The dynamics of stock market participation

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Theories of stock market participation

- Standard portfolio choice models predict that all individuals should participate in the stock market.
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- ...yet empirically, we see participation rates far below 100%
  - Explanations: participation costs, non-standard preferences, income risks, cultural/social influences, experience effects

Much less is known about the dynamics of stock market participation

Are the set of participants and non-participants the same over time?

If transitions exist, are they one-way?

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What can we learn about theories of stock market participation by looking at dynamics?
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What can we learn about theories of stock market participation by looking at dynamics?
Preview of results: short, multiple spells are common

New empirical facts:

Short:
1. Almost 1 of all spells are short spells (1-2 years)
   More common for low financial literacy groups

Multiple:
3. Re-entry is common, particularly for high financial literacy groups
4. Re-entry typically happens very soon after exit, often 1 year later
5. As time spent out of the market increases, the re-entry likelihood falls

Model:
1. Propose a theory of participation whereby investors learn about their ability using experienced returns but suffer from imperfect memory

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**Model:**
1. Propose a theory of participation whereby investors learn about their ability using experienced returns but suffer from imperfect memory
Data

- Norwegian administrative tax records (annual from 1993-2018)
  - Contains wealth information by broad asset class as of Dec 31st
    - Financial wealth: deposits & cash, directly-held listed stocks, directly-held unlisted stocks (private equity), stock mutual funds, money market funds, financial wealth held abroad, other
    - Real wealth: housing, other

Advantages:
1. Very low measurement error due to third-party reporting
2. Long time dimension (26 years)
3. Covers the whole population in every year (97m observations) and no non-random attrition
4. Can link to other administrative datasets

Drawbacks:
1. Occupational and public pension wealth information not available

An individual participates if they hold a positive amount of wealth in directly-held listed stocks or stock mutual funds, or hold wealth abroad

Data requirements
- Summary statistics
- Participation rate time series
- Entry/exit rate time series

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Fact 1: short spells are common

- Approximately 15% of spells end in 1 year and 23% end within 2 years
Fact 1: determinants of short spells

- Is there heterogeneity in the prevalence of short spells?
- Estimate the following linear probability model:

\[
\Pr(\text{spell ends within 2 years}) = \alpha_i + \delta_t + \beta'X_{it} + \epsilon_{it}
\]

where \( i \) is an individual who enters at time \( t \)

- \( X_{it} \) is a vector of observable characteristics measured at the point of entry
  - College degree, homeowner, unemployed, single, enter into directly-held stocks, age group FE\( s \), income decile FE\( s \), wealth decile FE\( s \)
### Fact 1: determinants of short spells

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Estimate (SE)</th>
<th>Estimate (SE)</th>
</tr>
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<tr>
<td>Male</td>
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<td></td>
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<tr>
<td></td>
<td>(0.001)</td>
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<td>College degree</td>
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<td>-0.023***</td>
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<td></td>
<td>(0.001)</td>
<td>(0.004)</td>
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<td>-0.009**</td>
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<td>(0.003)</td>
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<td>Unemployed</td>
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<td>(0.003)</td>
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<td>Directly-held stocks</td>
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<td>Yes</td>
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<tr>
<td>Age group FE</td>
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<td>Yes</td>
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<td>Income &amp; wealth decile FEs</td>
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<td>Yes</td>
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<td>Observations</td>
<td>2242427</td>
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<td>R-squared</td>
<td>0.04</td>
<td>0.47</td>
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</tbody>
</table>
Fact 1: determinants of short spells

Figure: Income

Figure: Wealth
Fact 2: exit rate falls with spell duration

- Are investors more likely to exit soon after entry or after staying in the market for a prolonged period?
Fact 2: exit rate falls with spell duration

- Are investors more likely to exit soon after entry or after staying in the market for a prolonged period?
- Hazard function $h(d)$ gives the probability of exiting $d$ years after entry conditional on not exiting until then.
- Standard challenge with hazard function estimation: separating true duration dependence from (unobserved) heterogeneity.
Fact 2: exit rate falls with spell duration

- Are investors more likely to exit soon after entry or after staying in the market for a prolonged period?
- Hazard function $h(d)$ gives the probability of exiting $d$ years after entry conditional on not exiting until then.
- Standard challenge with hazard function estimation: separating true duration dependence from (unobserved) heterogeneity.
- Exploit multiple spells and apply the GMM estimator of Alvarez et al. (2021).

Assume $h_i(d) = \theta_i b_d$ for $d \in \{D, ..., \bar{D}\}$

- Can identify $b$ up to a multiplicative constant.
- Based on discrete time identification results.
- No assumptions on the frailty distribution.
- Consistent under large $N$ and allows for a short time dimension.
Fact 2: exit rate falls with spell duration

- The longer you have been participating, the lower is the probability of exiting.
Fact 3: re-entry does occur

Figure: All individuals

Figure: Have at least 1 spell
Fact 3: determinants of re-entry

**Figure: Income**

**Figure: Wealth**
Fact 4: re-entry occurs soon after exit
Fact 5: re-entry rate falls with exit duration

- The longer it has been since your exit, the lower is the probability of re-entry
- Hazard rate effectively zero by 10 years after exit
Can standard models generate these dynamics?

- Basic unconstrained model à la Merton (1969) predicts full participation (no dynamics)
- Four broad classes of explanations for underparticipation:
  1. Non-standard preferences
  2. Participation costs
  3. Risks faced by households
  4. Cultural and social environment
- Other candidate explanations
  1. Liquidity shocks
  2. Sophisticated market timing
  3. Pensions
  4. Tax optimisation
Three characteristics of human behaviour

1. Heterogeneous abilities in the stock market
   - Some individuals achieve persistently higher returns
   - Bach et al. (2020) and Fagereng et al. (2020) provide empirical support
   - Positive correlation between financial literacy and returns (Gaudecker (2015); Bianchi (2018); Deuflhard et al. (2018))
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2. Learning about ability
   - Stock market is a complex environment and it is difficult to know how you will perform
   - Seru et al. (2010) and Linnainmaa (2011) find empirical support for learning about ex-ante ability using Finnish transaction-level data
   - Relates to literature on experience effects (Malmendier and Nagel (2011, 2015))
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     (Malmendier and Nagel (2011, 2015))

3. Imperfect memory
   - Memories are costly to store
     (Poldrack and Foerde (2008); Brocas and Carrillo (2016))
   - Azeredo da Silveira et al. (2020) show that it is optimal for individuals to recall a single summary statistic of past experiences
Model overview

- Individuals can invest in a risk-free bond with return $r_s$ and a risky financial asset with return $r_{it}$
- **Characteristic 1:** two ability types $a_i \in \{l, h\}$
  - Individuals do not know their own ability
  - $r_{it} | a_i = a \sim N(\mu_a, \sigma^2)$ with $\mu_h > r_s > \mu_l$
- **Characteristic 2:** use experienced returns and Bayes rule to update beliefs of own ability
- **Characteristic 3:** individuals recall the average of their experienced return with noise
  - An individual $i$ at time $t$ who participated for $s \leq t$ years recalls:
    $$m_{it} = \frac{1}{s} \sum_{q=1}^{t} r_{iq} \cdot 1(\text{part}_{iq} = 1) + \epsilon_{it}$$
Short spells occur due to drawing poor returns and inferring low ability
Model simulations: hazard rates for exit

Those remaining after many years must be confident in their ability
Multiple spells occur due to noisy memory
Quick re-entry occurs as most of those who re-enter did moderately badly and need only a small positive recollection to re-enter.
Those who are still “out” after many years likely had poor past returns and require an unlikely strong positive recollection to re-enter.
Conclusion

- Uncovers 5 new empirical facts on the dynamics of stock market participation using Norwegian administrative data
  1. About $\frac{1}{4}$ of spells last $\leq 2$ years
  2. Downward-sloping hazard function for exit from participation
  3. Re-entry is common
  4. Re-entry, if it occurs, often happens soon after exit
  5. Downward-sloping hazard function for re-entry
- Consistent with a participation model of learning about ability with imperfect memory
- Avenues for future research
  1. Are these behaviours present in other countries?
  2. How does the nature of portfolios change across spells?
  3. Testing imperfect memory in the context of financial markets
  4. Intensive margin
  5. Aggregate implications of short spells and re-entry
Roadmap of the paper

1. Uncover five new empirical facts on the dynamics of participation using Norwegian administrative data
2. Are standard models of participation consistent with these facts?
3. Which established features of human behaviour are consistent with these dynamics?
Connection to the literature

**Stock market entry and exit:** Poterba and Samwick (1997); Hurst et al. (1998); Vissing-Jørgensen (2002, 2003); Ameriks and Zeldes (2004); Fagereng et al. (2017); Bonaparte et al. (2021); Brandsaaas (2021)

**Learning and experience effects:** Seru et al. (2010); Linnainmaa (2011); Malmendier and Nagel (2011, 2015)

**Heterogeneous beliefs and returns:** Dominitz and Manski (2011); Hudomiet et al. (2011); Hurd et al. (2011); Bach et al. (2020); Fagereng et al. (2020)

**(Imperfect) memory:** Averell and Heathcote (2009, 2011); Brocas and Carrillo (2016); Azeredo da Silveira et al. (2020)
Data requirements for studying dynamics

1. Reliable and accurate data on wealth holdings at the individual level
   - Surveys can have measurement error
   - Brokerage data only gives holdings with one brokerage firm and sample may not be representative
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3. Long time dimension with sufficiently narrow time intervals
   - Survey waves can be multiple years apart
   - Commonly-used brokerage and administrative datasets often have short time dimensions
## Summary statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. dev</th>
<th>P10</th>
<th>Median</th>
<th>P90</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (in years)</td>
<td>48.48</td>
<td>18.41</td>
<td>25.00</td>
<td>46.00</td>
<td>75.00</td>
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<tr>
<td>Male</td>
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<td>0.50</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
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<tr>
<td>Single</td>
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<td>0.48</td>
<td>0.00</td>
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<tr>
<td>College degree</td>
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<td>0.45</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td><strong>Income and wealth (2011 $’000s)</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Gross income</td>
<td>42.52</td>
<td>55.75</td>
<td>0.00</td>
<td>37.02</td>
<td>93.35</td>
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<tr>
<td>Financial wealth</td>
<td>64.46</td>
<td>1,576.90</td>
<td>0.05</td>
<td>9.98</td>
<td>110.60</td>
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<tr>
<td>Financial wealth in public equity</td>
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<td>351.36</td>
<td>0.00</td>
<td>0.00</td>
<td>8.08</td>
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<tr>
<td>Non-financial wealth</td>
<td>153.21</td>
<td>272.87</td>
<td>0.00</td>
<td>67.67</td>
<td>406.08</td>
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<tr>
<td>Gross wealth</td>
<td>217.67</td>
<td>1,651.38</td>
<td>0.29</td>
<td>105.75</td>
<td>495.22</td>
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<tr>
<td>Net wealth</td>
<td>209.40</td>
<td>1,854.63</td>
<td>0.80</td>
<td>99.09</td>
<td>457.76</td>
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<td><strong>Participation and wealth shares</strong></td>
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<tr>
<td>Participates in public equity</td>
<td>0.26</td>
<td>0.44</td>
<td>0.00</td>
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<td>1.00</td>
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<td>Participates in mutual funds</td>
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<td>0.40</td>
<td>0.00</td>
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<tr>
<td>Participates in indiv. stocks</td>
<td>0.10</td>
<td>0.30</td>
<td>0.00</td>
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<td>0.00</td>
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<tr>
<td>Public eq. share (of gross wealth)</td>
<td>3.03</td>
<td>11.08</td>
<td>0.00</td>
<td>0.00</td>
<td>6.08</td>
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<td>Public eq. share (of fin. wealth)</td>
<td>7.97</td>
<td>19.57</td>
<td>0.00</td>
<td>0.00</td>
<td>30.93</td>
</tr>
</tbody>
</table>

Observations 97189499
Participation rate over time

- Participation accelerates in the 1990s (dot-com bubble, rise of mutual funds, improved financial access for retail investors)
- Steady decline since 2001
Entry and exit rates over time

- Entry rate has fallen by half from 5% in 2000 to 2.5% in 2018.
A concern could be that short spellers or re-entry can be due to gifts or inheritances of stocks that are quickly sold. While the exact contents of such gifts are not observed, we run 3 robustness checks that aim to deal with these concerns. We exclude individuals who:

1. Receive a gift or inheritance above 10,000 NOK (≈ $1670 in 2011 USD) in the year of or before entry
2. Experienced the death of a parent or grandparent in the year of or before entry
3. Had a parent or grandparent participating in the year of or before entry
Fact 1: short spells are common (household-level)
Fact 1: short spells are common (account for censoring)
Fact 1: short spells are common (no gift over 10,000 NOK)
Fact 1: short spells are common (no (grand)parent death)
Fact 1: short spells are common (no participating (grand)parent)
Fact 1: short spells are common (no employee stocks)
Fact 1: short spells are common (drop small participants)

**Figure:** Invest > $100

**Figure:** Invest > $1000
Fact 1: Short spells are common (by characteristics)

- Income
- Wealth
- Education
- Gender
- Asset class
Fact 1: short spells are common (by income)
Fact 1: short spells are common (by wealth)
Fact 1: short spells are common (by college education)
Fact 1: short spells are common (by gender)
Fact 1: short spells are common (by asset class)

The graph shows the distribution of the length of spells by asset class. The x-axis represents the length of spells in years, ranging from 0 to right censored. The y-axis represents the fraction of spells, normalized to sum to 1. The bars are colored to differentiate between Funds (red) and Stocks (green). The graph indicates that the majority of spells are short, with a significant portion of spells lasting for less than 5 years. The length of spells increases with asset class, with Stocks showing a longer distribution compared to Funds.
Fact 1: determinants of short spells (age)

![Graph showing the impact of age on the probability of a short spell (<=2 years).]

- **Impact on probability of a short spell (<=2 years)**
  - Age group at point of entry:
    - 20−29
    - 30−39
    - 40−49
    - 50−59
    - 60−69
    - 70+

**Without FEs**

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Fact 1: determinants of short spells (age) - exc. individual FEs

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The dynamics of stock market participation

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The dynamics of stock market participation
Fact 1: determinants of short spells (exc. individual FEs)

Impact on probability of a short spell (<=2 years)

Income decile at point of entry

Wealth decile at point of entry

Figure: Income

Figure: Wealth
Fact 2: details on Alvarez et al. (2021) GMM estimator

The Alvarez et al. (2021) GMM estimator uses the following environment:

- Proportional hazards data generating process for durations $d \in \{\bar{D}, ..., \bar{D}\}$ where $h_i(d) = \theta_i b_d$
- Individual $i$ experiences $K^i$ spells of measured duration $\zeta^i = \{\zeta^i_0, \zeta^i_1, ..., \zeta^i_K\}$
- Spells $\zeta = (\zeta_0, \zeta_1, ..., \zeta_K)$ are drawn from a proportional hazards model with a baseline hazard $b_0$

Defining

$$f_{d_1,d_2}^{[b]}(\zeta; b) \equiv \sum_{(j,k): 1 \leq j \leq k \leq K} (b_{d_2} 1_{\zeta_j = d_1, \zeta_k \geq d_2} - b_{d_1} 1_{\zeta_j = d_2, \zeta_k \geq d_1})$$

then $E[f_{t_1,t_2}^{[b]}] = 0 \forall \bar{D} \leq d_1 < d_2 \leq \bar{D}$ iff $b = \lambda b_0$ for some $\lambda > 0$. To estimate $b_0$, use two-step GMM:

$$\hat{b}_0 = \arg \min_b \left( \frac{1}{N} \sum_{i=1}^{N} f_{d_1,d_2}^{[b]}(\zeta^i; b) \right)^T W \left( \frac{1}{N} \sum_{i=1}^{N} f_{d_1,d_2}^{[b]}(\zeta^i; b) \right)$$
Fact 3: determinants of re-entry

- Are certain characteristics associated with re-entry?
- Estimate the following linear probability model:

  \[ Pr(\text{re-enter within 4 years}) = \alpha_i + \delta_t + \beta'X_{it} + \epsilon_{it} \]

  where \( i \) is an individual who exits the market in year \( t \)
  
  \( X_{it} \) contains observable characteristics measured at the point of exit
  - College degree, homeowner, unemployed, single, age group FEs, income decile FEs, wealth decile FEs
Fact 3: determinants of re-entry

<table>
<thead>
<tr>
<th></th>
<th>Re-entry in 4y</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>0.037***</td>
<td>(0.001)</td>
</tr>
<tr>
<td>College degree</td>
<td>0.030***</td>
<td>0.011</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.007)</td>
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<td>-0.022***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>Unemployed</td>
<td>-0.005**</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>Single</td>
<td>-0.028***</td>
<td>-0.056***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Sample mean</td>
<td>0.35</td>
<td>0.59</td>
</tr>
<tr>
<td>Individual FE</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Exit year FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Age group FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Income &amp; wealth decile FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>1436019</td>
<td>518995</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.14</td>
<td>0.54</td>
</tr>
</tbody>
</table>
Fact 3: determinants of re-entry (exc. individual FE)
Fact 3: determinants of re-entry (age)

The diagram illustrates the impact on the probability of re-entering within 4 years based on the age group at the point of exit. The x-axis represents the age groups from 20-29 to 70+, while the y-axis shows the impact on probability. The data points indicate a trend where younger age groups have a higher negative impact on the probability of re-entering within 4 years compared to older age groups.
Fact 3: determinants of re-entry (age) - exc. individual FEs

Impact on probability of re-entering within 4 years

Age group at point of exit

-15 -1 -0.5 0 0.5 1

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The dynamics of stock market participation
Fact 4: re-entry occurs soon after exit (no employee stocks)
Fact 4: re-entry occurs soon after exit (no gift over 10,000 NOK)
Fact 4: re-entry occurs soon after exit (no (grand)parent death)
Fact 4: re-entry occurs soon after exit (no participating (grand)parent)
First-order risk aversion can make zero stockholding an optimal outcome (Segal and Spivak (1990))

To generate dynamics, we require time-varying preferences:
- Cannot simply be changes in coefficient of relative risk aversion
- Need to switch between orders of risk aversion

However, the standard view in economic models is that preferences are stable over time

Some empirical evidence that risk aversion isn’t necessarily fixed over time:
- Age effects (Dohmen et al. (2017))
- Effects of economic crises (Dohmen et al. (2016); Guiso et al. (2018))
Fixed participation costs can reflect monetary, pecuniary or information costs (Vissing-Jørgensen (2002, 2003))

On-entry participation costs - no reason to leave after first entry

Per-period participation costs
  - Fluctuations in financial wealth can make such costs binding
    - ...but require very volatile process to get quick exit and re-entry
  - Hard to explain dynamics for high income/wealth groups
Impact of labour income risk on portfolio allocation depends on the nature of the risk:
- Riskless labour income $\Rightarrow$ invest more in stocks
- Risky labour income but uncorrelated with stock returns $\Rightarrow$ invest less in stocks
- Risky labour income and correlated with stock returns $\Rightarrow$ hedging component

To generate exit/entry, you need the correlation to change over time, not the level of wage risk alone

Hard to explain dynamics for high income/wealth groups
Cultural and social environment

- Cultural factors can influence beliefs and preferences, thus affecting economic outcomes (Guiso et al. (2006))
  - Empirical evidence showing a causal link from cultural factors to financial decisions (Haliassos et al. (2017))
  - ...but cultural factors tend to be slow moving ⇒ hard to explain high frequency entry and exit

Social interactions can affect investment decisions (Shiller et al. (1984))
Evidence suggests positive rather than negative experiences are shared (Kaustia and Knüpfer (2012))
Hard to rationalise the downward-sloping hazard functions
Complete exit vs. exit from a particular stock?
Cultural and social environment

- Cultural factors can influence beliefs and preferences, thus affecting economic outcomes (Guiso et al. (2006))
  - Empirical evidence showing a causal link from cultural factors to financial decisions (Haliassos et al. (2017))
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- Social interactions can affect investment decisions (Shiller et al. (1984))
  - Evidence suggests positive rather than negative experiences are shared (Kaustia and Knüpfers (2012))
  - Hard to rationalise the downward-sloping hazard functions
  - Complete exit vs. exit from a particular stock?
Consider 3 types of shocks: house purchase, divorce, unemployment

No difference in prevalence of liquidity shocks by spell length
Performance of exiters by spell length

**Figure:** Report only gains

**Figure:** Report only losses
Performance of exiters by spell length

Figure: Report gains

Figure: Report losses
In principle, exposure to the stock market through pensions could affect the optimal desired risky share out of non-retirement wealth.

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- **Public pension:** defined-benefit in nature and depends on income during working life.
- **Occupational pensions:**
  - Public sector occupational pensions are defined-benefit schemes.
  - Private sector occupational pensions: typically defined-contribution schemes, but only took off from 2006.
- **Private pensions:**
  - Low uptake in population and short spells robust to excluding these individuals.

---

Galaasen and Raja

The dynamics of stock market participation

EEA 2022
In principle, exposure to the stock market through pensions could affect the optimal desired risky share out of non-retirement wealth.

To explain dynamics, need 1) desired risky share out of total wealth changes and/or 2) exposure to stocks from pension wealth changes.

- Need individuals to rebalance using their non-retirement accounts.
- ...but papers have shown portfolio rebalancing is slow, both in retirement accounts and in general.

---

Galaasen and Raja

The dynamics of stock market participation

EEA 2022

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In principle, exposure to the stock market through pensions could affect the optimal desired risky share out of non-retirement wealth. To explain dynamics, need 1) desired risky share out of total wealth changes and/or 2) exposure to stocks from pension wealth changes. Need individuals to rebalance using their non-retirement accounts. ...but papers have shown portfolio rebalancing is slow, both in retirement accounts and in general.

3 pillars of Norwegian pension system:

1. Public pension: defined-benefit in nature and depends on income during working life.
2. Occupational pensions:
   - Public sector occupational pensions are defined-benefit schemes.
   - Private sector occupational pensions: typically defined-contribution schemes, but only took off from 2006.
3. Private pensions:
   - Low uptake in population and short spells robust to excluding these individuals.
Prevalence of short spells over time

The graph shows the proportion of entrants over time, categorized into different time periods: 1 year, <=2 years, and <=3 years. The x-axis represents the years from 1995 to 2015, while the y-axis represents the proportion of entrants.

The dynamics of stock market participation

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Participation in private pensions over time

The dynamics of stock market participation

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Fact 1: short spells are common (exclude private pension contributors)
Maybe individuals choose to exit to reduce their tax liabilities in a given year.

**Wealth tax**
- Individuals are taxed on net wealth above a given threshold
  - Most do not hit this threshold due to favourable valuation discounts for housing (tax value is 25% of market value)

**Capital gains tax**
- Gains above a risk-free return are taxed, while losses are tax deductible
- ...but taxation is linked to individual securities, not the overall portfolio
- To obtain complete exit, need all securities to be loss-making
Model setup: environment

- In each period $t \in \{1, \ldots, T\}$, $N_t$ new entrants enter the market for the first time.
- Individual $i$ can invest in a risk-free bond with return $r_s$ and a risky financial asset with idiosyncratic stochastic return $r_{it}$.
- Two ability types: high (h) and low (l)
  - A share $a_l$ of the $N_t$ entrants are low ability.
  - An individual of ability type $y \in \{l, h\}$ draws returns from a normal distribution with $r_{it|y} \sim N(\mu_y, \sigma^2)$
    - Assume iid draws conditional on type and $\mu_l < r_s < \mu_h$. 

Model setup: updating beliefs

- Individuals recall the average of their experienced return with noise.

- For an individual $i$ at time $t$ who participated for $s \leq t$ periods, their recollection of their experienced returns is given by:

$$m_{it} = \frac{1}{s} \sum_{q=1}^{t} r_{iq} \cdot 1(part_{iq} = 1) + \epsilon_{it}$$

where $\epsilon_{it} \sim (0, \sigma_{\epsilon}^2)$, $\epsilon_{it} \perp r_{iq} \forall (t, q)$

- Given normality assumptions:

$$m_{it|y} \sim N(\mu_y, \frac{\sigma^2}{s} + \sigma_{\epsilon}^2)$$
Model setup: participation decision

- Individuals do not know their true ability and update their beliefs of being low ability using Bayesian updating.

\[
b_{it} = \frac{a_l \exp \left[ -\frac{1}{2} \left( \frac{m_{it} - \mu_l}{\sqrt{\sigma_s^2 + \sigma_c^2}} \right)^2 \right]}{a_l \exp \left[ -\frac{1}{2} \left( \frac{m_{it} - \mu_l}{\sqrt{\sigma_s^2 + \sigma_c^2}} \right)^2 \right] + (1 - a_l) \exp \left[ -\frac{1}{2} \left( \frac{m_{it} - \mu_h}{\sqrt{\sigma_s^2 + \sigma_c^2}} \right)^2 \right]}
\]

- Expected return for individual \( i \) from investing in period \( t + 1 \) is:

\[
E_{i,t+1} = b_{it} \mu_l + (1 - b_{it}) \mu_h
\]

- Investors with “standard” preferences should participate in \( t + 1 \) as long as \( E_{i,t+1} > r_s \), i.e. participate iff

\[
b_{it} < \frac{\mu_h - r_s}{\mu_h - \mu_l}
\]

- Assume \( b_{i0} = a_l \) and \( a_l < \frac{\mu_h - r_s}{\mu_h - \mu_l} \)
Calibration

- Set $T = 25$ (match Norwegian sample period)
- Set $N_t$ equal to the number of entrants in the Norwegian data
- Set $r_s = 3.4\%$ (average 3-month Treasury bill rate in Norway)
- Use method of moments calibration for 5 remaining parameters, $\Theta$:

$$\hat{\Theta} = \arg\min_{\Theta} \sum_{j=1}^{5} \left( \frac{m_j(\Theta) - \hat{m}_j}{\hat{m}_j} \right)^2$$

- 2 external moments:
  - Average return from Fagereng et al. (2020)
  - Standard deviation of returns from Fagereng et al. (2020)

- 3 internal moments:
  - Average spell length across non-censored spells
  - Standard deviation of spell length across non-censored spells
  - Proportion of exiters re-entering within 4 years
## Calibration: parameter values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Method</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>$r_s$</td>
<td>Risk-free return</td>
<td>External</td>
<td>0.034</td>
</tr>
<tr>
<td>$\mu_h$</td>
<td>Mean return of high ability type</td>
<td>Internal</td>
<td>0.0656</td>
</tr>
<tr>
<td>$\mu_l$</td>
<td>Mean return of low ability type</td>
<td>Internal</td>
<td>0.0142</td>
</tr>
<tr>
<td>$a_l$</td>
<td>Share of low ability individuals</td>
<td>Internal</td>
<td>0.5055</td>
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<tr>
<td>$\sigma$</td>
<td>Standard deviation of returns</td>
<td>Internal</td>
<td>0.2459</td>
</tr>
<tr>
<td>$\sigma_\epsilon$</td>
<td>Standard deviation of memory noise</td>
<td>Internal</td>
<td>0.0100</td>
</tr>
</tbody>
</table>
Derivation of beliefs using Bayes rule

In a setting with discrete parameter values \( \theta \in \Theta \) and a continuous observation \( x \in X \), the Bayes rule formula is:

\[
P_{\Theta|X}(\theta|x) = \frac{P_{\Theta}(\theta) \cdot f_{X|\Theta}(x|\theta)}{f_X(x)}
\]

where \( f_X(x) = \sum_\theta P_{\Theta}(\theta) \cdot f_{X|\Theta}(x|\theta) \). In our setting, we have:

\[
b_{it} \equiv P(a_i = l|m_{it}) = \frac{P(a_i = l) \cdot f(m_{it}|a_i = l)}{f(m_{it})}
\]

where

\[
P(a_i = l) = a_l
\]

\[
f(m_{it}|a_i = l) = \frac{1}{\sqrt{2\pi(\frac{\sigma^2}{s} + \sigma^2_\epsilon)}} \exp\left[- \frac{1}{2} \left( \frac{m_{it} - \mu_l}{\sqrt{\frac{\sigma^2}{s} + \sigma^2_\epsilon}} \right)^2 \right]
\]

\[
f(m_{it}) = P(a_i = l) \cdot f(m_{it}|a_i = l) + P(a_i = h) \cdot f(m_{it}|a_i = h)
\]

\[
= a_l \frac{1}{\sqrt{2\pi(\frac{\sigma^2}{s} + \sigma^2_\epsilon)}} \exp\left[- \frac{1}{2} \left( \frac{m_{it} - \mu_l}{\sqrt{\frac{\sigma^2}{s} + \sigma^2_\epsilon}} \right)^2 \right]
\]

\[
+ (1 - a_l) \frac{1}{\sqrt{2\pi(\frac{\sigma^2}{s} + \sigma^2_\epsilon)}} \exp\left[- \frac{1}{2} \left( \frac{m_{it} - \mu_h}{\sqrt{\frac{\sigma^2}{s} + \sigma^2_\epsilon}} \right)^2 \right]
\]
Putting these terms all together, we get:

\[ b_{it} = \frac{a_l \exp \left[ - \frac{1}{2} \left( \frac{m_{it} - \mu_l}{\sqrt{\sigma^2_s + \sigma^2_\epsilon}} \right)^2 \right]}{a_l \exp \left[ - \frac{1}{2} \left( \frac{m_{it} - \mu_l}{\sqrt{\sigma^2_s + \sigma^2_\epsilon}} \right)^2 \right] + (1 - a_l) \exp \left[ - \frac{1}{2} \left( \frac{m_{it} - \mu_h}{\sqrt{\sigma^2_s + \sigma^2_\epsilon}} \right)^2 \right]} \]
Calibration: moments

<table>
<thead>
<tr>
<th>Moment</th>
<th>Data</th>
<th>Model</th>
</tr>
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<tbody>
<tr>
<td><strong>External moments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average return (Fagereng et al. (2020))</td>
<td>0.043</td>
<td>0.042</td>
</tr>
<tr>
<td>Std. dev of returns (Fagereng et al. (2020))</td>
<td>0.247</td>
<td>0.247</td>
</tr>
<tr>
<td><strong>Internal moments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average spell length (uncensored)</td>
<td>5.58</td>
<td>5.61</td>
</tr>
<tr>
<td>Std. dev of spell lengths (uncensored)</td>
<td>4.84</td>
<td>4.80</td>
</tr>
<tr>
<td>Re-entry within 4 years</td>
<td>0.33</td>
<td>0.33</td>
</tr>
</tbody>
</table>
Model simulations: short spells by ability type


References II


