Financial knowledge, fluid intelligence and investment decisions[1]

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Abstract

We combine insights from cognitive psychology and economics to distinguish knowledge from fluid intelligence and assess their role in households' financial decision making. Using a battery of financial knowledge questions and intelligence tests administered on two surveys, we show that financial knowledge is strongly associated with stockholding, and it is associated with more diversified household portfolios. The associations with financial knowledge remain strong controlling for fluid intelligence, while the associations with fluid intelligence diminish when financial knowledge is controlled. Neither fluid intelligence nor overall financial knowledge is associated with frequent active trading but knowing about the potential costs of such behavior seems to prevent it. Our results support the hypothesis that fluid intelligence acts as an input to the acquisition of financial knowledge. Research on financial literacy could benefit from distinguishing fluid and crystallized elements both for better measurement and for effective policy design.

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1 Introduction

Modern cognitive psychology recognizes the benefits to distinguish fluid intelligence (Gf) and crystallized intelligence (Gc) in classifying cognitive abilities. Fluid intelligence is thought to represent reasoning and thinking in novel situations, while crystallized intelligence is thought to represent acculturated knowledge, potentially as a result of individuals' investment into knowledge (Cattell, 1941, 1987; Horn and Cattel, 1967; Horn and McArdle, 2007; McArdle and Willis, 2011). There is a remarkable parallel between the theory of fluid and crystallized intelligence (Gf/Gc theory), and human capital theory. Just as remarkable, with a few notable exceptions, until recently economists were largely unaware of this theory while psychologists were equally ignorant of the theory of human capital in economics despite the fact that both theories began to be developed more than fifty years ago, have generated vast literatures and continue to be highly active fields of research.

In this paper we focus on the role of fluid intelligence and crystallized intelligence (knowledge) in household finances. Building on theoretical arguments first presented by Delavande, Rohwedder and Willis (2008) and later by Jappelli (2010), Jappelli and Padula (2011), Lusardi, Mihcaud and Mitchell (2013), we first present a simple model of investment in financial knowledge. Then, using a battery of financial knowledge questions and general intelligence tests administered on two independent surveys of the general U.S. population, we analyze correlations of financial decisions with financial knowledge and fluid intelligence.

Our theoretical argument highlights that financial knowledge is a form of human capital, acquired by investment. The costs of investment include cognitive effort. The benefits are higher expected wealth and lower risks due to better financial decisions. In general, the benefit of knowledge acquisition is proportional to total savings, while the cost is fixed, leading to increasing returns in volume of intended savings. Fluid intelligence, viewed as a trait by adulthood[2], affects the acquisition of financial knowledge through both its costs and benefits.

Our data has very detailed measures of fluid intelligence and a test of financial knowledge focusing on investments. Both of our two datasets have measures of diversification, and one contains high frequency observations on the trading behavior of households. Most of our results

[2] As we discuss later, after reaching adulthood fluid intelligence tends to decline throughout the rest of life. However, longitudinal analysis suggests that the ranking of individuals on fluid intelligence at the beginning of adulthood tends to remain stable over the remaining life cycle (McArdle, et. al., 2002). In this paper we assume that among adults, cross-sectional variations in the level of fluid intelligence (conditional on age) reflect differences in fluid intelligence that are pre-determined.

are remarkably similar in the two samples despite differences in age coverage and details of the fluid intelligence measures. We first show that the age profiles of our measures follow the patterns suggested by cognitive psychology: fluid intelligence declines with age throughout adulthood while crystallized financial knowledge increases in a concave fashion and starts declining only at old age. Then we look at four outcomes: stock market participation, diversification of stock portfolios, the frequency of active trading (actively buying and selling stock-market based assets at the same time twice a year or more frequently) and whether households remained stockholders during the financial crisis. We show that overall financial knowledge is strongly correlated with stock market participation, diversification and remaining stockholder during the crisis; these correlations remain strong after conditioning on fluid intelligence and other covariates, while the correlations with fluid intelligence are in general weaker and diminish considerably after conditioning on knowledge and other covariates. The frequency of active trading seems unrelated to both fluid intelligence and overall financial knowledge but specific knowledge of the potential costs of high frequency trading is associated with lower frequency.

Our paper has implications for studying financial literacy. Different papers on financial literacy (Lusardi and Mitchell, 2008; Guiso and Jappelli, 2009; Kimball and Shumway, 2010; van Rooij, Lusardi and Alessie, 2011) have defined their objects in different ways but most of them combine various abilities.[3] Correspondingly, these studies have used measures that typically combine answers to financial knowledge questions and performance on tasks involving numbers or math skills. Our results imply that it is important to distinguish between the different dimensions that make up financial literacy and keep them separate in empirical analyses (an argument made earlier by Hung, Parker and Yoong, 2009, too). Firstly, distinguishing the different dimensions will allow a deeper understanding of the mechanisms underlying the relationship between financial literacy and financial decision making. Secondly, in order to derive appropriate policy recommendations, we need to distinguish between components of financial literacy that more easily lend themselves to policy interventions (financial knowledge) compared to less malleable components (fluid intelligence).

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[3] The definition of financial literacy varies by source, but most include elements of knowledge and fluid intelligence. According to the G8 group, financial literacy is "the capacity to sufficiently understand financial market products, concepts and risks in order to make informed choices, to identify and avoid financial abuse, and to take other effective actions to improve well-being" (G8, 2006). According to another definition, formulated by The Investor Education Fund (IEF, 2012), "Financial literacy is the set of skills and knowledge that allow you to understand the financial principles you need to know to make informed financial decisions, and the financial products that impact your financial well-being."

Many studies have shown strong correlations between some measure of fluid intelligence on the one hand and stockholding and better investment strategies on the other hand (Banks and Oldfield, 2007; McArdle, Smith and Willis, 2009; Christelis, Jappelli and Padula, 2010; Grinblatt, Keloharju and Linnainmaa, 2011).[4] The correlation seems robust across countries and age groups, and it is arguably causal because fluid intelligence is an individual characteristic with little room for improvements in adulthood. In a New York Times article, Robert Shiller (2012) argued that the strong relationship uncovered by these papers is puzzling, as the investment strategies in question are relatively simple rules that should not require very high intelligence. Both our theoretical arguments and our empirical results suggest that an important channel for the effect of fluid intelligence is its role in investment in financial knowledge. Our results suggest that, however surprising it may be, it is indeed only people with relatively high levels of fluid intelligence who understand the role of diversification and other aspects of successful investment in risky assets. We argue that this is in part because only people with relatively high levels of fluid intelligence had enough incentives to invest in financial knowledge, and only in part because higher levels of intelligence are required for (or reduce the costs of) such investments.[5]

2. Theoretical framework

Modern cognitive psychology distinguishes fluid intelligence (also known as fluid reasoning, often denoted as Gf) and crystallized intelligence (also known as crystallized knowledge, often denoted as Gc). Fluid intelligence is the thinking part of intelligence, including abstract reasoning and executive function. In adulthood, fluid intelligence can be viewed as an individual characteristic, with little room for changing except for a steady linear decline starting on average around the age of 20. Crystallized intelligence includes specific bodies of knowledge

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[4] Dimitris Christelis, Tullio Jappelli and Mario Padula (2010) find that among individuals of age 50 and above in 12 European countries, less than 10 per cent own stocks among those in the lowest 20 per cent of numerical abilities, while close to 50 per cent own stocks in the highest 20 per cent. Mark Grinblatt, Matti Keloharju and Juhani Linnainmaa (2011) find that among Finnish men, less than 10 per cent owned stocks in the lowest 10 per cent of the “IQ distribution” (the age-adjusted distribution of scores on Raven’s matrices test, a fluid intelligence test), while almost 50 per cent owned stocks in the highest 10 per cent of the distribution. They also find that higher “IQ” is associated with investment strategies that are likely to yield higher returns and/or lower risk.

[5] Two papers show correlations between some measures of intelligence and financial knowledge. Banks and Oldfield (2007) find that numeracy, an indicator of fluid intelligence and perhaps arithmetic knowledge, is correlated with knowledge about pension arrangements in England. Jappelli (2010) compares a measure of financial knowledge across 55 countries and shows that it is positively correlated with the college attendance rate as well as average test scores of students in mathematics. Neither of these studies considers decision outcomes.

that may be results of individual investments. Typical elements of crystallized intelligence are malleable throughout much of adulthood, and they do not show substantial decline until older ages. Historically, the Gf/Gc distinction was proposed to address the limited success of the single factor "g" of cognitive abilities in explaining interpersonal variation in a wide variety of decision making capabilities. This research arrived to the conclusion that "Spearman's concept of g is in major respects the concept of Gf, fluid reasoning." (Horn and McArdle, 2007) Naturally, many other aspects of cognition influence decision making capabilities, including memory and apprehension of experience etc. We focus on crystallized intelligence and its relationship with fluid intelligence, and we abstract away from those other aspects of cognition because these two appear to be the most relevant aspects of cognition in financial decisions.

In order to highlight the role of incentives and fluid intelligence in the acquisition of financial knowledge we outline a simple model of investment in financial knowledge, with special focus on the role of fluid intelligence. Our model is an application of Becker's Human Capital theory (1964). An earlier version of the model was presented in Delavande, Rohwedder and Willis (2008). There is an expanding macro and finance literature with models for financial decisions that incorporate endogenous acquisition of knowledge relevant for those decisions. Veldkamp (2011) provides an excellent review. In these models the role of knowledge is usually to reduce uncertainty. In our model, instead, increased returns are the main driver, although a stochastic extension incorporates reduction of uncertainty as well. Jappelli and Padula (2011) and Lusardi, Michaud and Mitchell (2013) present models that are similar to ours but are more ambitious and focus on the endogenous determination of financial knowledge. We keep our models simpler and emphasize the direct and indirect effects of fluid intelligence on learning and stock market participation.

Financial knowledge is a form of human capital. The acquisition of financial knowledge is an investment with costs in order to bring benefits. The costs may include direct monetary costs and time, as well as cognitive effort. The benefits are higher wealth due to better financial decisions. We present simple models that highlight these mechanisms. First we consider a model without uncertainty in order to focus on the most important implications and comparative static results. We consider the role of uncertainty in a separate, more elaborate model. The second model reinforces all the conclusions of the first model, and it adds some additional implications.

Individuals can invest in two tangible assets. The first asset is simple with return R_b, which is independent of financial knowledge (subscript b may be read as "basic" or "bank savings account"). The second asset is complex, and it requires sophisticated investment decisions.

Returns on sophisticated investment, denoted by R, depend on financial knowledge K. In the simple setup without uncertainty, $R = \mu(K)$. Financial knowledge might affect potential returns because people can make better judgments about the performance of different portfolios available to them and they can choose a more appropriate one. More sophisticated households might also benefit from financial advice more as they better understand the language the finance industry uses and they can differentiate between a legitimate advice and a financial scam. The returns on the sophisticated investment are increasing but concave in financial knowledge. Importantly, we assume that at zero level of financial knowledge, returns on the sophisticated asset are lower than returns on the basic asset.

$$\mu'(K) > 0$$
$$\mu''(K) < 0$$
$$\mu(0) < R_b$$

Households consist of a single member who receives labor income y_1 in the first period and is retired in the second period with y_2 of pension revenue. In each period, households make a decision about consumption. In the first period (after having their earnings realized) households can invest in their financial knowledge, and then, with the resulting financial knowledge, they can consume, save and make an investment decision. The investment decision amounts to specify the proportion of savings invested in the sophisticated asset S as opposed to the basic asset B. A household's total savings are denoted by W so that $W = S + B = sW + (1 - s)W$.

Financial knowledge can be acquired at a unit cost ("price") $p(A)$ where A is learning ability that decreases the unit cost of investment. Learning ability includes fluid intelligence as well as pre-determined knowledge (crystallized intelligence) that the individual may have. Prior knowledge summarizes all knowledge that the individuals acquired as before making the decision of investing into (additional) financial knowledge with the goal of increasing the returns on the sophisticated asset. The source of this prior knowledge may be formal education, work experience, or knowledge acquired from family or friends.

The solution of the model can be illustrated in Fisher's diagram. In a standard diagram we have consumption in the first period on the horizontal axis and consumption in the second period on the vertical axis. In our framework the budget curve is nonlinear since a household can choose between different investment technologies. Figure 1 shows the budget set for two different levels of financial knowledge. Point E represents the endowment point with income values y_1 and y_2. Section E—B is the standard budget line with slope R_b representing the available consumption values when households invest into the basic asset B. Section *E–A* is the budget line if households invest into the sophisticated asset only, and they do not acquire any financial knowledge. The slope of this section is μ(0) which is assumed to be less than R_b, therefore this budget line is always below the basic budget line and it is always suboptimal to invest in the sophisticated asset without learning. When the household invests and acquires financial knowledge K, the endowment point decreases from E to D, where the distance between E and D is p(A)K. At the same time, the slope of the budget line increases from μ(0) to μ*(K)*.

The level of financial knowledge to acquire is a choice variable, and the available budget line is different for each level. With various choices of K, the budget curve is the envelope of budget lines for different values of financial knowledge K. It is convex, which gives rise to the possibility of multiple optima.

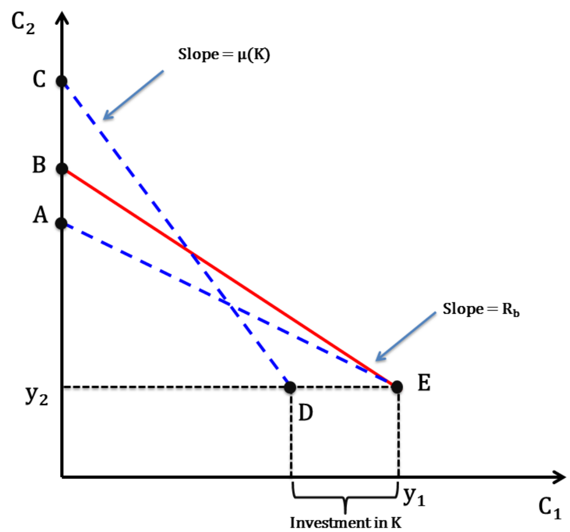

Figure 1. Budget set for different values of financial human capital

Figure 2 illustrates a case where both point C and point B are optima on the same indifference curve. Point B represents the optimum where the household does not acquire financial knowledge and invests into the basic asset only. Point C is the other optimum where the household acquires financial knowledge and invests into the sophisticated asset only. In this second case, the amount of investment into financial knowledge is $p(A)K$ and is represented by the D-E segment, and the amount of savings is represented by the F-D segment. The tangent of the budget curve at point C is $\mu(K)$ and this is the slope of the C-D segment.

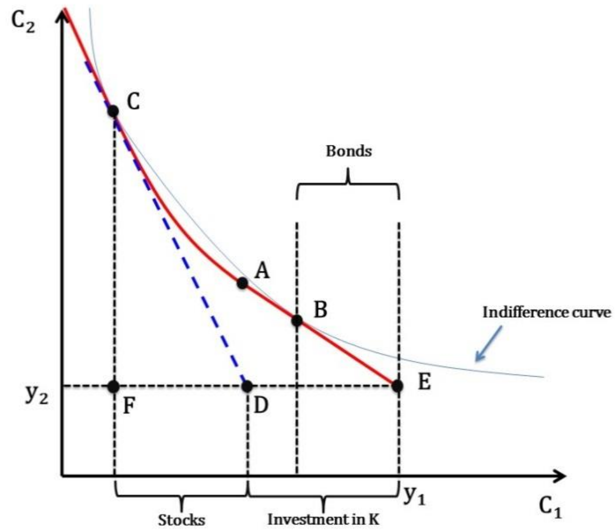

Figure 2. Optimal acquisition of financial knowledge and savings in the model without uncertainty

In this model households invest in either the basic or the sophisticated asset but they never combine the two. Point A at Figure 2 is the point where agents switch from the basic asset to the sophisticated asset. The slope of segment A-E is R_b, and any optimum point on this segment corresponds to a scenario where agents invest into the basic asset only. Any optimum left of point A corresponds to investment into the sophisticated asset only.

This model yields simple but interesting comparative static results. The effect of learning ability on optimal learning is straightforward but the effect on savings decisions is more complicated. People with better learning abilities can achieve higher return on the sophisticated asset with the same investment in their knowledge. This makes the budget set of the more able higher and steeper. Consequently, more able people invest more in financial human capital, and they achieve higher terminal wealth and higher utility. The effect on savings is ambiguous. On the one hand, the more able want to save more to benefit from the higher return on stocks. This effect can be viewed as a substitution effect of learning. On the other hand, the more able expect higher wealth in the second period because of the better investment. A rational agent would want to smooth this gain by decreasing second period wealth and increase first period consumption. This second effect may be viewed as the income effect of learning.

The effects of lifetime earnings on savings and learning are straightforward. Holding the shape of the age-earnings profile fixed, higher lifetime earnings shift the budget set to the right and up. In case of homothetic utility, higher lifetime income induces to learn more and save more in the first period. This is because the benefit of learning is proportional to wealth, while the cost is fixed, increasing the returns to this investment. Another comparative static result is that an increase of period-two income and a decrease in period-one income, keeping lifetime earnings constant, results in lower financial knowledge and lower savings. One implication is that Social Security and defined benefit pension systems decrease the incentives to learn, particularly for the poor for whom the replacement rate is high.

In reality, returns to the sophisticated assets are uncertain. In Appendix A, we show the counterpart of our simple deterministic model that incorporates uncertainty. We set up the model assuming power utility but without restricting the distribution of returns. Comparative statics cannot be derived analytically in that model and thus we use simulations the results of which are presented in Figure 4 in the Appendix. Those results lead to the same conclusions as the comparative static results of the deterministic model: lower unit costs of knowledge acquisition and higher lifetime earnings increase the amount of financial knowledge and the share of the sophisticated (and risky) asset in household portfolios. Optimal knowledge is zero for high levels of unit cost and low levels of lifetime earnings, and there are threshold values in both from which knowledge acquisition becomes profitable. The implications are modified by the degree of risk aversion: the more risk tolerant the individual the higher the unit cost threshold and the lower the earnings thresholds required to invest into financial knowledge. The comparative static results are all in line with the implications of the more complex dynamic model of Lusardi, Michaud and Mitchell (2013).

Our model implies that heterogeneity in fluid intelligence leads to heterogeneity in financial knowledge and, in turn, financial decisions and outcomes, for two reasons. First, people with higher fluid intelligence face a lower unit cost for acquiring financial knowledge and should invest more in their financial knowledge. Second, people with higher fluid intelligence have stronger incentives to invest in financial knowledge because they tend to have higher earnings capacity. That leads to higher lifetime income, which creates positive incentives to learn both because of the higher income level and the lower replacement rates for Social Security benefits. Besides fluid intelligence, general education, family networks and other factors that may affect the costs of the acquisition of financial knowledge may be correlated with earnings capacity as well.

These results imply that empirical correlations between fluid intelligence, education, family networks and other potential inputs on the one hand and financial decisions on the other hand show the mix of these effects. The results also highlight the need to take into account the endogenous acquisition of financial knowledge when thinking about policies that affect savings. For example, changes in the replacement rate or other parameters of the social security system can affect not only the level but also the composition of savings through their effects on investments in financial knowledge. Finally, our results suggests that changes in inputs that affect both the costs of and benefits to financial knowledge, such as fluid intelligence or general education, may have substantial consequences for household portfolios and welfare.

3. Data

In the empirical part of this paper we analyze partial correlations using measures of fluid intelligence and financial knowledge. We use data from two surveys. The first one is the Cognitive Economics Survey (CogEcon), matched to cognitive test data from the CogUSA survey. The second one is the American Life Panel survey (ALP).[6] The two surveys contain the same battery of questions on financial knowledge. The CogEcon/CogUSA survey has very detailed measures of fluid intelligence and other cognitive functioning, but it covers a limited age range. ALP covers the entire adult age range and contains many background variables, but its cognitive measures are less detailed.

CogEcon is a panel survey with observations from 2008, 2009 and 2011. The survey was designed by a team of economists to help understand the cognitive bases of economic decision-making.[7] The first wave was administered by mail and internet to a national sample of 1,222 persons, age 51 and older and their spouses regardless of age. Respondents were drawn from the pool of participants in the CogUSA study (formerly known as NCGS+HRS) led by John J. McArdle. That project conducted a detailed, three hour cognitive assessment of sample members, measuring many components of intelligence. The sample for our empirical analysis consists of respondents of the first wave of the CogEcon survey with linked CogUSA test scores. Because of small cell size considerations, we further restricted our sample to individuals of 51 through 80 years of age. The size of this final sample is 825. The CogEcon/CogUSA sample is aimed to be nationally representative, but selection into participating in the lengthy cognitive testing led to a final sample that is somewhat better educated and has higher cognitive abilities than the national average.

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[6] The CogEcon data is described in detail on the University of Michigan Cognitive Economics Project website, http://cogecon.isr.umich.edu/survey/index.html. The CogUSA data, along with other cognitive surveys, is described on the CogUSC website of the University of Southern California, http://kiptron.usc.edu/studies/index.html. The ALP is administered by RAND http://www.rand.org/labor/roybalfd/american_life.html.

[7] In addition to Willis, the design team includes Daniel Benjamin, Andrew Caplin, Miles Kimball, Kathleen McGarry, Claudia Sahm, Matthew Shapiro, and Tyler Shumway. Gwen Fisher, Brooke Helppie, Joanne Hsu oversaw the data collection and also provided valuable help on the survey design.

The ALP is an internet based panel survey of the adult American population (of age 18 and older). Individuals with no internet connection are provided a small laptop or a Web TV to mitigate selectivity based on exposure to computer technology. Participants are paid roughly $20 for a half hour interview and they are offered an interview once a week or once every other week. All questions of the 2008 wave of CogEcon were asked in wave 48 of the ALP in November 2008. As a result, the ALP contains the same financial knowledge battery as CogEcon. For our analysis, we restricted the sample to 1631 persons aged 20 to 80 years, who participated in both wave 48 (CogEcon on ALP) and wave 102 (cognitive measures).

Among other information, the ALP collected high frequency monthly data on stock market participation as well as buying and selling stock-market based accounts in order to study the effect of the financial crisis on the wellbeing of the American households[8]. The first wave of this series, called the Financial Crisis Surveys, was administered in November 2008, the second in February 2009 and the third in May 2009. Starting with May 2009 the data collection has been carried out at monthly frequency. The ALP survey waves with this information are called the ALP Financial Crisis Surveys. Altogether there have been 45 waves between November 2008 and November 2012. In our analysis of trading behavior we use all 45 waves; for the evolution of stockholding status between 2008 and 2011 we use the first 29 waves.

We created weights in both surveys to adjust the marginal distributions of gender, age, household income, education and race to the 2009 American Community Survey.[9] Appendix B shows that the weighted sample has lower cognitive scores, lower cognition and is less likely to hold stocks in both samples. In the main text we show results with weights; the Online Appendix repeats the most important results without the weights. The unweighted results are very similar to the weighted results.

Our preferred measure of fluid intelligence is the score on the number series test in the CogUSA study. The test was adapted from the Woodcock-Johnson (WJ-R) battery (McArdle, Fisher and Kadlec, 2007). The questions behind this test present puzzles that have to be solved by recognizing patterns. The number series puzzles are presented in numbers. Therefore, solving

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[8] The so-called ALP Financial Crisis Surveys were designed by Michael Hurd and Susann Rohwedder at RAND (seeHurd and Rohwedder (2010) for further details).

[9] Our methodology is based on the proposal of the Rand Corporation (https://mmicdata.rand.org/alp/index.php?page=weights). We use a raking weight approach separately for men and women. Within gender groups, the weight adjusts the marginal distributions of age (less than 30; 30-40; …; 70-80 for ALP and 50-60; 60-70 and 70-80 for CogEcon), of income (less than 40k, 40k-80k and 80k and above), of education (high school or less; some college or BA and more than BA) and of race (non-Hispanic whites and others).

them may involve some mathematic knowledge besides pure fluid intelligence. Nevertheless, the number series score is strongly correlated with alternative measures of intelligence (McArdle et al, 2007), and is often used as the preferred measure of fluid intelligence (Banks and Oldfield, 2007; McArdle, Smith and Willis, 2009). A 47-item version of the number series test was administered in the CogUSA survey in person, and, in addition, two shorter versions were administered in two telephone interviews. We use the 47-item version in this paper. Two similar but somewhat shorter (15-item) versions of the number series test was administered in the ALP survey as well, in wave 102 in 2010, and we use the average of these two scores.[10]

Financial knowledge is measured the same way in the two surveys. The 2008 CogEcon and the 48th wave of ALP contained the same 25 item battery of financial literacy questions (Table 12 in Appendix B). Survey participants were randomly assigned a true or a false version of each question. 5 of the 25 questions measured something else besides financial knowledge: two questions consisted of arithmetic exercises, and three questions were likely affected by the trust in the financial system. Additional 7 questions were problematic because either the true or the false version of the questions had wording problems. Our measure of financial knowledge is based on the remaining 13 questions. These questions focus on investments and include topics such as diversification, mutual funds, the appropriate frequency of stock trading etc. We converted each answer into a correct/incorrect format and created a score (the fraction of correct

[10] The number series test is not the only measure of fluid intelligence. The CogUSA survey administered 5 of such alternative tests together with number series, including the matrix reasoning measure that is commonly used in intelligence measurement (e.g., the Raven's matrices test, see, for example, Raven, 2000, which was used in the Finnish study by Grinblatt et al, 2011). Even though these measures aim at estimating the same theoretical construct, there are important differences between them in practice. The number series questions present puzzles in numbers, while other questions present puzzles in pictures or words. Table 10 in Appendix B shows that the pairwise correlations between six different fluid intelligence measures are moderate, ranging from 0.43 to 0.66. The number series score has the highest correlations with the other measures, followed by the matrix reasoning score. Table 11 in Appendix B shows that when financial knowledge is regressed on all six fluid measures, the number series score has the strongest coefficient and is significant at 1 percent; the similarities score (a measure of verbal concept formation) has smaller coefficients but still significant at 5 percent, and the coefficients of the other four measures (including the matrix reasoning score) are not significantly different from zero. When entered one by one, the number series score has again the strongest coefficient. We take these results as evidence that the number series score is a good measure of fluid intelligence for understanding economic behavior of individuals. Nevertheless, we carried out robustness checks for all of our results using the matrix reasoning score or the principle component of all scores instead of the number series score, and all of our qualitative results remain the same (see the Online Appendix).

answers) as well as a standardized measure. For the standardization we used the weighted mean and standard deviation.[11]

4. Relationship of the cognitive measures and their age pattern

An important feature of the Gf/Gc model is the differential age patterns of the two types of intelligence. Fluid intelligence peaks at early adulthood and declines afterwards, while crystallized knowledge usually increases until old age. Panel A of Figure 3 shows a stylized figure of these age profiles. Panel B shows the empirical counterpart to the stylized age profiles from our data: these are averages of the standardized score as functions of age in the ALP sample. For this figure, the mean of the financial knowledge score and the number series scores are set to zero for people younger than 30. The figure shows mean estimates and 95 percent confidence intervals in 10-year age groups (20-29,…,70-80) Figure 6 in Appendix B shows the corresponding figure in the CogEcon sample, normalized to be zero at age 51.)

Our estimates are remarkably close to the stylized patterns in Panel A. The number series score declines with age in our sample, at least starting after age 30, following the theoretical pattern of fluid intelligence in the relevant age range. The age profile of financial knowledge score is concave and increasing until age 70, following the theoretical pattern of crystallized intelligence in the relevant age range. (The corresponding figures in the older CogEcon sample are also consistent with the theoretical profiles; see Figure 6 in Appendix B.) Note that the estimated age profiles mix cohort effects with age effects, and the cohort effects are likely to be positive (cohorts born later having higher scores conditional on age), leading to a downward bias in the age profile of both measures (we would see negative slopes in a cross section if genuine aging effects were zero). Fluid intelligence, at least as measured by tests like ours, increased in younger cohorts, a phenomenon called the Flynn effect (Flynn, 1987). Financial knowledge is likely to be higher in younger cohorts in the U.S. because of the advance of defined contribution pensions and the increased incentives they provided to invest in financial knowledge. Even

[11]Table 13 in Appendix B shows the leave-one-out correlations for each item, separately for the true and the false version. The true versus false question format has some effect on the responses for many questions. That does not affect our analysis because the question format was randomized across respondents. However, the 7 ambiguous questions show extreme discrepancies between true and false formats and low correlations in general, that is why we dropped them from the analysis. Besides their guess for the correct answer, the answer scale used in the original questions included information about respondents' certainty of their own answer. Our scoring ignores that information because including the certainty information would have mixed actual self-confidence with the measure of knowledge. Nevertheless, all of our results are very similar if we use the full answer scale in the financial knowledge measure. Similarly, all qualitative results remain unchanged if we use all 25 items. (See the Online Appendix for the robustness checks.)

with these caveats, the age patterns support our interpretation of the number series score as a measure of fluid intelligence and the financial knowledge score measuring a dimension of crystallized intelligence. These results are also in line with Agarwal, Driscoll, Gabaix and Laibson (2009) who find that the prices paid for financial services are lowest for people in their 50's.

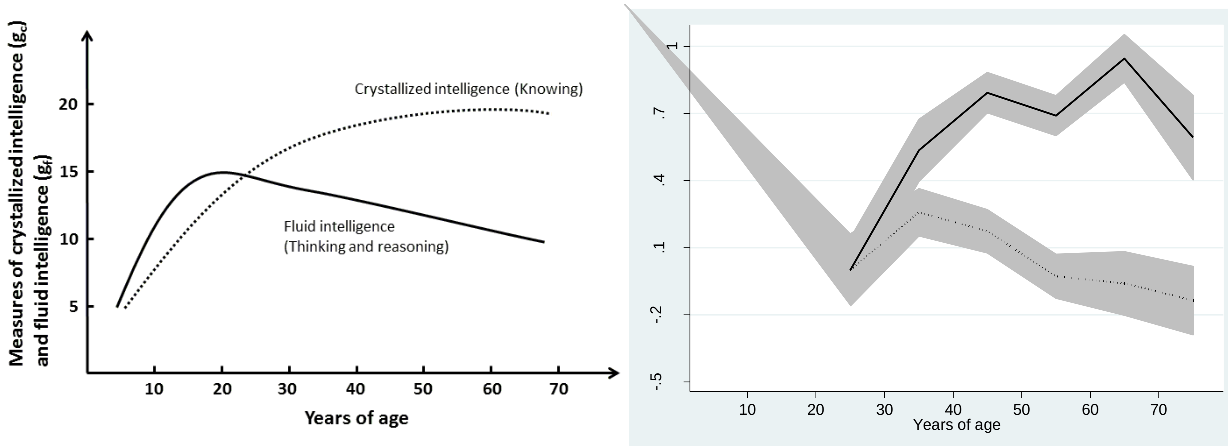

Figure 3.

Panel A
Theoretical description of the age patterns of fluid intelligence and crystalized intelligence
Reproduced from Cattel, 1998, p. 206

Panel B
Mean test score estimates of number series (solid) and financial knowledge (dashed) by age groups, with 95% confidence intervals (grey area)
Source: ALP survey

Table 14 in Appendix B shows summary statistics of the number series score and the financial knowledge score in the two surveys, while Figure 5 in Appendix B shows the corresponding histograms. The number series score in the CogEcon sample is standardized to its population mean in the relevant age group. The mean of the financial knowledge score indicated that the CogEcon respondents found the correct answer in 73 per cent of the times, on average, and the ALP respondents were correct in 71 per cent of the times. These scores should be compared to 50 per cent, the expected value if answers were random guesses. Weighted scores are somewhat lower than unweighted scores because of the mild selectivity of the samples and the weighting procedure that aims at correcting that. The histograms show that there is substantial heterogeneity in both the financial knowledge score and the number series score, and the distribution of financial knowledge is skewed with a long left tail, while the distribution of number series score is symmetric with a few negative outliers in the CogEcon data.

In the remainder of this section we show correlations that may shed some light on the production of financial knowledge. In particular, we look at whether people with characteristics that signal lower costs and higher incentives to invest into financial knowledge indeed possess higher levels of financial knowledge. On the incentives side, income and the ownership of defined contribution pensions (as opposed to defined benefit pensions) are of key interest. On the costs side, we are primarily interested in the relationship between financial knowledge and fluid intelligence. By comparing associations without control variables to associations conditional on control variables, our results can shed some light on the effect of fluid intelligence through the cost versus the benefits channels. Besides fluid intelligence, we are also interested in the role of education in explaining the heterogeneity in financial knowledge. We show evidence from both the CogEcon and the ALP samples, whenever possible, in order to show the robustness of our results.

Financial knowledge and fluid intelligence are strongly related. Figure 7 in Appendix B shows the relationship between the standardized number series score and the standardized financial knowledge score in the two samples, both the raw and the age-adjusted versions. In the range of plus and minus two standard deviations around the mean, the two test scores are strongly related, the relationship is linear, and it is similar in the two samples. Table 1 shows regression estimates withfinancial knowledge on the left hand-side and number series and covariates on the right hand-side. Columns (1) through (3) show results from the CogEcon survey; columns (4) through (6) show results from the ALP survey. Columns (1) and (4) include the number series score only; these estimates show the strong correlation between fluid intelligence and financial knowledge. Columns (2) and (5) include other right hand-side variables but not the number series score. These other right hand-side variables include demographics, education, the number of economics classes one had in school, log household income, whether someone in the household has DB pension plan, whether someone in the household has DC pension plan, and self-assessed risk tolerance. The baseline models do not control for wealth because that is an outcome of financial knowledge, but the results are very similar with wealth included as well (see the Online Appendix). Columns (3) and (6) include both the number series score and the other right hand-side variables.

Table 1. Financial knowledge and fluid intelligence. Results from OLS linear regressions.

Left hand-side variable:	CogEcon survey			ALP survey		
Financial knowledge score	(1)	(2)	(3)	(4)	(5)	(6)
Number series score	0.403		0.132	0.355		0.195
	[0.052]**		[0.049]**	[0.052]**		[0.042]**
Female		-0.347	-0.317		-0.215	-0.183
		[0.077]**	[0.078]**		[0.080]**	[0.075]*
African American		-0.668	-0.602		-0.412	-0.299
		[0.163]**	[0.161]**		[0.133]**	[0.140]*
Age		-0.022	-0.007		0.042	0.043
		[0.081]	[0.082]		[0.014]**	[0.014]**
Age squared /100		0.021	0.011		-0.031	-0.031
		[0.064]	[0.064]		[0.015]*	[0.015]*
Education (years)		0.056	0.038		0.088	0.070
		[0.015]**	[0.016]*		[0.015]**	[0.016]**
# econ classes		0.037	0.032		0.046	0.040
		[0.013]**	[0.014]*		[0.010]**	[0.010]**
Log household income		0.061	0.056		0.080	0.066
		[0.027]*	[0.027]*		[0.034]*	[0.030]*
Has DB pension plan		0.222	0.204		0.065	0.044
		[0.080]**	[0.080]*		[0.073]	[0.071]
Has DC pension plan		0.484	0.440		0.427	0.385
		[0.089]**	[0.091]**		[0.084]**	[0.079]**
Risk tolerance category		0.013	0.008		0.040	0.040
		[0.019]	[0.019]		[0.020]*	[0.019]*
Constant	0.003	-1.194	-1.436	0.000	-3.692	-3.347
	[0.048]	[2.588]	[2.589]	[0.048]	[0.582]**	[0.543]**
Observations	825	825	825	1631	1631	1631
R-squared	0.16	0.33	0.34	0.13	0.34	0.37

Standard errors in brackets are clustered at the household level.
Weighted estimates.
* significant at 5%; ** significant at 1%

The results are qualitatively similar across the two samples. People with one standard deviation higher number series score have a higher financial knowledge score by 0.4 standard deviation in the CogEcon sample and 0.36 standard deviation in the ALP sample. The strong correlation between fluid intelligence and financial knowledge drops considerably when the other covariates are included, but it remains significant. Women and African Americans have lower financial knowledge, and these differences decrease little when controlling for the number series score in old age (the CogEcon sample), but they decrease more in younger ages (the ALP sample. Conditional on the other covariates, age is not associated with financial knowledge in the CogEcon sample, while the age profile is positive and concave in the ALP sample, peaking at age 70. Education is strongly associated with financial knowledge in both samples, and this association decreases a little bit but remains significant when fluid intelligence is controlled, especially in the ALP sample.

The number of economics classes individuals took in school has a strong positive association with financial knowledge, and this association drops only a little when fluid intelligence is controlled. Remarkably, the coefficients are very similar in the regressions across the two samples, unlike the coefficients on general education or race. Past exposure to economics education predicts financial knowledge in adulthood, and this is true conditional on general levels of education, income and demographics, as well as our measure of fluid intelligence. Of course we cannot claim causality for these results, but the strength of the coefficient is remarkable: one more economics class is associated with an increase in financial knowledge comparable to between one half of a year and an entire year of more general education. To the extent it reflects a causal relationship, it may be a result of various mechanisms. Exposure to economics education may increase financial knowledge in a direct fashion, and this increase may be long-lasting enough to be seen in our data on adults. A perhaps more plausible channel is that exposure to economics education may have an effect on career choices, and it is employment in jobs that require a background in economics that increases, or maintains, financial knowledge.[12]

Household income is strongly positively associated with financial knowledge, while our measure of risk tolerance is not significantly related to financial knowledge once the other covariates are controlled. Individuals in households with DB pension plan have somewhat higher financial knowledge than households without such pension. On the other hand, individuals in households with a DC pension plan have substantially higher financial knowledge than individuals without DC pension plans. The difference is large: those with DC pension plans are, on average, 0.4 standard deviation higher in the financial knowledge distribution, while those with DB pension plan are only 0.05-0.2 standard deviation higher (controlling for age, gender, education, income, risk tolerance and past exposure to economics classes). The advantage of DC pension holders over DB pension holders remains virtually unaffected by entering the number series score in the regression.

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[12] The estimates of Christiansen, Joensen and Rangvid (2008) support this mechanism even though the authors do not emphasize this channel. Using panel data on Danish households, they show that households with an economist are more likely to hold stocks, and this effect is causal in the sense that a household member completing an economics degree or a new household member with an economics degree leads to an increase in the likelihood of stockholding.

Taken together, the regression results are consistent with the Gf/Gc theory of cognitive psychology and our theoretical model for the acquisition of financial knowledge. People with higher incentives to learn indeed possess higher financial knowledge. Higher levels of fluid intelligence seem to result in higher levels of financial knowledge, and at least part of this association seems to be driven by higher benefits to learning as suggested by the reduction in the coefficient on the number series variable when controlling for income and other characteristics.

5. Financial knowledge, fluid intelligence and investment decisions

In this section we show correlations between with stock market participation and the quality of investment decisions on the one hand and financial knowledge and fluid intelligence on the other hand.

As we indicated in the introduction, an increasing body of evidence suggests a strong correlation between fluid intelligence and stockholding. (Christelis, Jappelli and Padula, 2010; Grinblatt, Keloharju and Linnainmaa, 2011). In this section we reproduce those results in our samples and focus on partial correlations with financial knowledge, conditional on fluid intelligence as well as other covariates. First, we show the probability of having stock-market based assets in household portfolios conditional on the joint distribution of fluid intelligence and financial knowledge. Then we turn to regression analysis controlling for other observable characteristics.

5.1 Stock market participation

Table 2 shows the fraction of respondents in our sample who live in households that own stock-market based assets (individual stocks, mutual fund shares, etc.) either through retirement accounts or outside such accounts. The first panel shows the figures in the CogEcon sample, and the second panel shows them in the ALP sample. The overall fraction of stockholders is 0.59 and 0.54 in the two samples, respectively, which are close to estimates from other sources[13].

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[13] A little more than 50 per cent of American households own stocks (including stock-market based assets held in retirement accounts), according to estimates in the Statistical Abstract of the United States 2012, based on data from the Survey of Consumer Finances (Table 1211). Stockholding is lower among young people, which is consistent with the lower estimates in the ALP sample. Stockholding is between 50 per cent and 60 per cent of households in the age range covered by the CogEcon sample.

Table 2. The probability of stock market participation by fluid intelligence and financial knowledge

	Panel A: CogEcon				Panel B: ALP			
	Financial knowledge				Financial knowledge			
Number series score	Low	Medium	High	All	Low	Medium	High	All
Low	0.30	0.63	0.84	0.45	0.28	0.49	0.69	0.37
Medium	0.60	0.72	0.87	0.71	0.43	0.80	0.90	0.63
High	0.61	0.81	0.88	0.79	0.53	0.69	0.90	0.72
All	0.41	0.71	0.87	0.60	0.36	0.65	0.86	0.54

Notes. Age 51 to 80 in the Cogecon sample and 20 to 80 in the ALP sample. Weigthed estimates. N=824 in CogEcon and 1631 in ALP.

Fluid intelligence is strongly correlated with stock market participation in our sample, and the strength of the association is very similar to previous results. According to the last column of the CogEcon panel of Table 2, moving from the lowest third of the fluid intelligence distribution to the highest third increases the likelihood of stockholding by 34 percentage points. The corresponding increase in the ALP sample is 35 percentage points. These differentials are close to the 30 percentage points differential in the Finnish data between highest three IQ groups ("stanines," i.e. ten equal-sized groups) and the lowest three groups, reported by Grinblatt, Keloharju and Linnainmaa (2011).

The association between financial knowledge and stock market participation is even stronger. According to the last row of Table 2, moving from the lowest to the highest third in the financial knowledge distribution increases the likelihood of stockholding by 46 percentage points in the CogEcon sample and 50 percentage points in the ALP sample. Van Rooij, Lusardi and Alessie (2011) show similar but somewhat weaker associations for Dutch households: those in the top 25 per cent of their advanced financial knowledge distribution are 37 per cent more likely to hold stock-market based assets than those in the bottom 25 per cent of the distribution. Kimball and Shumway (2010), using a sample of the Survey of Consumers from the U.S. show that one standard deviation of their measure of financial sophistication is associated with a 23 percentage point increase in the probability of owning stock-market based assets. Our corresponding estimates are virtually the same, around 25 per cent, as the difference between the mean financial knowledge score in the lowest and the highest third is about 2 standard deviations in both of our samples.

The relationship between financial knowledge and stock market participation remains strong if we control for fluid intelligence. The differential in the stockholding rate between high and low financial knowledge is 0.54 in the lowest fluid intelligence group, 0.27 in the middle group and 0.27 in the highest group in the CogEcon sample (0.41, 0.47 and 0.37 in the ALP sample). At the same time, the correlation between fluid intelligence and stockholding decreases substantially if we control for financial knowledge. The differential in the stockholding rate between high and low fluid intelligence is 0.31 in the lowest financial knowledge group, 0.18 in the middle group and 0.04 in the highest group in the CogEcon sample (0.25, 0.20 and 0.21 in the ALP sample).

The relationship between stock market participation and fluid intelligence is stronger at low levels of financial knowledge. Similarly, the relationship between stockholding and financial knowledge is stronger at low levels of fluid intelligence, although this pattern is weaker than the previous one. If one is willing to interpret the correlations as causal effects, these patterns suggest substitution between fluid intelligence and financial knowledge, at least in cases when one is at low levels.

Table 3 shows the same qualitative patterns among the wealthiest 25 per cent. While all (or, in the ALP sample, almost all) individuals with high financial knowledge hold stock-market based assets regardless of fluid intelligence, stockholding varies considerably with financial knowledge among those with high levels of fluid intelligence. Among the wealthiest, stock market participation varies with fluid intelligence only among those with lower levels of financial knowledge.

Table 3. The probability of stock market participation by fluid intelligence and financial knowledge among the wealthiest 25 percent sample.

	Panel A: CogEcon				Panel B: ALP			
	Financial knowledge				Financial knowledge			
Number series score	Low	Medium	High	All	Low	Medium	High	All
Low	0.61	0.83	1.00	0.75	0.55	0.76	0.92	0.69
Medium	0.81	0.96	1.00	0.91	0.52	0.94	0.96	0.82
High	0.80	0.95	1.00	0.91	0.76	0.90	0.98	0.91
All	0.71	0.91	1.00	0.84	0.57	0.87	0.96	0.81

Notes. Age 51 to 80 in the Cogecon sample and 20 to 80 in the ALP sample. Weigthed estimates. N=257 in CogEcon and 512 in ALP.

We estimated the probability of stock market participation as a function of fluid intelligence and financial knowledge controlling for other right hand-side variables in the form of linear probability models. The other right hand-side variables in the regressions are gender, age, education, log household income, log household wealth, a dummy for non-positive wealth and the degree of risk tolerance. Risk tolerance is measured as the answer to how willing the respondent is to take risks, with answers ranging from zero (not at all willing) to 10 (very willing).

Table 4 shows the results; panel A shows them in the CogEcon sample and panel B in the ALP sample. In both panels, columns (1) through (4) repeat the findings in Table 2 in a more concise way but using standardized test scores instead of quantiles. Column (5) shows associations with the covariates (demographic characteristics, education, income, wealth, risk tolerance). Column (6) shows the association of stockholding with financial knowledge and fluid intelligence conditional on the covariates.

The results are remarkably similar in the two samples. When both financial knowledge and fluid intelligence is included, financial knowledge retains most of its predictive power while fluid intelligence loses most of it. Conditional on the number series score, people with one standard deviation higher financial knowledge score are, on average, 18 to 20 percentage points more likely to be stockholders. Conditional on the financial knowledge score, people with one standard deviation higher number series score are, on average, 8 to 10 percentage points more likely to be stockholders. Column (4) shows that there is a negative but statistically insignificant interaction between the two.

Column (6) shows that controlling for gender, race, age, education, income, wealth and self-rated risk tolerance as well as fluid intelligence decreases the association between stockholding and financial knowledge, but the remaining association is statistically significant. At the same time, controlling for these covariates as well as financial knowledge reduces the association between stockholding and fluid intelligence to zero in the CogEcon sample and a weakly significant 5 per cent in the ALP sample. Comparing the coefficients on the covariates between column (5) and column (6) suggests that a substantial part of the associations between stockholding and education or wealth is related to financial knowledge.

Table 4. The probability of stock market participation as a function of financial knowledge, fluid intelligence and other covariates. Linear probability models. Weighted regressions.

Panel A: The CogEcon sample.

Left hand-side variable: stockholder household (0 or 1)	(1)	(2)	(3)	(4)	(5)	(6)
Financial knowledge score	0.217		0.178	0.174		0.106
	[0.018]**		[0.022]**	[0.022]**		[0.022]**
Number series score		0.168	0.097	0.096		0.001
		[0.019]**	[0.023]**	[0.023]**		[0.023]
Interaction				-0.022		
				[0.016]		
Female					0.020	0.055
					[0.029]	[0.030]
African American					-0.148	-0.090
					[0.074]*	[0.071]
Age					0.033	0.034
					[0.035]	[0.034]
Age squared over 100					-0.031	-0.031
					[0.027]	[0.026]
Education (years)					0.018	0.011
					[0.008]*	[0.008]
Log household income					0.006	0.000
					[0.011]	[0.011]
Log financial wealth					0.124	0.114
					[0.013]**	[0.013]**
Financial wealth nonpositive					-0.512	-0.471
					[0.061]**	[0.062]**
Log housing wealth					-0.016	-0.027
					[0.017]	[0.017]
Housing wealth nonpositive					-0.048	-0.022
					[0.051]	[0.050]
Risk tolerance category					0.014	0.013
					[0.007]	[0.007]
Constant	0.600	0.601	0.600	0.609	-1.740	-1.409
	[0.022]**	[0.023]**	[0.021]**	[0.025]**	[1.177]	[1.137]
Observations	825	825	825	825	825	825
R-squared	0.19	0.12	0.23	0.23	0.38	0.41

Standard errors in brackets are clustered at the household level.
* significant at 5%; ** significant at 1%

Panel B: The ALP sample

Left hand-side variable: stockholder household (0 or 1)	(1)	(2)	(3)	(4)	(5)	(6)
Financial knowledge score, std.	0.238		0.211	0.211		0.119
	[0.013]**		[0.017]**	[0.017]**		[0.018]**
Number series score, std.		0.151	0.077	0.077		0.045
		[0.022]**	[0.020]**	[0.021]**		[0.019]*
Interaction				0.002		
				[0.015]		
Female					-0.014	0.016
					[0.032]	[0.031]
Black					-0.114	-0.043
					[0.060]	[0.054]
Age					0.006	0.001
					[0.009]	[0.008]
Age squared over 100					-0.008	-0.003
					[0.008]	[0.008]
Education (years)					0.045	0.026
					[0.009]**	[0.008]**
Log household income					0.055	0.044
					[0.016]**	[0.016]**
Log financial wealth					0.047	0.04
					[0.019]*	[0.018]*
Financial wealth nonpositive					-0.315	-0.273
					[0.059]**	[0.055]**
Log housing wealth					-0.005	-0.009
					[0.014]	[0.012]
Housing wealth nonpositive					-0.1	-0.069
					[0.057]	[0.050]
Risk tolerance category					0.012	0.006
					[0.008]	[0.007]
Constant	0.543	0.543	0.543	0.542	-1.182	-0.579
	[0.019]**	[0.023]**	[0.019]**	[0.022]**	[0.292]**	[0.279]*
Observations	1631	1631	1631	1631	1631	1631
R-squared	0.23	0.09	0.25	0.25	0.32	0.37

Standard errors in brackets are clustered at the household level.
* significant at 5%; ** significant at 1%
The sample mean is imputed for people with zero or negative financial and housing wealth.

Taken together, the results show that stock market participation is strongly associated with financial knowledge even after controlling for education, income and wealth. It is stronger than the association of stockholding with fluid intelligence, and a substantial part of the association with fluid intelligence is explained, in a regression sense, by financial knowledge. Of course, the observed associations do not prove a causal relationship in themselves even if education, income and wealth are controlled. Reverse causality from stock market participation to financial knowledge as well as other omitted variables may explain the findings. However, the fact that controlling for financial knowledge substantially reduces the effect of fluid intelligence is consistent with the hypothesis from our theoretical model that fluid intelligence is an input to financial knowledge formation.

5.2 Non-diversified stock portfolios

Besides stockholding itself, fluid intelligence is known to be associated with better investment strategies among stockholders. (Grinblatt, Keloharju and Linnainmaa, 2011). We now look at similar associations with financial knowledge as well as our measure of fluid intelligence. We first look at diversification among stock market participants.

We created a measure for the stock portfolio to be non-diversified. The measure is defined for stock market participants: individuals who live in households where household members own stock market-based assets either within our outside tax-sheltered accounts. It is a conservative indicator with value one if the portfolio is very unlikely to be well diversified and zero if the portfolio may be well diversified. We define the portfolio unlikely to be well diversified if it contains shares in one through eight individual stocks and nothing else (in particular, no stock market fund shares of any kind). Table 5 shows the probability of non-diversified portfolios by fluid intelligence and financial knowledge.

Table 5. The probability of non-diversified portfolios among stock market participants by three groups of the number series score and three groups of the financial knowledge score.

	Panel A: CogEcon				Panel B: ALP			
	Financial knowledge				Financial knowledge			
Number series score	Low	Medium	High	All	Low	Medium	High	All
Low	0.17	0.14	0.07	0.12	0.17	0.09	0.03	0.10
Medium	0.24	0.11	0.04	0.11	0.11	0.18	0.03	0.08
High	0.12	0.07	0.06	0.07	0.26	0.04	0.02	0.06
All	0.18	0.10	0.06	0.10	0.18	0.10	0.02	0.07

Notes. Age 51 to 80 in the Cogecon sample and 20 to 80 in the ALP sample. Weigthed estimates. Number of observations and unweighted estimates are in Appendix B.

The results suggest moderate associations with fluid intelligence and substantially stronger associations with financial knowledge. Moving from the lowest third to the highest third in the distribution of the fluid intelligence distribution is associated with a 5 percentage-point decrease in likelihood of non-diversified stock portfolios in the CogEcon sample and a 4 percentage-point decrease in the ALP data. On the other hand, moving from the lowest third to the highest third in the distribution of the financial knowledge distribution is associated with a 12 percentage-point decrease in likelihood of non-diversified stock portfolios in the CogEcon sample and a 16 percentage-point decrease in the ALP data. Financial knowledge is significantly associated with lower likelihood of non-diversification within fluid intelligence categories, while the reverse is not true.

We estimated linear regressions with the non-diversification indicator on the left hand-side. The structure of the regressions is similar to the stockholding regressions reported in Table 4 above. Financial knowledge and fluid intelligence are entered as standardized scores, their interaction is also entered in some regressions, and we control for gender, age, education, income, wealth and self-rated risk aversion.

Table 6 shows the results. The estimates are remarkably similar across the two samples. Columns (1) and (2) show that the negative association of non-diversified portfolios with financial knowledge is substantially stronger than its correlation with fluid intelligence, in both samples. One standard deviation higher score in financial knowledge is associated with 6 percentage points lower likelihood of non-diversification. The unconditional association with fluid intelligence is about half as strong. The coefficient on financial knowledge drops slightly when the numbers series score is included, and it remains significant, while the coefficient on the number series score drops substantially, and becomes insignificant, when financial knowledge is included (column 3). The other control variables diminish the coefficient on financial knowledge only to a small extent ad it remains statistically significant (Column 6).

Table 6. The probability of non-diversified stock portfolios among stockholders as a function of financial knowledge, fluid intelligence and other covariates. Weighted OLS linear regression estimates.

Panel A: The CogEcon sample						
Left hand-side variable: non-diversified portfolio (0-1)	(1)	(2)	(3)	(4)	(5)	(6)
Financial knowledge score	-0.065 (0.018)**		-0.060 (0.018)**	-0.061 (0.019)**		-0.055 (0.019)**
Number series score		-0.034 (0.013)*	-0.020 (0.013)	-0.021 (0.017)		-0.016 (0.014)
Interaction				0.003 (0.016)		
Female					-0.009 (0.025)	-0.026 (0.025)
African American					-0.041 (0.112)	-0.083 (0.117)
Age					-0.002 (0.028)	-0.003 (0.027)
Age squared over 100					0.000 (0.000)	0.000 (0.000)
Education (years)					-0.008 (0.006)	-0.001 (0.006)
Log household income					0.002 (0.004)	0.003 (0.003)
Log financial wealth					-0.049 (0.014)**	-0.043 (0.014)**
Financial wealth nonpositive					-0.714 (0.187)**	-0.659 (0.185)**
Risk tolerance category					0.013 (0.065)	0.020 (0.065)
Constant	0.113 (0.015)**	0.106 (0.014)**	0.118 (0.016)**	0.117 (0.015)**	0.730 (0.898)	0.630 (0.853)
R-squared	0.04	0.01	0.04	0.04	0.06	0.09
Observations	539	539	539	539	534	534

Standard errors in brackets are clustered at the household level.
* significant at 5%; ** significant at 1%

Panel B: The ALP sample						
Left hand-side variable: non-diversified portfolio (0-1)	(1)	(2)	(3)	(4)	(5)	(6)
Financial knowledge score	-0.062 (0.011)**		-0.056 (0.011)**	-0.061 (0.012)**		-0.044 (0.012)**
Number series score		-0.037 (0.012)**	-0.020 (0.011)	-0.025 (0.013)		-0.022 (0.012)
Interaction				0.032 (0.015)*		
Female					0.031 (0.015)*	0.010 (0.015)
African American					0.063 (0.066)	0.033 (0.066)
Age					-0.009 (0.006)	-0.008 (0.006)
Age squared over 100					0.000 (0.000)	0.000 (0.000)
Education (years)					-0.006 (0.004)	-0.000 (0.004)
Log household income					-0.003 (0.010)	-0.001 (0.010)
Log financial wealth					-0.011 (0.008)	-0.007 (0.007)
Constant	0.087 (0.010)**	0.075 (0.009)**	0.090 (0.011)**	0.083 (0.010)**	0.550 (0.163)**	0.393 (0.157)*
R-squared	0.05	0.02	0.05	0.06	0.03	0.06
Observations	988	988	988	988	925	925

Standard errors in brackets are clustered at the household level.
* significant at 5%; ** significant at 1%

5.3 Frequent active trading

According to standard financial advice households should not trade stocks very frequently because of high transaction costs and questionable benefits. The advice is especially strong against rearranging the composition of the stock portfolio often. The ALP data collected at monthly frequency after 2009 offer a unique opportunity to study trading frequency and its relationship to fluid intelligence and financial knowledge.

We created a dummy variable that takes the value one if the household both bought and sold stock market-based assets, at the same time, at least twice a year and zero otherwise. The measure is defined only for stock market participant households. We call this measure the indicator of frequent active trading. We estimated two different regressions, one for the probability of frequent active trading outside retirement accounts and one for the probability of frequent active trading within retirement accounts.

Importantly, in each regression we enter not only the financial knowledge score but whether the respondent answered the one financial knowledge question on trading frequency right. The particular question asked whether it was true that “to make money in the stock market, you should not buy and sell stocks too often.” Table 7 shows the results.

The results suggest that neither fluid intelligence nor general financial knowledge is associated with frequent active trading. Instead, if anything, people with higher levels of general financial knowledge seem more likely to engage in such behavior. Column (4) and (8) show that this is most likely because of their other characteristics not their financial knowledge.

At the same time, knowing that frequent trading is not a very good idea is negatively associated with the probability of frequent active trading in the sample. This association is statistically insignificant for trading outside retirement accounts but significant for trading within retirement accounts even when controlling for other covariates.

Table 7. The probability of frequent active trading among stockholders as a function of financial knowledge (both general knowledge and the knowledge that frequent trading is bad), fluid intelligence and other covariates. Weighted OLS linear regression estimates. ALP sample

	Frequent active trading outside retirement accounts				Frequent active trading within retirement accounts			
numserst	0.032		0.02	-0.002	0.013		0.008	0.005
	[0.023]		[0.025]	[0.025]	[0.005]*		[0.005]	[0.006]
financial knowledge[a]		0.051	0.044	0.017		0.02	0.017	0.004
		[0.026]*	[0.028]	[0.028]		[0.008]**	[0.008]*	[0.007]
fin.k. Q20[b]		-0.06	-0.06	-0.058		-0.039	-0.039	-0.04
		[0.039]	[0.039]	[0.039]		[0.012]**	[0.012]**	[0.012]**
female				-0.135				0.001
				[0.041]**				[0.010]
age				-0.025				-0.009
				[0.011]*				[0.003]**
agesqc				0.022				0.009
				[0.010]*				[0.004]*
educy				0.006				0.006
				[0.009]				[0.003]*
black				-0.113				-0.003
				[0.126]				[0.009]
risktol				0.012				0.004
				[0.011]				[0.003]
lnincome				0.034				-0.001
				[0.022]				[0.005]
lntotwealth				0.02				0.018
				[0.017]				[0.005]**
totw_nonpos				0.352				0.196
				[0.223]				[0.051]**
_cons	0.417	0.429	0.425	0.375	0.033	0.048	0.046	-0.079
	[0.022]**	[0.032]**	[0.031]**	[0.358]	[0.005]**	[0.009]**	[0.009]**	[0.111]
N	631	631	631	631	1094	1094	1094	1094
R2	0.00	0.01	0.01	0.06	0.00	0.02	0.02	0.06

[a] Without the frequent trading question. [b] Whether knows that frequent trading is bad.

5.4 Retaining Stock Investments Throughout The Financial Crisis

Another measure of the quality of financial decisions looks at what stockholders did with their stock-market based assets during the great recession after 2008. The Dow Jones Industrial Average reached its bottom at a 10-year low by March 2009. By the middle of 2011, though, the Dow increased to its pre-crisis level. The return on the index was roughly 50 per cent between March 2009 and May 2011. Stockholding households that sold out their stocks could not realize this gain, while households that held on to their stocks could.

Holding on to stocks can be viewed as better investment strategy not primarily by its realized return (it could have been just a chance event) but because that reflects resistance to movements in prices. An investor who believes that stock prices followed a random walk with drift during that period (with expected returns not very different from previous periods) should have held on to her or his stock market investment. Of course, this argument is ceteris paribus: households may sell out their stock-market based assets because of income or expenditure shocks, and the occurrence of such shocks may be correlated with financial knowledge and fluid intelligence. When we look at the association with financial knowledge and fluid intelligence, we also try to control for such shocks by controlling for the unemployment experience of the respondents and their spouses.

We can look at this behavioral outcome using data from the financial crisis waves of the ALP survey. We restricted the sample to 1097 persons, who owned stock-market based assets any time between November 2008 and July 2009, and who participated in the study at least once between January 2011 and July 2011. Table 8 looks at the fraction of those that remained stockholders anytime in the first half of 2011, by financial knowledge and fluid intelligence. Panel A shows all respondents, while Panel B shows respondents who live in households where neither the respondent nor his or her spouse experienced unemployment during the analyzed period.

The marginal probabilities in Panel A show strong associations. 67 per cent remained stockholders in the lowest third of the fluid intelligence distribution, compared to 87 per cent in the highest third. The association with financial knowledge is stronger: 68 per cent remained stockholders in the lowest third of the financial knowledge distribution, compared to 93 per cent in the highest third. The association with financial knowledge conditional on fluid intelligence is similar to the unconditional association, while the association with fluid intelligence gets very weak conditional on financial knowledge. Panel B shows very similar patterns at somewhat higher levels of stockholding.

Table 8. Fraction of stockholders in the first half of 2011 among those who were stockholders in the first half of 2009, by financial knowledge and fluid intelligence. The ALP survey. Weighted estimates,

	Panel A: All, N=1097				Panel B: Stayed employed through the recession, N=821			
	Financial knowledge				Financial knowledge			
Number series score	Low	Medium	High	All	Low	Medium	High	All
Low	0.60	0.77	0.91	0.67	0.66	0.86	0.91	0.72
Medium	0.77	0.95	0.93	0.86	0.82	0.96	0.95	0.90
High	0.73	0.88	0.96	0.87	0.87	0.93	1.00	0.94
All	0.68	0.88	0.93	0.79	0.74	0.93	0.96	0.84

Table 9 shows the corresponding linear regression estimates. Besides demographics and education, we control for the experience of unemployment spells as well. According to the regression estimates, one standard deviation increase in financial knowledge is associated with 15.7 percentage points higher chance of remaining a stockholder in 2011 (column 1). In the regressions, the association of the probability of remaining stockholder with the financial knowledge score and the number series score are comparable, both separately and conditional on each other, and the same is true when the other right hand-side variables are controlled. The regression results in Table 9 imply that fluid intelligence and financial knowledge equally strongly predict stock ownership in 2011 among previous stockholders conditional on other covariates.

Overall, the results on investment decisions show that the association of better investment decisions of stockholders is strongly related to financial knowledge. This association remains strong conditional on fluid intelligence and other covariates. In most cases the association with financial knowledge is significantly stronger than the association with fluid intelligence once the other is controlled for.

Table 9. The probability of stockholding in the first half of 2011 among those who were stockholders in the first half of 2009. Linear probability model estimates using the ALP survey. Weighted estimates.

Left hand-side variable: Stockholder in the first half of 2011	(1)	(2)	(3)	(4)	(5)	(6)
Financial knowledge score, std.	0.157		0.118	0.121		0.075
	[0.022]**		[0.023]**	[0.024]**		[0.021]**
Number series score, std.		0.139	0.098	0.098		0.087
		[0.025]**	[0.027]**	[0.027]**		[0.030]**
Interaction				-0.01		
				[0.017]		
Ever unemployed					-0.253	-0.23
Nov 2008 to July 2012					[0.063]**	[0.061]**
Spouse ever unemployed					-0.108	-0.129
Nov 2008 to July 2012					[0.074]	[0.065]*
Fraction of month					0.097	0.1
unemployed, 08-12					[0.139]	[0.141]
Fraction of month					0.054	0.154
spouse unemployed, 08-12					[0.308]	[0.254]
Female					-0.003	0.041
					[0.036]	[0.035]
Black					-0.023	0.068
					[0.071]	[0.067]
Age					0.026	0.023
					[0.009]**	[0.008]**
Age squared over 100					-0.028	-0.023
					[0.009]**	[0.008]**
Education (years)					0.016	0.003
					[0.009]	[0.007]
Log household income					0.026	0.027
					[0.019]	[0.019]
Log financial wealth, Nov. 08					0.081	0.069
					[0.014]**	[0.013]**
Financial wealth nonpositive					-0.115	-0.1
					[0.054]*	[0.054]
Log housing wealth, Nov. 08					-0.044	-0.044
					[0.011]**	[0.010]**
Housing wealth nonpositive					0.067	0.075
					[0.046]	[0.044]
Risk tolerance category					0.009	0.006
					[0.009]	[0.009]

Constant	0.725	0.757	0.719	0.721	-0.71	-0.403
	[0.026]**	[0.022]**	[0.025]**	[0.026]**	[0.295]*	[0.278]
Observations	1097	1097	1097	1097	1097	1097
R-squared	0.1	0.09	0.13	0.13	0.24	0.3

Standard errors in brackets are clustered at the household level.
* significant at 5%; ** significant at 1%

6. Conclusions

Our results show that financial knowledge, measured by a 13-question test focusing mostly on investments, is strongly associated with stockholding as well as better investment decisions of stockholders both before and throughout the financial crisis. Financial knowledge is a stronger predictor than fluid intelligence (measured by a long battery of number series pattern recognition items). Financial knowledge remains important conditional on fluid intelligence, while a substantial part of the association with fluid intelligence is explained, in a regression sense, by financial knowledge. These results suggest that, if there is a causal relationship from fluid intelligence to stockholding, a substantial part of it operates through financial knowledge. These results are robust across two samples with considerable difference in their age composition and their measure of fluid intelligence, and they are also robust to the choice of the fluid intelligence measure.

While it is not surprising to see that those who know better do better, our results also suggest that there is no need for high intelligence on top of solid financial knowledge for making sensible investment decisions. We argue that many people don't have solid financial knowledge because they did not make appropriate investment into their knowledge, and for many of them, this was an optimal decision. Our empirical results also suggest that, while being smart certainly helps developing one's financial knowledge, it is not the only input. Appropriate incentives and education are strongly associated with financial knowledge even conditional on fluid intelligence. Stronger exposure to incentives in terms of defined contribution pension plans, for example, is strongly associated with higher financial knowledge. These results are in line with a simple theory of optimal investment in financial knowledge. Fluid intelligence, education and other factors that may affect the costs of the investment in financial knowledge may also have effects the benefits to it and can have substantial effects on financial decisions. The theory also highlights that policies that change the incentives to save may affect the composition of savings by changing the incentives to invest in financial knowledge.

A remarkable empirical result that highlights the possibility of such substantial effects is that, even conditional on general education, each economics class taken in school is associated with as large an increase in financial knowledge as an additional year of general education. The association is identified from the intensive margin (number of economics classes) as well as the extensive margin (any economics class). Of course, this association may not be causal: unobserved characteristics may lead to higher financial knowledge as well as higher levels of economics education. If the relationship is causal, various mechanisms may play their roles, from internalized knowledge through learning from early investments induced by economics education or peers, through career choice. In any case, the results are suggestive in the sense that solid knowledge requires solid education instead of crash courses. These are potentially important findings because, unlike fluid intelligence, incentives or economics education can be influenced by policy.

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Appendix A. Details of the theoretical model with uncertainty

In this Appendix we present an enriched version of our simple two-period model by adding uncertainty to the returns of the sophisticated asset. We set up the model first, then we present its analytical solution, and finally, we show simulation results.

A1. Setup

From now, we shall call the sophisticated asset (S) stocks. Stock returns are assumed to be drawn from the following distribution:

$$R = \mu(K) + \sigma(K)\varepsilon \tag{1}$$

where ε is a random variable with zero mean and variance one. Ex ante, returns are uncertain and are denoted as R_s. Ex post, returns are realized and are denoted as R_s^r. Financial knowledge is assumed to affect the standard deviation of effective returns besides its mean, so that

$$\begin{aligned} \mu'(K) &> 0 \\ \mu''(K) &< 0 \\ \mu(0) &< R_b \\ \sigma'(K) &< 0 \\ \sigma''(K) &> 0 \end{aligned} \tag{2}$$

We specify the per-period utility function of the unitary household as CRRA and we use time-separable utility function with time discount β

$$\begin{aligned} U &= u(c_1) + \beta E\left[u(c_2)\right] \\ u(c) &= \frac{c^{1-\gamma}}{1-\gamma} \end{aligned} \tag{3}$$

As before, households can invest in their financial knowledge in the first period (after having their earnings realized), and then, with the resulting financial knowledge, they can save (and consume) and make an investment decision. Investment in financial knowledge has a unit cost ("price") of p. The returns of the investment are realized in period 2.

Since the model does not feature bequests, the household simply consumes all its wealth in the second period:

$$c_2^* = y_2 + BR_b + SR_s^r \tag{4}$$

where R_b is the realized return on the risk-free basic asset, and R_s^r is the realized return on the risky sophisticated asset.

In the first period, the individual decides about three variables: acquisition of financial knowledge K, investment in the basic asset B and investment in stocks S. We solve the model in two steps. In the second step, the individual makes a portfolio choice (*S*) given financial knowledge (*K*) and total savings (*W*). In the first step, he decides about knowledge (*K*) and savings (*W*).

Let *s* denote the fraction of total savings (*W*) held in stocks, and let R_e denote the excess return on stocks:

$$R_e = R_s - R_b \tag{5}$$

In the second step, the individual's problem is finding the value function by choosing an optimal value of the share of stocks in savings (*s*) for any value of financial knowledge and savings (*K*,*W*):

$$\begin{aligned} v_2(K,W) &= \max_s \left\{ \beta E u\left(y_2 + W\left(R_b + sR_e\right)\right)\right\} \\ s.t.\quad & 0 \le s \le 1 \end{aligned} \tag{6}$$

In the first step, he solves

$$\begin{aligned} v_1 &= \max_{K,W} \left\{ u\left(y_1 - pK - W\right) + v_2\left(K,W\right)\right\} \\ s.t.\, & 0 \le y_1 - pK - W \end{aligned} \tag{7}$$

A2. Solution of the second step

We first analyze the properties of the value function $v_2(K, W)$ and the policy function $s(K, W)$. It is useful to rewrite the problem in the following form

$$\begin{aligned} v_2(K,W) &= \max_z \left\{ \beta E u\left(A\left(R_b + zR_e\right)\right)\right\} \\ s.t.\quad & 0 \le z \le \frac{W}{A} \end{aligned} \tag{8}$$

where $A = W + y_2 / R_b$ denotes the lifetime assets of the individual, and $z = \frac{S}{A} = s\frac{W}{A}$ is the share of risky assets in lifetime assets. Once we solve the modified problem we can easily recover the solution to the original problem. The advantage of the new setup is the lack of a separate labor income term, which simplifies the derivation significantly.

Throughout the derivation we neglect the constraints for now. This amounts to assuming that individuals never want to invest all their money in stocks. We shall discuss the effect of these constraints later. Assuming interior solution, the first order conditions are:

$$\frac{\partial v_2(K,W)}{\partial z} = \beta E\left[u'\left(A\left(R_b + zR_e\right)\right)AR_e\right] = 0 \tag{9}$$

This equation implicitly defines the optimal policy function *z(K, L)*. Although we cannot solve for it explicitly we can still analyze its properties using the implicit function theorem. It can be shown that

$$\frac{\partial z(K,A)}{\partial A} = 0 \tag{10}$$

A3. Solution of the first step

The problem in the first step is choosing the optimal amount of savings and financial knowledge:

$$\begin{aligned} v_1 &= \max_{K,W} \left\{ u\left(y_1 - pK - W\right) + v_2\left(K,W\right) \right\} \\ &s.t.\ 0 \le y_1 - pK - W \end{aligned} \tag{11}$$

The first order conditions are the following:

$$u'(c_1) = \frac{1}{p}\frac{\partial v_2(K,W)}{\partial K} = \frac{1}{p}\beta S(K,W)\left(\mu'(K) - \sigma'(K)\frac{\mu(K)-R_b}{\sigma(K)}\right)E\left[u'(c_2)\right] \tag{12}$$

$$u'(c_1) = \frac{\partial v_2(K,W)}{\partial W} = \beta R_b E\left[u'(c_2)\right] \tag{13}$$

We can combine these two conditions into

$$pR_b = S(K,W)\left(\mu'(K) - \sigma'(K)\frac{\mu(K)-R_b}{\sigma(K)}\right) \tag{14}$$

This equation shows that the marginal cost and the marginal benefit of acquiring financial knowledge must be equal in optimum. The marginal cost is forgone savings due to investment, and the marginal benefit is the gain from making the portfolio more efficient.

Let us turn now to the first order condition with respect to savings (*W*) in equation (13). Substituting in for consumption, we get

$$u'\left(y_1 - pK - W\right) = \beta R_b E\left[u'\left(y_2 + W\left(R_b + s(K,W)R_e\right)\right)\right] \tag{15}$$

This equates the marginal utility loss in the first period and marginal utility gain in the second period for an increase in savings. The solution to the model is the *K,W* pair that solves (14) and (15).

A4. Extensive margins of stockholding

In this subsection we investigate the relevance of the constraints on s(K, W). Throughout the derivation we assumed that the constraints $0 \le s \le 1$ do not bind. A sufficient and necessary condition for an optimal zero share of risky assets is

$$s^{*}=0 \Leftrightarrow 0 \geq E\left[u'\left(y_2+WR_b\right)R_e\right]=u'\left(y_2+WR_b\right)E\left[R_e\right] \quad (16)$$

In other words, as long as expected excess returns are positive, households always invest some amount in stocks. This result is independent of the form of the utility function or the distribution of risky returns, but it assumes that trading risky assets is free. Moreover, the result is true for any risk (σ) and wealth (W) levels. Viewing it another way, this formula points out a mechanism that creates non-participation without fixed costs of trading. Some people may decide not to invest in their financial knowledge and facing inferior returns they rationally stay out of the stock market. Empirical studies find that poorer households are more likely to stay out of the labor market. Given that the benefit of learning is higher for the rich while the costs are not, our model predicts this empirical relationship even without assuming participation constraints or costs. Participation costs likely increase the difference between the investment behavior of richer and poorer households.

After the extensive margin of stock market participation, let's look at the upper limit on the share of risky returns ($s \leq 1$). A sufficient and necessary condition for the constraint to bind is

$$0 \leq E\left[u'\left(y_2+WR\right)R_e\right] \quad (17)$$

That is, the larger the excess returns are on stocks, the more likely households will invest all their savings in these risky assets. This is more likely for more knowledgeable households, but conditional on knowledge it is more likely for the poor (low *W*).[14]

A5. Setup of the simulation exercise

In this section we graphically illustrate the results of this simple model. We are interested in the optimal amount of financial knowledge (*K*), financial wealth (*W*) and portfolio choice (*s*) for various exogenous parameter values. The direct effect of fluid intelligence can be illustrated by varying the unit cost of financial knowledge (*p*): smarter people face lower costs of acquiring financial knowledge. Beyond, we also look at the effect of earnings: smarter people are more likely to earn more.

The goal of this section is illustration rather than precise calibration. While some parameters are chosen based on the literature, others are selected in an ad hoc fashion to make the graphs illustrative. The used parameters are:

$$y_1 = 2$$

$$y_2 = 1$$

[14] It can be easily shown, for example, that as *W* goes to zero, the condition will be satisfied as long as expected excess returns are positive.

$$p = 0.0065$$

$$\gamma \in \{2;4;6\}$$

$$R_b^{yearly} = 1.02$$

$$\beta^{yearly} = 1/R_b^{yearly}$$

Income is normalized to 2 in period 1 and the replacement rate of pension income is 0.5. Yearly risk-free return is 2% and the number of years is set to 20 in both periods. The discount rate is equal to the inverse of the risk-free return. The CRRA γ has two roles in the model. It is both the parameter of risk-aversion and the inverse of the intertemporal elasticity of substitution. Higher γ means higher risk aversion and lower elasticity of substitution. Although there is no agreement in the literature about the value of γ, it is generally believed to be below 10 (Kocherlakota, 1996). Because the results are very sensitive to this parameter we run all simulations for three different values of γ.

The unit cost of knowledge is set to 0.0065. Finally we need to specify how knowledge affects the return on stocks. We use the following functional form assumptions for the yearly gross returns:

$$\mu(K) = 1 + \mu^{hist}\left(1 - \exp\left(-\delta_\mu K\right)\right)$$

$$\sigma(K) = \frac{\delta_{\sigma 2}\sigma^{hist}}{\delta_{\sigma 2} - \exp\left(-\delta_{\sigma 1}K\right)}$$

μ^{hist} and σ^{hist} refer to the historical moments of a broad stock mutual fund (like the Dow Jones Industrial Average). Our functional form assumptions imply that the expected return on stocks approaches the historical average in a marginally decreasing rate; and the risk approaches the historical one in a marginally decreasing rate from above. The chosen parameter values are the following.

$$\mu^{hist} = 0.06$$

$$\sigma^{hist} = 0.15$$

$$\delta_\mu = 0.2$$

$$\delta_{\sigma 1} = 0.1$$

$$\delta_{\sigma 2} = 1.2$$

A6. Comparative statics

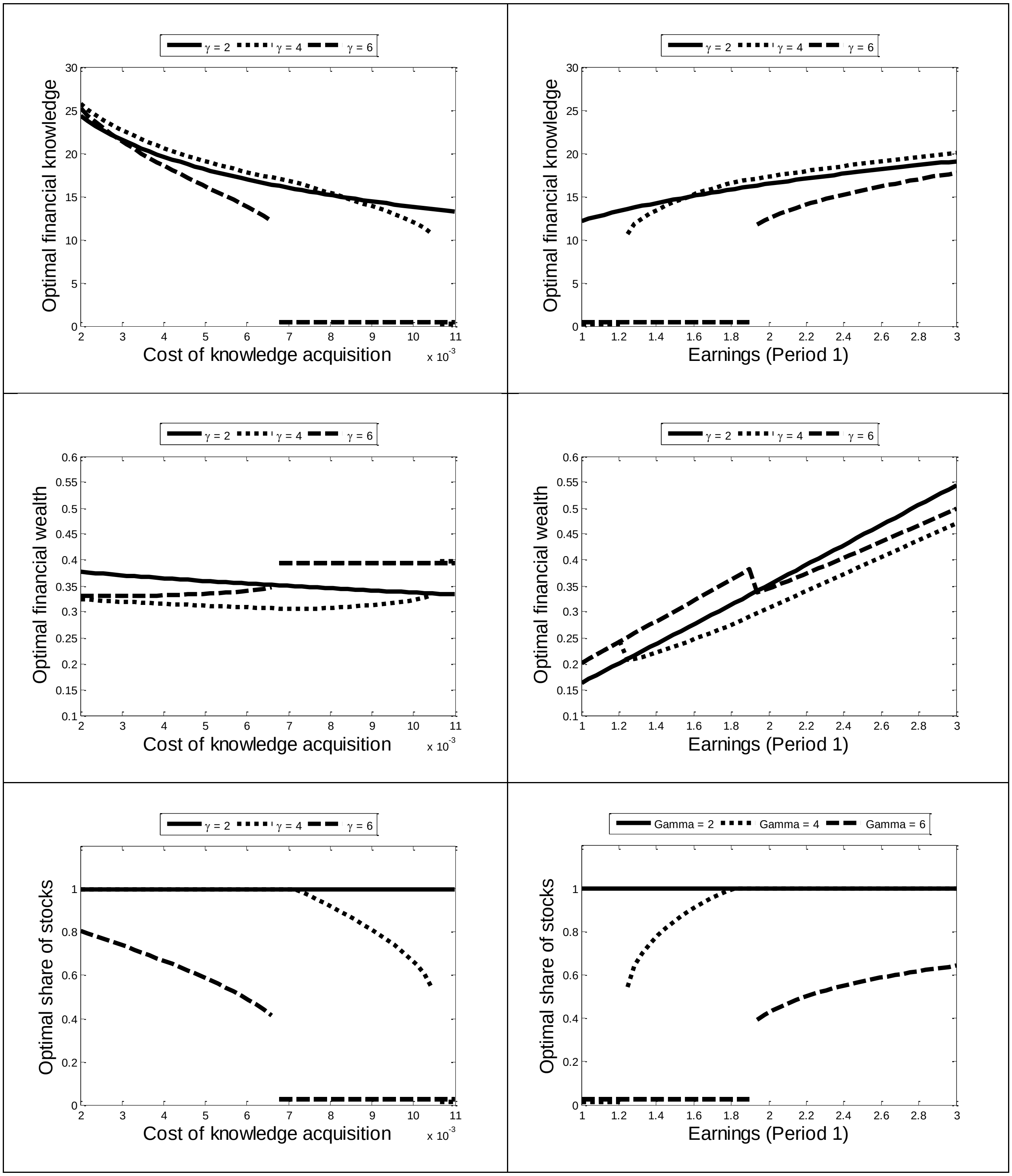

Figure 4: The effect of the unit cost of financial knowledge and lifetime earnings on knowledge acquisition, savings and portfolio choice in the general model

Column 1 of Figure 4 shows the effect of the unit cost of financial knowledge (the inverse of fluid intelligence on knowledge, financial wealth and the share of stocks in total savings. The second column shows the effect of earnings on the same variables. As we can see, smarter and richer persons are more likely to learn; conditional on learning they learn more; and they hold riskier portfolios. We can also see that those who do not learn do not hold any stocks either.

The effect on total savings is more complicated. In both figures we can observe a jump in savings at the point where individuals decide to learn. The jump occurs because learning is costly. Figure 4 also shows that more income in general leads to more savings. The only exception from this rule is those jump points that we just discussed. The effect of fluid intelligence on savings is ambiguous. The reason for this is that there are two competing effects. First, cheaper financial knowledge leaves more money at the households that induces more savings. Second, an increase in financial knowledge makes the portfolio more efficient that induces households to consume more and save less. The first can be thought of as an income effect and the second as a substitution effect of knowledge. The net of the two is ambiguous. As we can see on Figure 4, for low γ (low risk aversion and high intertemporal elasticity of substitution) the less knowledgeable individuals save less, while for high γ, they save more. It means that if households respond a lot to savings opportunities, than the substitution effect is more likely to dominate the income effect of knowledge on savings.

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Appendix B. Additional tables and figures

Table 10. Pairwise correlations of the fluid intelligence measures in CogEcon/CogUSA

	Number Series	Matrix Reasoning	Block Design	Concept Formation	Similarities	Verbal Analogies
Number Series	1.00					
Matrix Reasoning	0.66	1.00				
Block Design	0.60	0.66	1.00			
Concept Formation	0.50	0.44	0.44	1.00		
Similarities	0.54	0.56	0.43	0.43	1.00	
Verbal Analogies	0.58	0.56	0.51	0.45	0.50	1.00

Table 11. Financial knowledge score and the various measures of fluid intelligence in the CogEcon/CogUSA survey

Left hand-side variable: Financial knowledge score	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Number Series	0.256	0.403					
	[0.067]**	[0.052]**					
Matrix Reasoning	0.075		0.351				
	[0.073]		[0.056]**				
Block Design	0.064			0.311			
	[0.048]			[0.046]**			
Concept Formation	-0.036				0.216		
	[0.043]				[0.040]**		
Similarities	0.144					0.336	
	[0.060]*					[0.053]**	
Verbal Analogies	0.005						0.282
	[0.066]						[0.051]**
Constant	0.003	0.003	0.002	0.002	0.002	0.003	0.003
	[0.047]	[0.048]	[0.048]	[0.050]	[0.051]	[0.048]	[0.050]
Observations	825	825	825	825	825	825	825
R-squared	0.19	0.16	0.12	0.09	0.05	0.11	0.08

Table 12. The list of the financial knowledge questions (in the CogEcon and the ALP surveys)

Category	Item	Question
Financial knowledge	3	When an investor spreads money between 20 stocks, rather than 2, the risk of losing a lot of money decreases
	6	Mutual funds pay a guaranteed rate of return
	7	A young person with $100,000 to invest should hold riskier financial investments than an older person with $100,000 to invest
	8	It is easy to find mutual funds that have annual fees of less than one percent of assets
	10	Using money in a bank savings account to pay off credit card debt is usually a bad idea
	11	You could save money in interest costs by choosing a 15-year rather than a 30-year mortgage
	13	If the interest rate falls, bond prices will rise
	14	Taxes do not affect how you should invest your money
	17	It is best to avoid owning stocks of foreign companies
	19	You should invest most of your money in a few good stocks that you select rather than in lots of stocks or in mutual funds
	20	To make money in the stock market, you should not buy and sell stocks too often
	22	It is important to take a look at your investments periodically to see if you need to make changes
	25	Buying a stock mutual fund usually provides a safer return than a single company stock
Calculation	1	[...] $1000 in an investment that [...] would double in value to $2000 after 20 years. If so, that investment would not be worth $4000 for at least 45 years
	4	If you start out with $1,000 and earn an average return of 10% per year for 30 years, the initial $1,000 will have grown to more than $6,000
Trust	2	Financially, investing in the stock market is no better than buying lottery tickets
	12	There is no way to avoid people taking advantage of you if you invest in the stock market
	18	Older retired people should not hold any stocks
Ambiguous	5	The more you diversify among stocks, the more of your money you can invest in stocks
	9	If you are smart, it is easy to pick individual company stocks that will have better than average returns
	15	An employee of a company with publicly traded stock should have little or none of his or her retirement savings in the company's stock
	16	For a family with a working husband [...], life insurance that will replace three years of income is not enough life insurance
	21	If you have to sell one of your stocks, you should sell one which has gone up in price rather than one which has gone down
	23	[...] it is better for young people saving for retirement to combine stocks with long-term bonds than with short term bonds
	24	If you invest for the long run, the annual fees of mutual funds are unimportant

Table 13. Correlations of the financial knowledge items with the overall leave-one-out score as well as the number series score. True and false versions separately. Weighted pairwise correlation coefficients.

Panel A: CogEcon

		Correlations with the financial knowledge score from all items*		Correlations with the number series score	
	Item	True version**	False version**	True version**	False version**
Financial knowledge	3	0.24	0.52	0.07	0.33
	6	0.15	0.37	0.10	0.30
	7	0.31	0.44	0.22	0.25
	8	0.16	0.22	0.12	0.17
	10	0.07	0.26	0.13	0.33
	11	0.07	0.28	0.04	0.08
	13	0.16	0.16	0.12	0.12
	14	0.20	0.24	0.21	0.25
	17	0.22	0.38	0.08	0.20
	19	0.38	0.33	0.17	0.13
	20	0.13	0.35	0.02	0.25
	22	0.14	0.32	-0.01	0.20
	25	0.24	0.45	0.14	0.29
Calculation	1	0.29	0.27	0.26	0.27
	4	0.11	0.26	0.13	0.15
Trust	2	0.39	0.37	0.16	0.26
	12	0.23	0.29	0.08	0.24
	18	0.18	0.20	0.01	0.22
Ambiguous	5	-0.05	0.41	-0.26	0.26
	9	-0.11	0.16	-0.18	0.13
	15	-0.09	0.23	-0.14	0.14
	16	0.07	0.00	-0.01	-0.05
	21	-0.26	0.01	-0.13	-0.18
	23	-0.02	0.25	-0.01	0.10
	24	0.07	0.03	-0.04	0.00

* The financial knowledge score used for this correlation is created, for each variable, as a leave-me-out score (without including the variable in question

** Each item was asked in two formats: some respondents received the true version of the statement as a question while other respondents received the false version (respondents were randomized to question formats).

Panel B: ALP

	Item	Correlations with the financial knowledge score from all items*		Correlations with the number series score	
		True version**	False version**	True version**	False version**
Financial knowledge	3	0.15	0.37	0.06	0.23
	6	0.23	0.29	0.15	0.25
	7	0.17	0.39	0.14	0.24
	8	0.10	0.17	0.18	0.07
	10	0.15	0.32	0.07	0.10
	11	0.38	0.36	0.13	0.12
	13	0.03	0.24	0.13	0.09
	14	0.07	0.23	0.18	0.16
	17	0.41	0.35	0.16	0.13
	19	0.22	0.38	0.13	0.15
	20	0.07	0.39	-0.03	0.24
	22	0.14	0.42	0.20	0.29
	25	0.24	0.44	0.08	0.23
Calculation	1	0.11	0.25	0.20	0.21
	4	0.21	0.24	0.13	0.06
Trust	2	0.24	0.42	0.15	0.15
	12	0.23	0.13	0.15	0.18
	18	0.28	0.04	0.15	0.08
Ambiguous	5	-0.18	0.45	-0.15	0.25
	9	-0.14	0.16	-0.10	0.01
	15	-0.11	0.35	-0.08	0.08
	16	0.18	0.20	0.00	-0.01
	21	-0.29	-0.04	-0.16	-0.17
	23	0.08	0.19	0.09	0.09
	24	0.05	0.05	-0.02	0.12

* The financial knowledge score used for this correlation is created, for each variable, as a leave-me-out score (without including the variable in question

** Each item was asked in two formats: some respondents received the true version of the statement as a question while other respondents received the false version (respondents were randomized to question formats).

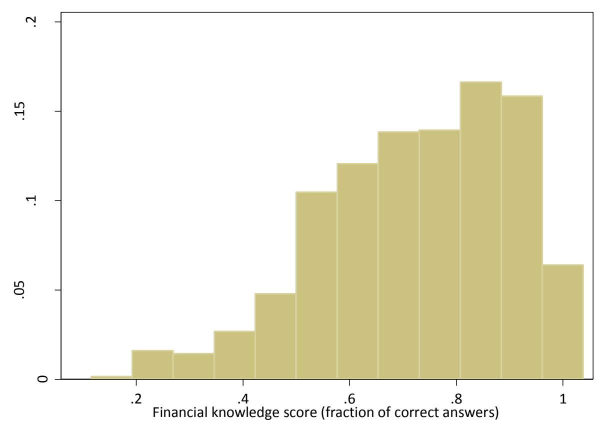
Table 14. Summary statistics of the of the financial knowledge score and the standardized number series score. Weighted and unweighted statistics, CogEcon and ALP samples.

Panel A: The CogEcon sample

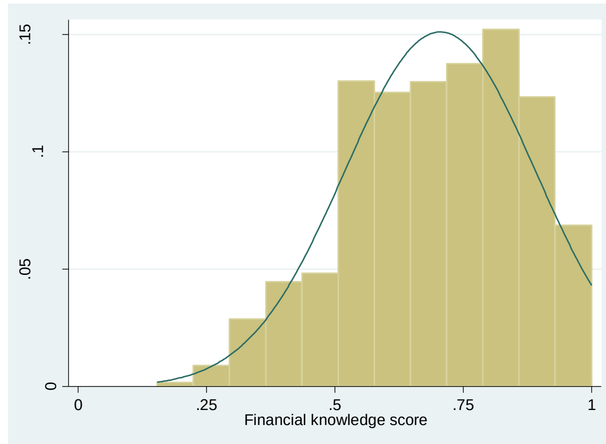
	Mean	Std. dev.	Min	25th pctile	50th pctile	75th pctile	Max	Obs.
CogEcon, weighted								
Financial knowledge score	0.73	0.18	0.15	0.62	0.77	0.85	1.00	825
Number series test score	0.00	1.00	-4.46	-0.64	-0.04	0.74	2.87	825
CogEcon, unweighted								
Financial knowledge score	0.76	0.17	0.15	0.62	0.77	0.92	1.00	825
Number series test score	0.25	0.95	-4.46	-0.49	0.23	0.98	2.87	825

Panel B: The ALP sample

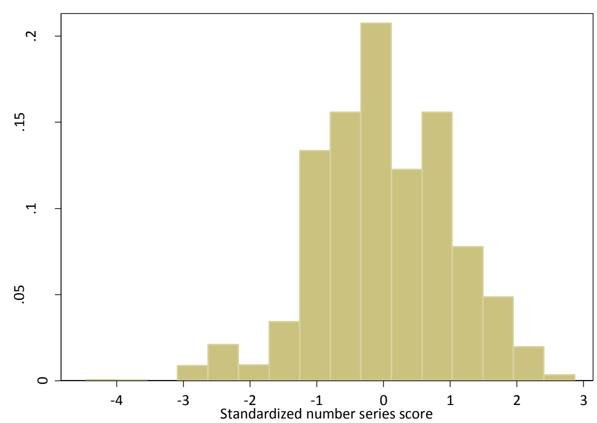
	Mean	Std. dev.	Min	25th pctile	50th pctile	75th pctile	Max	Obs.
ALP, weighted								
Financial knowledge score	0.71	0.19	0.15	0.54	0.69	0.85	1.00	1631
Number series test score	0.00	1.00	-5.34	-0.63	0.14	0.69	1.43	1631
ALP, unweighted								
Financial knowledge score	0.76	0.17	0.15	0.62	0.77	0.92	1.00	1631
Number series test score	0.20	0.92	-5.34	-0.29	0.39	0.75	1.43	1631



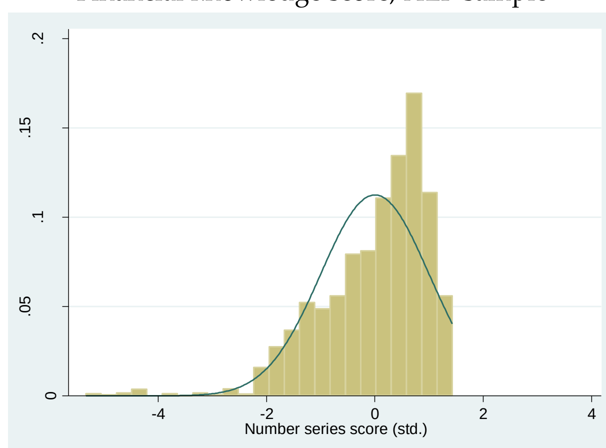
Panel A
Financial knowledge score, CogEcon sample



Panel B
Financial knowledge score, ALP sample



Panel C
Standardized number series score, CogEcon sample



Panel D
Standardized number series score, ALP sample

Figure 5. Histograms of the financial knowledge score (fraction of correct answers) and the standardized number series score. Weighted distributions.

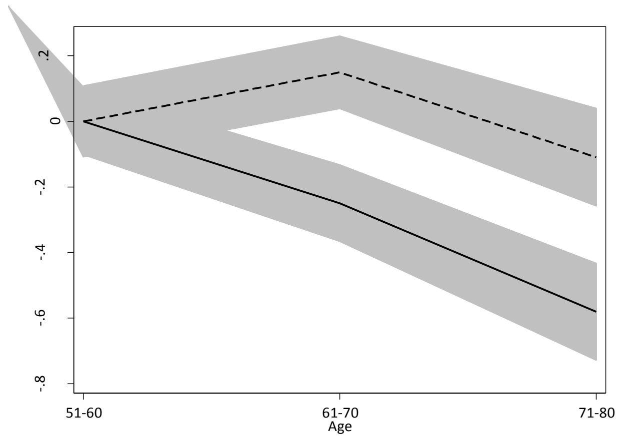
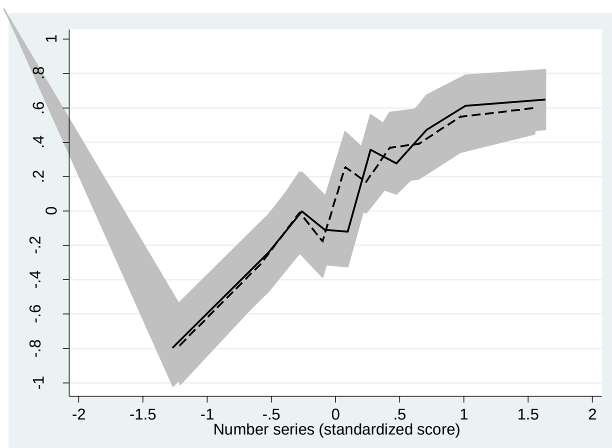
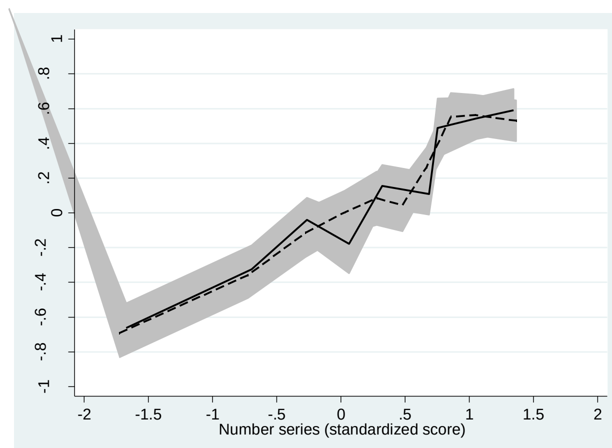


Figure 6.
Mean test score estimates of number series (solid) and financial knowledge (dashed) by age groups, with 95% confidence intervals (grey area)
Source: CogEcon survey.



Panel A
CogEcon sample



Panel B
ALP sample

Figure 7. Number series score and financial knowledge score: nonparametric regression results. Not age-adjusted scores (solid line) and age-adjusted scores (dashed line).

Table 15. Wording of the questions used to construct the measure of the quality of investment decisions

Item no.	Question
1	On average, about how often do you (or your spouse/partner) buy or sell stocks, bonds, or other investments, or change the allocations in a retirement account?
2a	Do you (or your spouse/partner) hold any of the following assets in RETIREMENT ACCOUNTS? Stock of a company that currently employs you or your spouse/partner.
2b	NOT INCLUDING what is in retirement or educational savings accounts, do you (or your spouse/partner) directly hold any of the following? Stock of a current employer?
3	In all, in how many different companies do you (or your spouse/partner) hold stock, outside of mutual funds?
4a	Do you (or your spouse/partner) hold any of the following assets in RETIREMENT ACCOUNTS? Balanced or life-cycle funds (funds that hold both stocks and bonds).
4b	… Global, international, emerging market, country or area funds (funds that focus on foreign investments).
4c	...U.S. index funds (funds that closely track broad market indexes, such as the S&P 500 index).
4d	...Other U.S. stock funds, such as growth, income, or value funds).
4e	NOT INCLUDING what is in retirement or educational savings accounts, what is the total value you (and your spouse/partner) hold in balanced or life-cycle funds (funds that hold both stocks and bonds)?
4f	… global, international, emerging market, country or area funds (funds that focus on foreign investments)?
4g	… U.S. index funds (funds that closely track broad market indexes, such as the S&P 500 Index)?
4h	… other U.S. stock funds such as growth, income or value funds?
4i	… any other mutual funds not entered above?