0. College refers to households with a head with a college degree.

Controlling for traditional suspects

Following Fagereng et al. (2019) I estimate a simple model with $\mathbf{x}_{it}$ = age, earnings, education, marital status ...

$$\omega_{it} = \alpha + \sum_{p=2}^{100} \delta_p D_{it,p} + f(\mathbf{x}_{it}) + \mu_t + \varepsilon_{it},$$

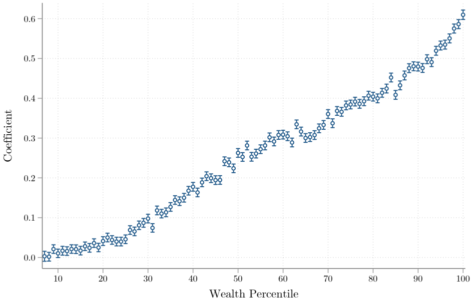
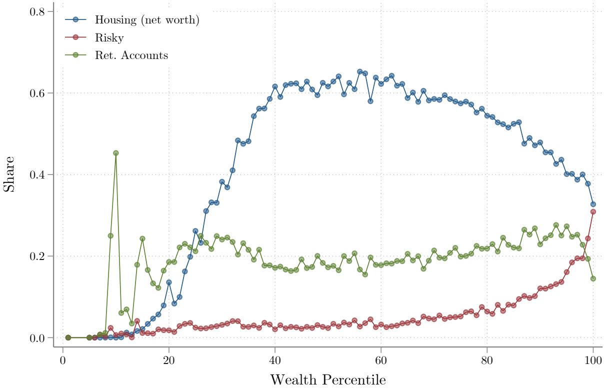


Figure 1: Percentile Dummies δ_p

Alternative Definitions of Financial Wealth

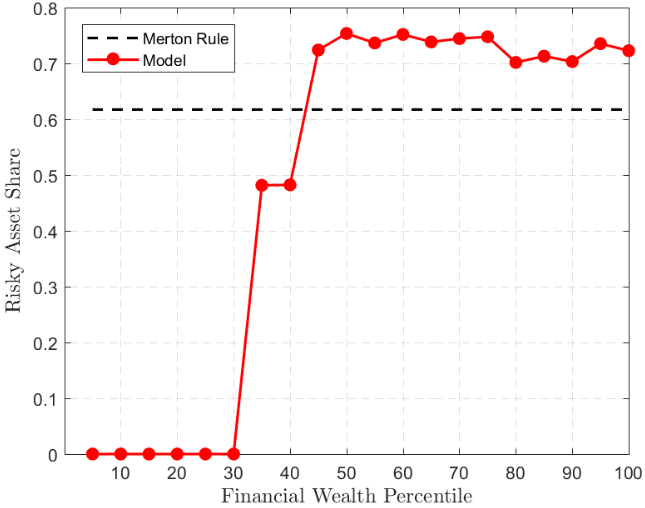
Notes: Wealth distribution is computed using the baseline definition of financial wealth (blue), the baseline definition excluding retirement accounts (red) and the baseline definition including housing net worth (green).

Asset Shares Across Wealth Distribution



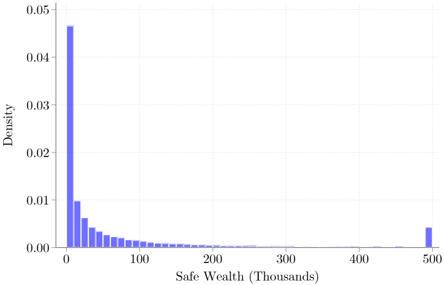
Notes: This figure considers the baseline definition of financial wealth plus housing and retirement account assets for computing both shares and the percentiles of the wealth distribution.

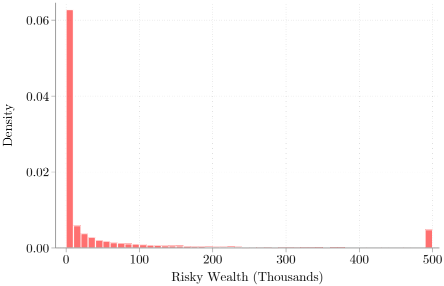
Model's Risky share Across the Wealth Distribution



Financial Wealth Distribution in the SCF

Risky and Safe Wealth Distribution





Why Continuous time? Ben Moll's take: Back

1. Borrowing Constraint only shows up in boundary conditions
   $\Longrightarrow$ FOCs always hold with "="

2. FOCs are "static" and can be computed by hand: $c^{-\gamma} = \partial_b v_k$

3. Sparcity: Solving the problem = Inverting giant (but sparse) matrix.

4. Two birds with one stone: diff. operator in KF is the adjoint of opeator in HJB
   $\Longrightarrow$ after solving HJB, KF comes "for free".

Bonus: It can be shown that HJBQVI $\Longrightarrow$ smooth pasting condition

Calibration of the Income Process ◂ Calibration

As in Laibson et al. (2020) I assume an AR(1) process for log-labor income

$$\log(z_t) = \varphi_z \log(z_t) + \nu_t$$

and calibrate $\varphi_z = 0.9$ and $\sigma_\nu = 0.2$ (Guvenen et al., 2019). Then recover the drift and the diffusion of the Ornstein-Uhlenbeck process

$$\mathrm{d}\log(z_t) = -\theta_z \log(z_t) + \sigma_z \mathrm{d}W_t,$$

where

$$\varphi_z = e^{-\theta_z}, \quad \sigma_z = \frac{\sigma_\nu^2}{2\theta_z}(1 - e^{-2\theta_z})$$

Finally, I set z_L, z_H to -1,+1 standard deviations and computer transition probabilities from

$$\lambda^{z \to z'} = \left[\frac{\theta_z}{2\pi\sigma_z^2\,(1 - e^{-2\theta_z})}\right] \exp\left[-\frac{\theta_z}{\sigma_z^2}\frac{(\log(z') - \log(z)e^{-\theta_z})^2}{1 - e^{-2\theta_z}}\right], \quad (1)$$

Derivation of the HJBQVI ◂ Return

Discrete time version of the problem:

$$
\begin{aligned}
\upsilon_j(a_t, b_t) = & \max_c \; u(c_t)\Delta + \beta(\Delta)\,\mathbb{E}\left[\upsilon_j(a_{t+\Delta}, b_{t+\Delta})\right] \\
s.t. \;\; a_{t+\Delta} = & \; r_t^a a_t \Delta + a_t \\
b_{t+\Delta} = & \; (y_j + r_t^b b_t - c_t)\Delta + b_t,
\end{aligned}
$$

for $j = L, H$. Given the probability $p_j(\Delta) = e^{-\lambda_j \Delta}$ to keep the current income, we have

$$
\begin{aligned}
\upsilon_j(a_t, b_t) = \max_c \; u(c_t)\Delta + \beta(\Delta)\Big\{ & p_j(\Delta)\mathbb{E}\left[\upsilon_j(a_{t+\Delta}, b_{t+\Delta})\right] \\
& + (1 - p_j(\Delta))\,\mathbb{E}\left[\upsilon_{-j}(a_{t+\Delta}, b_{t+\Delta})\right] \Big\}
\end{aligned}
$$

Derivation of the HJBQVI Return

For a small enough Δ we have

$$\beta(\Delta) = e^{-\rho\Delta} \approx 1 - \rho\Delta$$
$$\rho_j(\Delta) = e^{-\lambda_j\Delta} \approx 1 - \lambda_j, \Delta$$

and thus substituting into the equation above

$$\begin{aligned} \upsilon_j(a_t, b_t) = \max_c \; u(c_t)\Delta + (1-\rho\Delta)\Big\{(1-\lambda_j\Delta)\mathbb{E}\left[\upsilon_j(a_{t+\Delta}, b_{t+\Delta})\right] \\ + \lambda_{-j}\Delta\mathbb{E}\left[\upsilon_j(a_{t+\Delta}, b_{t+\Delta})\right]\Big\}, \end{aligned}$$

re-arranging terms

$$\begin{aligned} \upsilon_j(a_t, b_t) = \max_c \; u(c_t)\Delta + (1-\rho\Delta)\Big\{\mathbb{E}\left[\upsilon_j(a_{t+\Delta}, b_{t+\Delta})\right] \\ + \lambda_j\Delta\mathbb{E}\left[\upsilon_{-j}(a_{t+\Delta}, b_{t+\Delta}) - \upsilon_j(a_{t+\Delta}, b_{t+\Delta})\right]\Big\} \end{aligned}$$

Derivation of the HJBQVI ◂ Return

Subtracting $(1-\rho\Delta)\upsilon_j(a_t, b_t)$, dividing by Δ and taking $\Delta \to 0$ we get

$$\rho\upsilon_j(a_t, b_t) = \max_c \; u(c_t) + \frac{\mathbb{E}[\mathrm{d}\upsilon(a_t, b_t)]}{\mathrm{d}t} + \lambda_j \left(\upsilon_{-j}(a_t, b_t) - \upsilon_j(a_t, b_t)\right)\}$$

For the missing term, note that by Ito's Lemma we have

$$\mathrm{d}\upsilon(a_t, b_t) = \Bigg(\partial_b\upsilon(a_t, b_t)(y_t + r_t^b b_t - c_t) + \mu a\partial_a\upsilon(a_t, b_t) + \frac{\sigma^2 a^2}{2}\partial_{aa}\upsilon(a_t, b_t)\Bigg)\mathrm{d}t + \sigma a\partial_a\upsilon(a_t, b_t)\mathrm{d}W_t,$$

taking expectations and noticing that $\mathbb{E}[\mathrm{d}W_t] = 0$

$$\frac{\mathbb{E}[\mathrm{d}\upsilon(a_t, b_t)]}{\mathrm{d}t} = \partial_b\upsilon(a_t, b_t)(y_t + r_t^b b_t - c_t) + \mu a\partial_a\upsilon(a_t, b_t) + \frac{\sigma^2 a^2}{2}\partial_{aa}\upsilon(a_t, b_t)$$

Numerical Solution ◂ Return

Following Achdou et al. (2017), I use a finite-difference upwind scheme where

$$\text{Backward difference: } \partial_{x,B}\, v = \frac{v_i - v_{i-1}}{\Delta x}$$
$$\text{Forward difference: } \partial_{x,F}\, v = \frac{v_{i+1} - v_i}{\Delta x}$$
$$\text{Central difference: } \partial_{xx}\, v = \frac{v_{i+1} - 2v_i + v_{i-1}}{(\Delta x)^2},$$

for $x \in \{a, b\}$ and where the households problem is discretized as:

$$\min\left\{\rho\mathbf{v} - u(\mathbf{v}) - A(\mathbf{v})\,\mathbf{v}, \mathbf{v} - \mathbf{v}^*(\mathbf{v})\right\} = 0$$

Main idea: Use backward difference when drift is negative and forward difference when positive

Solving the Household's Problem

As mentioned earlier, the discrete-time version of the HJBQVI is given by

$$\min \left\{ \rho \mathbf{v} - u(\mathbf{v}) - A(\mathbf{v})\,\mathbf{v}, \mathbf{v} - \mathbf{v}^*(\mathbf{v}) \right\} = 0$$

- Where A is a $I \times J \times Z$ transition matrix that summarizes the evolution of the state variables.

- Note from the left branch that $u(\cdot)$ depends on υ... Why?

  $\Longrightarrow$ From FOC: $u'(c) = \partial_b \, \upsilon_k$

Solving the Households' Problem

Algorithm for solution:

1. As initial guess $\mathbf{v}^0$ use the solution to the no-adjustment case:

$$\rho \mathbf{v} - u(\mathbf{v}) - A(\mathbf{v})\,\mathbf{v} = 0$$

2. Given $\mathbf{v}^n$, find $\mathbf{v}^{n+1}$ by solving:

$$\min\left\{\frac{\mathbf{v}^{n+1} - \mathbf{v}^n}{\Delta} + \rho \mathbf{v}^{n+1} - u(\mathbf{v}^n) - A(\mathbf{v}^n)\,\mathbf{v}^{n+1},\, \mathbf{v}^{n+1} - \mathbf{v}^*(\mathbf{v}^n)\right\} = 0,$$

3. Iterate until convergence.

Solving the KF Equation

Without adjustment, the solution is given by

$$\mathbf{A}^T g = 0,$$

where $\mathbf{A}^T$ is the transpose of the transition matrix A from the HJB equation.

- Introducing notation: define (a_k^*, b_k^*) as the optimal adjustment targets, $\ell = 1, \dots, L$ the staked and discretized state-space, $\mathcal{I}$ as the inaction regions and $k^*(\ell)$ reached from the point ℓ upon adjustment

- Define the binary matrix $\mathbf{M}$, with elements $M_{\ell,k}$

$$M_{\ell,k} = \begin{cases} 1, & \text{if } \ell \in \mathcal{I} \text{ and } \ell = k \\ 1, & \text{if } \ell \notin \mathcal{I} \text{ and } k^*(\ell) = k \\ 0, & \text{Otherwise} \end{cases}$$

$\implies$ Matrix $\mathbf{M}$ moves points to the adjustment targets.

Solving the KF Equation

This opens two questions:

1. How we treat the density at grid points in the adjustment region?

2. How to treat points in $\mathcal{I}$ but from which the stochastic process for idiosyncratic state variables ends up in the adjustment region?

The following algorithm tackles both problems:

1. Given g^n, find $g^{n+\frac{1}{2}}$ from:

$$g^{n+\frac{1}{2}} = \mathbf{M}^T g^n$$

2. Given $g^{n+\frac{1}{2}}$, find g^{n+1} from:

$$\frac{g^{n+1} - g^{n+\frac{1}{2}}}{\Delta t} = (A\mathbf{M})^T g^{n+1}$$

Richer return heterogeneity and *type* dependence

- Model abstracts from *type* dependence $\longrightarrow$ all differences in wealth accumulation comes from either *luck* or scale dependence
- However, empirical evidence suggests returns are increasing in wealth even within narrow asset classes Fagereng et al. (2020); Xavier (2020)
- Also collapsing all risky assets into one ignores imperfect portfolio diversification

One way to deal with this is assume a more general return process

$$\mathrm{d}r_t^a = \mu(a)\mathrm{d}t + \sigma(a)\mathrm{d}W_t$$

Possible channels: Imperfect portfolio diversification, information frictions, heterogeneous investment opportunities, and so on.

Imperfect Portfolio Diversification

Assume that the volatility of the risky asset decreases exponentially with risky wealth a at a rate ϑ

$$\sigma(a) = \hat{\sigma} e^{-\vartheta a}$$

I choose the set of parameters Θ that minimizes the weighted deviation between resulting moments $m(\Theta)$ from the model

$$Q(\Theta) = (m - \hat{m}(\Theta))' \mathcal{W} (m - \hat{m}(\Theta))$$

$$\hat{\Theta} = \arg\min_{\Theta} Q(\Theta),$$

Parameter	Value	Target	Model
Fixed adjustment cost (κ)	0.19	51.2[a]	49.7
Exponential decay rate (ϑ)	0.01	77.8[b]	74.7
Scale parameter volatility ($\hat{\sigma}$)	0.22	0.18[c]	0.21[d]

[a] Risky asset participation rate.

[b] Top 10% wealth share.

[c] Gomes and Michaelides (2005).

Imperfect Portfolio Diversification

Measure	Data	Baseline Model	Imperfect Diversification
Top 1%	37.5	22.2	19.2
Top 5%	64.6	49.6	54.2
Top 10%	77.8	66.1	74.7
Middle 40%	19.5	33.8	26.8
Bottom 50%	0.98	0.10	-0.2

- Better fit for most of the distribution.
- However, predicted top 1% share decreases
  $\Longrightarrow$ Model "needs" volatility to get some households to draw apart!

Decreasing Relative Risk Aversion

What if richer households "can afford to take more risk"?

Two opposing forces come to play

- Risk averse households are less willing to hold risky assets
- Risk aversion increases savings which increases wealth and thus participation rates

Two easy ways to incorporate this:

1. Exogenous preference heterogeneity

$$u^i(c_t) = \frac{c_t^{1-\gamma_i}}{1-\gamma_i}$$

2. Preferences with decreasing RRA (e.g. Stone-Geary utility)

$$u(c_t) = \frac{(c_t - \bar{c})^{1-\gamma}}{1-\gamma},$$

Decreasing Relative Risk Aversion

I solve both extensions separately by assuming "unemployed" are more risk averse, e.g. $(\gamma_1, \gamma_2) = (1.5, 2.5)$ and calibrate $\bar{c}$ following Achury et al. (2012)

Measure	Data	Baseline Model	Pref. Heterogeneity	Stone-Geary
Top 1%	37.5	22.2	23.0	20.3
Top 5%	64.6	49.6	49.4	47.3
Top 10%	77.8	66.1	65.7	63.8
Middle 40%	19.5	33.8	33.9	34.7
Bottom 50%	0.98	0.10	0.5	1.5

- Results remain overall unchanged $\longrightarrow$ Both forces offset each other
- Very stylized examples, e.g. IES $= 1/$RRA