Human-Robot Interactions in Investment Decisions

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Introduction

Robo-Advising

- Households are required to take complex financial decisions, and they are not always well equipped (Campbell 2006, Lusardi Mitchell 2014)
- Traditional financial advice has its limits (Beshears et al. 2018, Gomes et al. 2021)
- Increasing interest for financial advice based on automated procedures - robo-advisors (D'Acunto and Rossi 2021; Bianchi and Brière 2021)
  - Lower operating costs (minimal capital requirements, management fees), so possibly more inclusive
  - Accountable procedures (Philippon 2019)

Human-robo interactions

- Is the robo intended to replace or promote investors' judgment and actions?
  - Optimal degree of automation is not obvious
- Human-robo interactions can reduce algo aversion (Bianchi Brière 2021)
  - Can these interactions promote reliance on the robot? Even in response to shocks?
- Long-term effects of robo-advice
  - Promote learning and financial capability
- Having humans-in-the-loop may be harmful to performance
  - Ge et al. (2021) on peer-to-peer lending, Green and Chen (2019) on judges

This paper

- Robo-advisor introduced by a French asset manager on a large set of Employee Savings Plans
  - Robo builds the investor's profile, suggests a portfolio allocation, and sends alerts over time in case of deviations from the target
- Investors are the ultimate decision makers (as opposed to robo-managed accounts)
  - Focus on human-robo interaction: "intelligence augmentation" (IA) rather than AI, often about substitution
- Sample includes investors with small portfolios, little experience and typically no access to financial advising
  - Large debate on financial inclusion and financial inequalities
- Exploit knowledge of the robo rules and different sources of variation
  - Allows addressing self-selection issues

Main Results

- Increased attention after take up (complementarity)
- Increased trading and rebalancing activities
  - Reduced distance from target allocations (role of alerts)
- Increased portfolio returns
  - Mostly driven by improved rebalancing
  - Automatic rebalancing would improve only marginally

Related Literature

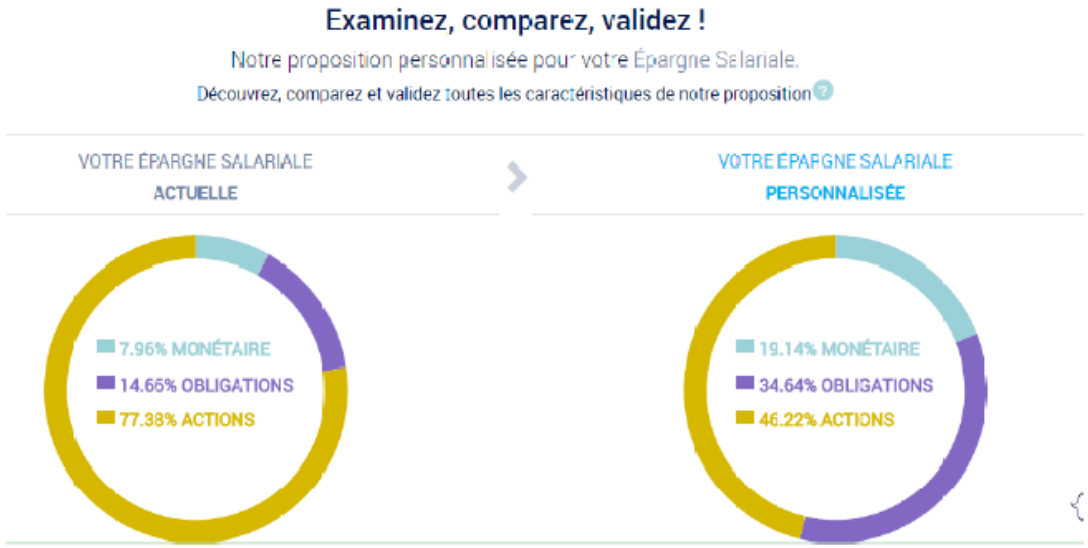
- Robo advising and financial decisions (D'Acunto and Rossi 2021; Bianchi and Brière 2021)
  - Focus on human-robo interactions and investors' choices over time, long term investment
- Automation and financial inclusion (Reher and Sokolinski 2021)
  - Small investors need not lose controls over their portfolios (key to promote learning and financial capability?)
- Asset returns and wealth inequality (Lusardi, Michaud and Mitchell 2017; Bach, Calvet and Sodini 2020, Fagereng, Guiso, Malacrino and Pistaferri 2020)
  - Automated advice may partly limit these patterns

Data

Data

- Employee Savings Plans
  - Each year, employees receive a sum of money that they allocate between a menu of funds proposed by their employer
  - Investment is locked in either for 5 years or until retirement, employees can increase their investment and rebalance their portfolio over time as they wish
- Robo treatment
  - Elicits information (risk-aversion, financial knowledge, horizon)
  - Proposes an allocation *within the current menu*, and if accepted implements it
  - Sends email alerts if current allocation is too far from proposed allocation

Quel épargnant êtes-vous ?
Vous avez un profil d'épargnant « Modéré » (résultat du questionnaire auquel vous avez répondu le 16/01/2018).
Continuez avec ce profil ou sélectionnez un profil moins risqué.
Prudent
Modéré
Équilibré
Dynamique
Audacieux
RETOUR
CONTINUER


Examinez, comparez, validez !
Notre proposition personnalisée pour votre Épargne Salariale.
Découvrez, comparez et validez toutes les caractéristiques de notre proposition
VOTRE ÉPARGNE SALARIALE
ACTUELLE
7.96% MONÉTAIRE
14.65% OBLIGATIONS
77.38% ACTIONS
VOTRE ÉPARGNE SALARIALE
PERSONNALISÉE
19.14% MONÉTAIRE
34.64% OBLIGATIONS
46.22% ACTIONS

JJ/MM/20AA

Alerte sur votre épargne personnalisée

Bonjour [champ Prénom] [champ Nom],

Dans le cadre du service « personnaliser mon épargne », nous vérifions tous les jours l'adéquation entre notre recommandation personnalisée, et la répartition de votre épargne [Nom dispositif].

Nous constatons aujourd'hui un décalage suite, par exemple à une opération (versement, remboursement, arbitrage), ou à une modification de l'environnement économique et financier.

Rendez-vous dans **votre espace personnel du site [nom du site]** pour mettre à jour votre épargne personnalisée.

Nous vous remercions pour la confiance que vous accordez à [redacted]

[redacted]

Votre correspondant
Service Clients

Data

- Robo is proposed to *employers* from August 2017
  - Monthly data from Sept 2016 to June 2021
- Sample: all takers as of November 2018 (14,576 - out of 1.2M exposed) and a random sample of 20,000 non takers, 20,000 non exposed, 20,000 curious
  - Account level data (portfolio choices, returns, risk) + digital footprints (connections) + robo data (profile, proposed allocation)

Basic Specification

- OLS:

$$y_{i,t} = \alpha_i + \beta T_{i,t} + X'_{i,t}\gamma + \mu_t + \varepsilon_{i,t}, \quad (1)$$

  - α_i and μ_t are contract and time fixed effects
  - $T_{i,t} = 1$ if the robo is adopted in contract i in period t
  - $X_{i,t}$ individual and portfolio characteristics (past risky share, past returns, account value, ...)
  - standard errors are clustered by individual and time
  - control group are individuals not exposed to the robo (unless specified otherwise)
  - similarly, for regressions at the individual level

Attention and Trading

Attention and Trading

Table: Investors' Attention and Trading

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable	Number of Connexions			Changes	Robo(>t)	Individual
Robo treated*after	0.299***	0.266**	0.138**	0.0904***	0.0437***	0.00542
	(0.0898)	(0.0984)	(0.0523)	(0.0161)	(0.00368)	(0.00364)
Sample		No rem	No Sub			
Observations	808,816	659,537	799,002	3,835,642	3,835,642	3,835,642
R-squared (within)	0.01	0.01	0.01	0.01	0.01	0.01

NOTE: This table reports the results of OLS regressions. In columns 1-3, the dependent variable is the number of connections per month. In column 2, we exclude the month before and the month at which the individual has received the variable remuneration. In column 3, the sample excludes the two months around the robo-subscription. In column 4, the dependent variable is the number of allocation changes per month; in columns 5-6, the dependent variable is the number of allocation changes suggested by the robot and directly chosen by the individual, respectively. Columns 1-3 include individual and time fixed effects, columns 4-6 include contract and time fixed effects. Controls include the average equity share and the average returns over the past 12 months, the account value in the previous month, the value of the yearly variable remuneration. Standard errors, double-clustered by individual and time, are in parenthesis. *, ** and *** denotes significance at 10%, 5% and 1% level, respectively.

Rebalancing

- Robo service sends alerts to investors when current allocation is far from the target (defined at the time of subscription or latest profiling).
- How do investors respond to those alerts?
  - Are alerts effective to get investors stay closer to the target? (typical problem for less sophisticated investors, Bianchi 2018)
  - Indirect evidence on whether trust in the robo persists after having experienced the service, and after relatively large shocks
- DiD on robo takers vs. robo curious (for whom we can construct counterfactual alerts)

Rebalancing

Table: Alerts and Rebalancing

	(1)	(2)	(3)	(4)	(5)
Dep. Variable	Connexions	Rebalancer	Change in Distance Actual - Target Equity		
Robo treated*Alert	0.188***	0.284***	-0.0407***		
	(0.0599)	(0.0567)	(0.00236)		
Alert	0.298***	0.134***	0.0350***	-0.00613***	
	(0.0855)	(0.0154)	(0.00292)	(0.00144)	
Alert MIF					0.00124*
					(0.000721)
Sample		Robo takers+curious		Robo takers	
Observations	128,774	1,865,018	1,865,018	679,577	614,292
R-squared (within)	0.01	0.1	0.01	0.01	0.01

NOTE: This table reports the results of OLS regressions. In column 1, the dependent variable is the number of connections per month. In column 2, the dependent variable is a dummy equal to one if the investor rebalances the portfolio in month t. In columns 3-5, the dependent variable is the change in the distance between the actual and the target equity share between t+1 and t-1. In columns 1-3, the sample is restricted to robo-takers and robo-curious. Alert is a dummy equal to one if the distance between the actual and the target allocation is above the alert threshold, and to zero otherwise. For robo-takers, the target allocation is the one proposed by the robot; for robo-curious, it is the one held at the time of the completion of the robo-survey. In columns 4-5, the sample is restricted to robo-takers. Alert MIF is a dummy equal to one if the investor receives an alert as they have not completed the profiling survey requested by the regulator. All regressions include time and contract fixed effects.

Alerts

- Alerts increase investors' attention (0.23 vs. 0.11 connections per month)
- Alerts increase the probability of rebalancing (28% vs. 13%)
- Alerts induce robo takers to decrease their distance from the target by 4% more than robo curious
  - Conditionally on being alerted, the average distance is 11%
  - Effect of the MIF alert is very small (placebo)

Returns

Returns

- Realized Returns
- Expected Returns (as in Reher Sokolinski 2021)
  - 5-factors model: 3 equity factors (Fama-French's market, size, value), 2 fixed-income factors (Barclays' U.S. and Global Bond Index, taken from Bloomberg)
  - Risk-free rate: one-month Treasury yield (also used for money market funds)
  - β^f computed on the longest possible time-series, from 1990, when our fixed-income factor become available, to 2021, the end of our sample
  - Time-varying expected returns: $R_t(x) = \sum_f \beta^f(x) R_t^f$

Returns

Table: Returns

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable		Realized Return			Expected Return	
Robo treated*after	0.0421***	0.0371***	0.0433***	0.0486***	0.0285***	0.0215***
	(0.00789)	(0.00778)	(0.00791)	(0.00110)	(0.00446)	(0.00446)
Equity share		0.0892***				0.125***
		(0.00764)				(0.00687)
Volatility			0.0484***			
			(0.00224)			
Beta				0.0159***		
				(0.00155)		
Observations	3,279,169	3,279,169	3,279,169	2,804,489	3,275,769	3,275,769
R-squared (within)	0.01	0.01	0.06	0.05	0.01	0.03

NOTE: This table reports the results of OLS regressions. In columns 1-4, the dependent variable is the annual returns at the contract level. In columns 5-6, the dependent variable is the expected annual returns at the contract level. All regressions include contract and time fixed effects. Controls include the account value in the previous month, the value of the yearly variable remuneration, a dummy if the variable remuneration was received in the current month and a dummy if the variable remuneration was received in the past month. Standard errors, double-clustered by individual and time, are in parenthesis. *, ** and *** denotes significance at 10%, 5% and 1% level, respectively.

Returns

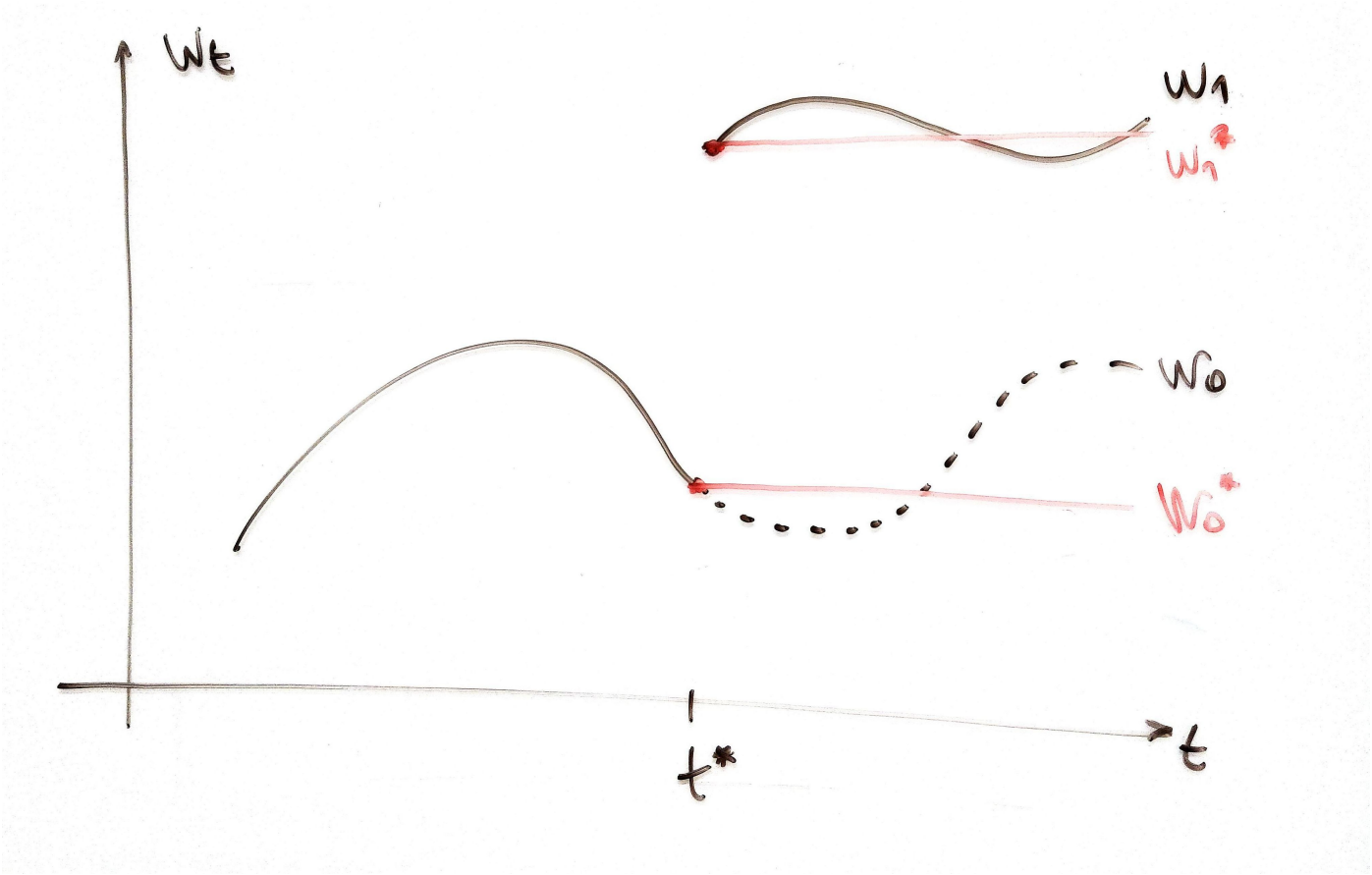
- Estimated effects are large
- For an average investor (38k euros in the plan, 17 years horizon), increase in yearly returns by 4.2% (2.8%) = increase in final wealth by 38k (23k) euros
- For robo-takers, the fee is on average equal to 0.04% of the portfolio.

Static vs. Dynamic Effects on Returns

- Total change in returns results from a static effect occurring at subscription (due to the allocation change) and a dynamic effect occurring after subscription (due to different portfolio rebalancing)
  - Both effects can be important, but difficult to estimate
  - Exploit the knowledge of the robo algorithm, which intends to induce constant weights

- Denote with t^* the date of subscription, $\omega_1(s,t)$ the observed portfolio weight on asset s at the beginning of $t \geq t^*$, observed returns are $R_1(t) = \sum_s \omega_1(s,t-1)R(s,t)$ and counterfactual returns without the robo are $R_0(t) = \sum_s \omega_0(s,t-1)R(s,t)$
  - Previous estimates: $R_1(t) - R_0(t) = 4.2\%$.

Figure: Static vs. Dynamic Effects on Returns



Static vs. Dynamic Effects on Returns

- Define $C_0(t) = \sum_s \omega_0(s, t^* - 1) R(s, t)$
  - constant weights, those observed just before the robo take-up

- If the robo took weights as given and just changed rebalancing, we would only have a dynamic effect

$$D(t) = C_0(t) - R_0(t).$$

- Static effect is the residual

$$S(t) = R_1(t) - R_0(t) - D(t) = R_1(t) - C_0(t).$$

Table: Returns: Static vs. Dynamic Effect

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable		Static (Realized)			Static (Expected)	
Robo treated*after	0.0132***	0.00879***	0.0134***	0.0134***	0.0110***	0.00425**
	(0.000433)	(0.000415)	(0.000432)	(0.000458)	(0.00172)	(0.00192)
Equity share		0.0795***				0.122***
		(0.00128)				(0.0127)
Volatility			0.0101***			
			(0.000763)			
Beta				0.00275***		
				(0.000247)		
Observations	3,279,169	3,279,169	3,279,169	2,804,489	3,275,769	3,275,769
R-squared (within)	0.01	0.01	0.01	0.01	0.01	0.06

NOTE: This table reports the results of OLS regressions decomposing the total change in returns associated to the robo-service between a static effect occurring at the time of the subscription and a dynamic effect associated to different portfolio dynamics after the subscription. For robo-takers, define t* as the date of robo-subscription and, for non-exposed, as the date of first reception of the variable remuneration. In columns 1-4, the dependent variable is the static effect on annual returns, computed according to equation (4), which is the difference between the returns the investor has experienced after t* and those she would have experienced had she kept her portfolio weights constant at the level observed just before t*. In columns 5-6, the dependent variable is the same static effect, computed instead on expected returns. All regressions include contract and time fixed effects. Controls include the account value in the previous month, the value of the yearly variable remuneration, a dummy if the variable remuneration was received in the current month and a dummy if the variable remuneration was received in the past month. Standard errors, double-clustered by individual and time, are in parenthesis. *, ** and *** denotes significance at 10%, 5% and 1% level, respectively.

Automatic rebalancing

- Dynamic effect accounts for about 60-70% of total effect
  - Not too far from rebalancing premia observed in the mutual fund literature (Brandt and Denison 2014, Berk and Van Binsbergen 2015, Maeso and Martellini 2020)
- What if the robot could implement automatic rebalancing?
  - Evidence in other domains that humans-in-the-loop may be harmful for performance (Ge et al. 2021, Green and Chen 2019)
  - Compute counterfactual returns in case of immediate rebalancing upon reception of the alert and exactly as suggested by the robot

Table: Realized and Counterfactual Returns

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. Variable	Realized - Counterfactual Returns (in %)						
Robo rebalancing			0.229*		0.153**		0.120***
			(0.116)		(0.0721)		(0.0428)
Free rebalancing			-0.759		-0.434		0.0240
			(0.765)		(0.505)		(0.214)
Age		-0.0012					
		(0.0052)					
Female		0.0514					
		(0.0684)					
Account value (ln)		0.0142					
		(0.0223)					
Var. remuneration (k)		-0.0024*					
		(0.0013)					
Constant	-0.0447***	0.00592	-0.0438***	-0.0756***	-0.0761***	-0.0888***	-0.0939***
	(0.0101)	(0.238)	(0.0102)	(0.0137)	(0.00619)	(0.0139)	(0.00293)
Horizon		1-month		3-months		6-months	
Contract FE	No	No	Yes	No	Yes	No	Yes
Observations	642,048	618,756	642,048	606,291	606,291	552,735	552,735
R-squared (within)	0.01	0.01	0.01	0.01	0.01	0.01	0.01

NOTE: The sample is restricted to robo-takers. The dependent variable is the difference in percentage points between the investor's annual returns and the counterfactual returns obtained by rebalancing the portfolio immediately upon reception of the alert as suggested by the robot.

Selection

Selection

- Previous analysis: address potential endogeneity of the take-up decision by exploiting discontinuities in the robo algorithm or by controlling for time-invariant individual-specific characteristics (while comparing takers to non-exposed)

- What if we vary the control group?
  - Compare takers to non-takers: conditional on exposure, effect of taking up the service
  - Compare takers to curious: conditional on expressing interest, effect of take up relative to observing profile and recommendation

- What if we look for shocks to take-up?
  - Instrument take-up by the fraction of takers in the same firm

Table: Control Groups

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. Variable	Connections		Trading		Returns		Static	
Robo treated*after	0.27**	0.29***	0.09***	0.09***	0.029***	0.029***	0.008***	0.007**
	(0.0974)	(0.0734)	(0.0181)	(0.0161)	(0.00469)	(0.00604)	(0.00174)	(0.00286)
Control group	Exposed	Curious	Exposed	Curious	Exposed	Curious	Exposed	Curious
Observations	831,846	879,065	3,676,837	4,768,327	3,184,405	4,129,632	3,184,405	4,129,632
R-squared (within)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

NOTE: This table reports the results of OLS regressions. In columns 1 and 2, the dependent variable is the number of connections per month; in columns 3 and 4, the dependent variable is the number of allocation changes per month; in columns 5 and 6, the dependents variable is the annual return; In columns 7 and 8, the dependent variable is the static effect as defined in equation (4). In columns 1,3,5 and 7, the control group are exposed individuals who did not take the robot. In columns 2,4,6 and 8, the control group are individuals who expressed interest but did not take the robot (robo-curious). In columns 1-2, we include individual and time fixed effects; in columns 3-8, we include contract and time fixed effects. Controls include the account value in the previous month, the value of the yearly variable remuneration, a dummy if the variable remuneration was received in the current month and a dummy if the variable remuneration was received in the past month. Standard errors, double-clustered by individual and time, are in parenthesis. *, ** and *** denotes significance at 10%, 5% and 1% level, respectively.

Table: IV Estimates

	(1)	(2)	(3)	(4)
Dep. Variable	Connexions	Trading	Returns	Static
Robo treated*after	0.153*	0.0666**	0.0630***	0.0369***
	(0.0840)	(0.0267)	(0.0150)	(0.00561)
		First Stage: Robo Treated		
Fraction of treated employees	12.992***	3.225***	3.084**	3.084**
	(2.0707)	(0.3299)	(0.3617)	(0.3617)
F-Stat (first stage)	39.37	95.55	72.7	72.7
Observations	28,917	3,822,677	3,267,180	3,267,180
R-squared (within)	0.012	0.006	0.008	0.002

NOTE: This table reports the results of 2SLS regressions in which the probability to adopt the robo-service is instrumented by the fraction of employees in the same firm who have taken-up the robot. In column 1, the dependent variable is the number of connections per month; in column 2, the dependent variable is the number of allocation changes per month; in column 3, the dependent variable is the annual return; In column 4, the dependent variable is the static effect as defined in equation (4). In column 1, we include individual and time fixed effects; in columns 2-4, we include contract and time fixed effects. Controls include the account value in the previous month, the value of the yearly variable remuneration, a dummy if the variable remuneration was received in the current month and a dummy if the variable remuneration was received in the past month. Standard errors, double-clustered by individual and time, are in parenthesis. *, ** and *** denotes significance at 10%, 5% and 1% level, respectively.

Selection

- When varying the control groups, results are similar to baseline estimates
  - Our estimates are mainly driven by changes in behaviors within the group of robo-takers
  - Effects depend on the adoption of the service, not just on the observation of the robo recommendation
- IV based on workplace adoption gives consistent results too

Discussion

Discussion

- Robo can improve financial decisions
- Importance of human/robo interactions (portfolio dynamics)
  - Possibly key for understanding long-term impacts
- Open questions
  - Effects in good and bad times? (Bianchi Brière ...)
  - "Simple" algorithms in financial services

Thank you.

Appendix

Descriptive Statistics

Table: Descriptive Statistics

Variable	p5	mean	p95	sd	N
Age	30.00	49.24	67.00	11.74	5,878,593
Female	0.00	0.31	1.00	0.46	5,860,982
Saving plan value	0.00	7,541	36,074	26,387	5,879,049
Total account value	0.00	37,764	155,248	76,579	5,879,049
Yearly variable remuneration	0.00	1,748	7,832	3,263	5,879,049
Nb of saving vehicles	1.00	4.71	12.00	3.57	5,879,049
Number of connexions per month	0.00	0.85	4.00	3.13	2,263,612
Equity share	0.00	0.19	0.84	0.28	3,799,350
Number of asset allocation changes	0.00	0.05	0.00	0.25	5,879,049
Number of asset allocation changes (robo)	0.00	0.01	0.00	0.08	5,879,049
Number of asset allocation changes (indiv)	0.00	0.01	0.00	0.12	5,879,049
Annual return (realized)	-0.18	0.04	0.29	0.16	3,300,663
Annual return (expected)	-0.01	0.08	0.30	0.12	3,299,682
Volatility	0.00	0.14	0.44	0.67	3,300,663
Beta	0.00	0.95	2.89	2.11	2,827,366

NOTE: This table reports descriptive statistics of our variables. Saving plan value refers to the single saving contract. Total account value is the aggregate across all contracts held by the same investor.

	(1)	(2)	(3)	(4)
Dep. Variable	Taker	Share	Taker	
Age	6.56e-05	0.000194	0.00269***	0.00272***
	(0.000107)	(0.000509)	(0.000668)	(0.000635)
Female	-0.00444**	-0.0204***	-0.0251*	-0.0251*
	(0.00209)	(0.00561)	(0.0142)	(0.0147)
Account value (ln)	0.000860	-0.0325***	-0.0187***	-0.0197***
	(0.00186)	(0.00378)	(0.00480)	(0.00519)
Equity share	0.0116	-0.0912**	-0.112***	0.0230
	(0.00812)	(0.0434)	(0.0279)	(0.0457)
Variable remuneration	2.80e-06***	-3.47e-06	-6.37e-06**	-8.06e-06**
	(9.91e-07)	(2.46e-06)	(3.11e-06)	(3.23e-06)
Returns	-0.126*	-2.132***	-0.196	-0.106
	(0.0711)	(0.420)	(0.753)	(0.680)
Connexions	0.00184	-0.00126	-0.00465***	-0.00429***
	(0.00112)	(0.00176)	(0.00155)	(0.00140)
Robo equity distance			0.154***	
			(0.0494)	
Robo equity change				0.160***
				(0.0400)
Sample	Takers + Exposed	Takers	Takers+Curious	
Mean Dep. Var.	0.02	0.74	0.07	0.07
Observations	27,616	13,676	7,746	7,746
R-squared	0.003	0.046	0.014	0.018
Number of Clusters	1,966	713	591	591

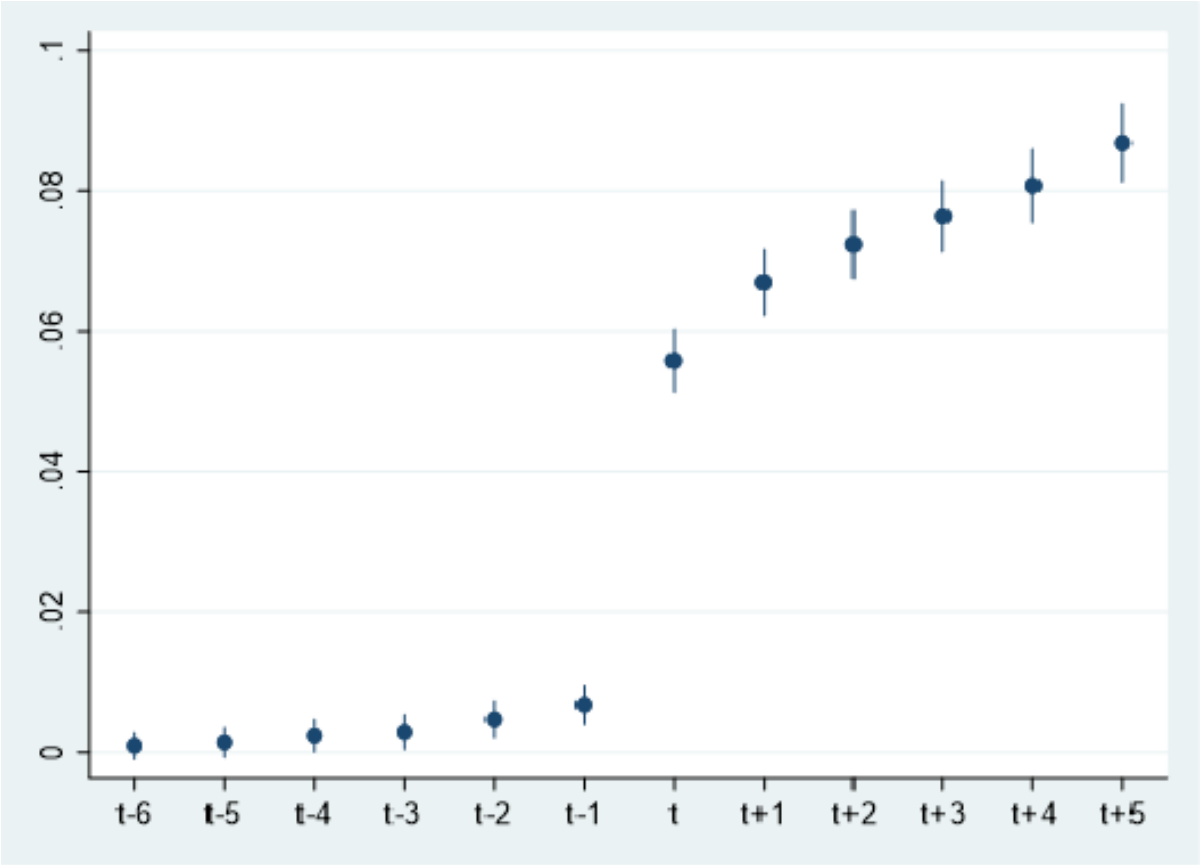
Equity Exposure

Table: Risk Taking

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable	Equity Sh.	Equity	Balanced	Employer	Bond	Money
Robo treated*after	0.0866***	0.0272***	0.228***	0.00234***	-0.155***	-0.0916***
	(0.00220)	(0.00183)	(0.00318)	(0.000721)	(0.00292)	(0.00250)
Observations	1,450,851	1,450,851	1,450,851	1,450,851	1,450,851	1,450,851
R-squared	0.069	0.010	0.199	0.005	0.118	0.058
N. of Clusters	34,398	34,398	34,398	34,398	34,398	34,398

NOTE: This table reports the results of OLS regressions at the saving account level. In column 1, the dependent variable is the equity share; in column 2, it is the portfolio weight in diversified equity funds; in column 3, it is the weight in balanced funds; in column 4, it is the weight in employer stock funds; in column 5, it is the weight in bond funds; in column 6, it is the weight in money market funds. All regressions include individual and time fixed effects. Controls include the average risky share and the average returns over the past 12 months, the account value in the previous month, the value of the yearly variable remuneration, a dummy if the variable remuneration was received in the current month and a dummy if the variable remuneration was received in the past month. Standard errors, clustered at the individual level, are in parenthesis. *, ** and *** denotes significance at 10%, 5% and 1% level, respectively.

Figure: Equity Exposure: Dynamics



NOTE: This figure displays how the changes in equity exposure differ between robo takers and non-takers, before and after the robo subscription. T-5/T-1 correspond to months before the treatment, T/T+5 correspond to months after the treatment. The points correspond to the estimated beta coefficients of equation (3), the bars correspond to 95% confidence intervals.

Financial Inclusion

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable		Equity Exposure			Annual return	
Robotreat*after*D<q25	0.133***	0.0557***	0.195***	0.0472***	0.0384***	0.0578***
	(0.00348)	(0.00751)	(0.00301)	(0.00153)	(0.00261)	(0.00148)
Robotreat*after*D(q25,q50)	0.0789***	0.127***	0.137***	0.0226***	0.0457***	0.0535***
	(0.00407)	(0.00316)	(0.00440)	(0.00185)	(0.00147)	(0.00132)
Robotreat*after*D(q50,q75)	0.0557***	0.0620***	0.0996***	0.0252***	0.0153***	0.0168***
	(0.00492)	(0.00439)	(0.00341)	(0.00215)	(0.00204)	(0.00197)
Robotreat*after*D>=q75	0.0270***	0.0480***	-0.0560***	0.0144***	0.0141***	-0.0512***
	(0.00600)	(0.00485)	(0.00502)	(0.00270)	(0.00225)	(0.00372)
Volatility				1.172***	1.171***	1.171***
				(0.0248)	(0.0249)	(0.0249)
D Variable	Assets	Remun	Risk	Assets	Remun	Return
Observations	1,450,851	1,450,851	1,450,851	1,365,421	1,365,421	1,365,421
R-squared	0.082	0.080	0.144	0.479	0.479	0.481
Number of Clusters	34,398	34,398	34,398	34,241	34,241	34,241

NOTE: This table reports the results of OLS regressions. In columns 1-3, the dependent variable is the equity share; in columns 4-6, the dependents variable is the annual return. The estimated coefficients refer to the interaction between the robo treatment and investor's quartile based on portfolio size, value of the variable remuneration, equity share, and returns. Quartiles are determined based on the average values observed before the first robo introduction (August 2017). All regressions include individual and time fixed effects. Controls include the account value in the previous month, the value of the yearly variable remuneration, a dummy if the variable remuneration was received in the current month and a dummy if the variable remuneration was received in the past month. Standard errors, clustered at the individual level, are in parenthesis. *, ** and *** denotes significance at 10%, 5% and 1% level, respectively.

Financial Inclusion

- Increase in equity exposure associated to the robo is larger for investors with smaller portfolio and smaller variable remuneration and lower baseline risk exposure
  - Q25 for portfolio size: 2176 euros, for equity share: 0.
- Increase in returns associated to the robo is larger for smaller investors (portfolio and remuneration value) and lower baseline returns
  - Q25 for returns: -0.01%
- Robo induces larger changes on smaller investors, those less likely to receive traditional advice and to participate to the stock market
  - Robo service can be an important instrument towards financial inclusion (possibly tempering wealth inequality)