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Fearless Woman: Financial Literacy, Confidence, and Stock Market Participation

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Abstract. Women are less financially literate than men, and it has been difficult to determine whether this gap reflects a lack of knowledge or, rather, a lack of confidence. To address this important research question, we designed two survey modules that enable us to calculate the extent to which confidence matters for both financial literacy and behavior. We developed and estimated a model that provides a new measure of financial literacy and disentangles confidence from knowledge. We find that confidence accounts for about 30% of the gender difference in financial literacy. Moreover, both financial knowledge and confidence are linked to stock market participation. We also provide researchers with a method to account for confidence in regressions.

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Keywords: financial knowledge • gender gap • measurement error • financial behavior

1. Introduction

Financial literacy matters for financial decisions, including stock market participation, investment choices, retirement planning, and wealth accumulation (see Lusardi and Mitchell 2014, 2023 for reviews). At the same time, there is a universal gender gap in financial literacy (see Bucher-Koenen et al. 2017 for a review). This gender difference has been documented in developed and developing countries (Klapper and Lusardi 2020). In most countries, women, when surveyed, disproportionately indicate that they "do not know" the answers to financial literacy questions. This is true across measures of financial literacy as well as across sociodemographic characteristics and cultures. It is also true in other domains, such as debt or pension literacy (Bucher-Koenen et al. 2017). The higher fraction of "do not know" responses among women might, on the one hand, reflect lower actual knowledge. On the other hand, it might reflect lower confidence, which research in different fields of economic decision-making has shown can contribute to gender gaps. For example, recent evidence has shown the role of confidence in explaining gender gaps in salaries (Risse et al. 2018, Sterling et al. 2020), bargaining behavior (Biasi and Sarsons 2021), and intelligence test results (Harrison et al. 2021). The literature has also documented gender differences in confidence in finance and investing, with overwhelming evidence that women are less confident in the financial domain (see, e.g., Beyer 1990, Prince 1993, and Chen and Volpe 2002) and that confidence matters for financial behavior (see, e.g., Anderson et al. 2017, Barber and Odean 2001, and Cupák et al. 2022). Therefore, the higher fraction of "do not know" responses could be an indicator of women's lower confidence in financial topics.

We examine whether and the extent to which confidence contributes to the persistent gender gap in financial literacy and financial behavior. The central questions we address are, *Are women financially literate*

yet lacking confidence in their knowledge? and *Is lack of confidence or lack of financial knowledge related to gender differences in stock market participation?* Specifically, we would like to assess whether the observed financial literacy gender gap is affected by how financial literacy is measured. Do the "do not know" answers reflect lack of knowledge or lack of confidence? And does the way in which financial literacy is measured affect the assessment of its impact on behavior?

To address these questions, we designed two survey modules, which were fielded to participants from the De Nederlandsche Bank (DNB) Household Survey (DHS). The modules use the Big Three financial literacy questions, which measure knowledge about basic but fundamental financial concepts: interest compounding, inflation, and risk diversification. These questions were included in each module, and we altered the survey design as follows. In the first module, we used the standard setup, which includes a "do not know" (DK) response option among the possible answers. In the second module, fielded about six weeks after the first, we took away the DK option and asked respondents how confident they were in their answer choices. Our central hypothesis is that if individuals (specifically women) know the correct answer to the financial literacy questions but lack confidence, then the fraction of correct responses should increase when the option to select DK is not available.

Based on the data from these two survey modules, we developed and estimated a latent class model (LCM) to predict "true" financial literacy. For each concept (interest compounding, inflation, and risk diversification), our model predicts the probability that the respondent knows the answer, conditional on the responses to the financial literacy questions in the two modules, information on confidence, and background variables. In contrast to the financial literacy measures often used in the literature, in which the number of correct answers across the three questions is added up, we developed a more rigorous measure that took into consideration the fact that answers do not always have a zero or one characterization. Using this new measure, we assessed the impact of financial literacy on stock market participation, an important outcome variable that has implications for both wealth accumulation and financial well-being and which has been studied frequently in the context of financial literacy (see, e.g., Van Rooij et al. 2011 and Lusardi and Mitchell 2014).

Our results show a pronounced gender gap in financial literacy, confirming previous findings; women are less likely to answer the Big Three questions correctly and more likely to choose the DK option. However, taking away the DK response option substantially reduces the gender gap. Applying our novel LCM, we can decompose the gender gap into a gap in knowledge and a gap in confidence. Specifically, we find that about 70% of the financial literacy gender gap is explained by lower financial knowledge, and the remaining 30% is due to lower confidence. We also show that the way in which financial literacy is measured matters for stock market participation. We find that both factors—knowledge and confidence—are critical for understanding gender differences in stock market participation, so it is useful to have information on both.

The central contributions of this paper are as follows. First and foremost, we provide a novel approach to measuring financial literacy and show how we can better use the Big Three financial literacy questions in empirical research. They have been added to many surveys around the world and have become a standard measure of financial literacy (Lusardi and Mitchell 2023). So far, most empirical papers using the Big Three or related measures consider information only on correct answers (number of correct answers, indicators for correct answers on specific questions or sets of questions). Almost all studies treat the DK responses as indicators of lack of knowledge; that is, when using dummies for financial literacy, DK responses are simply assigned a zero value.[1] Using our research design (survey experiment and LCM), we can show that this way of treating DK responses systematically results in an underestimation of financial knowledge, especially for respondents who lack confidence in their knowledge. The LCM enables us to separately measure "true" financial literacy and confidence.[2] This is important because good measurement forms the basis of rigorous research and is essential to making progress in the field (Lusardi and Mitchell 2023). The literature on financial literacy has grown rapidly in the past decade, and most empirical work in this field includes measures of financial literacy akin to the Big Three.[3]

Second, our study contributes to the literature investigating the role of gender differences in response behavior and survey measurement. For example, Luskin and Bullock (2011) investigated the role of DK responses in the measurement of political knowledge. Coffman (2014a) and Riener and Wagner (2017) found that women and girls are more likely to skip questions in multiple choice settings.[4] Davoli (2023) showed that the gender gap in financial literacy depends on the question format. Importantly, our study documents that these response patterns matter for financial literacy and financial behavior.

Third, we contribute to the literature on the gender gap in financial literacy. Fonseca et al. (2012) and Hsu (2016) suggested that, within households, men specialize in financial decision-making, but gender differences are also found among single people and teenagers (see Lusardi and Mitchell 2014, Driva et al. 2016, and Bucher-Koenen et al. 2017). History and gender norms also play an important role (see, e.g., Davoli and Rodrigues-Planas 2022). Ke (2021) is one of the first studies to systematically examine gender norms and

their influence on household financial decision-making. However, Filipiak and Walle (2015) showed that a sizable portion of financial literacy differences between women living in matrilineal and patriarchal societies remain unexplained and suggest nurture as a potential reason for those differences. Our work shows that as much as one-third of the gender difference in financial literacy can be attributed to lack of confidence.

Finally, we add to the growing literature on gender differences in long-term wealth accumulation. Much of the literature on gender differences in the economic domain has focused on gender differences in income and labor market participation.[5] Analyzing gender differences in wealth and financial decision-making is increasingly relevant, given, for example, the shift in responsibility for retirement savings onto workers and the importance of investing in the stock market in order to grow wealth. The literature shows that women, on average, hold lower amounts of wealth (see, e.g., Lusardi and Mitchell 2008 and Neelakantan and Chang 2010). Moreover, there is increasing evidence of differential treatments by financial institutions, including evidence from field experiments (see, e.g., Bhattacharya et al. 2024) and real-world data from advisor protocols (Bucher-Koenen et al. 2015) that women get lower-quality financial advice. Against this backdrop, it is important to understand the nature of gender differences in financial literacy, because such differences have been shown to be a crucial determinant of behavior, including retirement planning, wealth accumulation, and debt management (see reviews by Lusardi and Mitchell 2014, 2023). Specifically, in the context of our interest, more financially literate individuals are more likely to invest in the stock market (Van Rooij et al. 2011), hold better-diversified portfolios (Von Gaudecker 2015), earn higher returns (Bianchi 2018), and accumulate more wealth (Van Rooij et al. 2012, Lusardi et al. 2017). Our paper examines the role of financial literacy and confidence in explaining gender differences in stock market participation.

Examining gender gaps in financial literacy is also relevant from a broader economic and societal perspective. Even before the onset of the COVID-19 pandemic, women were found to be more financially fragile than men and to lack buffer stocks of savings (Hasler and Lusardi 2019). Moreover, women own fewer assets, are less likely to have pensions, and are less likely to invest in higher risk but also higher return assets. These differences are consequential. For example price-adjusted historical returns show that savings invested in risk-free assets versus stocks result in large differences in wealth holdings over a long period of time.[6]

We recognize that many researchers do not have access to the type of data we were able to collect to measure financial literacy and assess its impact on behavior. Our work shows that there is a simple remedy: to include the number of DK responses in addition to the number of correct answers to the financial literacy questions in empirical regressions assessing the impact of financial literacy on behavior. In other words, the information provided by the Big Three financial literacy questions is very rich and can be used more systematically.

The paper is organized as follows. In Section 2, we describe the data and report descriptive statistics on financial literacy based on the two modules of DHS data. In Section 3, we describe our econometric strategy for measuring financial literacy when there are differences in confidence across gender and possibly other personal traits. In Section 4, we explore the relationship between measures of financial literacy and financial behavior, and in Section 5, we explore the role of confidence. In Section 6, we discuss how we can make use of the DK answers. We provide concluding remarks in Section 7.

2. Data and Descriptive Evidence

2.1. The Data

We use data from the DHS, which is an online panel by the Dutch Central Bank and collected by Centerdata. The sample is representative of the Dutch-speaking population in The Netherlands.[7] The Central Bank of The Netherlands has collected financial literacy data for many years[8] and is one of the few central banks that have pioneered collecting such data; similar data have increasingly been collected in other national surveys around the world, including in the United States. We merge data from DHS with two survey models we designed to understand the gender gap in financial literacy, particularly what drives the gender difference in the DK responses. We focus on the Big Three questions only because they have become the traditional and more widely accepted measures of financial literacy and have been included in more than 20 national surveys around the world.[9] The exact wording of the questions is as follows (we indicate the correct answer with *):

1. **Interest question:** *Suppose you had €100 in a savings account and the interest rate was 2% per year. After 5 years, how much do you think you would have in the account if you left the money to grow? More than €102*/Exactly €102/Less than €102/Do not know (DK)/Refuse to answer*

2. **Inflation question:** *Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, how much would you be able to buy with the money in this account? More than today/Exactly the same/Less than today*/Do not know (DK)/Refuse to answer*

3. **Risk diversification question:** *Please tell me whether this statement is true or false. "Buying a single company's stock usually provides a safer return than a stock mutual fund." True/False*/Do not know (DK)/Refuse to answer*

We design the surveys in the following way: We ask the Big Three financial literacy questions to the same

respondents twice. When we asked the financial literacy questions in May 2012 (May module), respondents faced the standard list of response options, which includes the DK option.[10] When respondents were asked the same questions for the second time about six weeks later, at the end of June/beginning of July 2012 (July module), the DK options were not included. In the July module, each literacy question was followed by a new question that asked respondents to rate their level of confidence as follows:

Confidence question: *On a scale from 1 to 7, how confident are you in this answer? 1—not confident at all … 7—completely confident.*

Our sample includes all panel members who are household heads and their partners. Respondents were age 18 and older. For our analysis, we restricted the sample to respondents who participated in both the May and July modules (balanced panel). Because we allowed both the household head and his or her partner to participate, we often have two observations for each household (in the regression analysis, therefore, standard errors are clustered at the household level). We drop the small number of respondents who did not complete the financial literacy modules.[11] Our final sample contains 1,532 respondents; 861 (56.2%) are men and 671 (43.8%) are women. Further sociodemographic characteristics of our sample are provided in the summary statistics in Online Appendix Table A.1.

Because we work with a balanced panel, we consider whether attrition and learning effects are likely to affect our findings. To test for attrition between the modules, we partition the sample into those who participated in the May module only (N = 222) and those who participated in both modules (N = 1,532). We do not find a systematic difference in the average financial literacy of those groups. Thus, respondents did not systematically drop out after the May module based on their financial literacy. The same is true for attrition based on gender. Men and women both dropped out after the May module with equal probability (see Online Appendix Table A.2.1, panel A).

Because the same group of respondents was asked the same questions twice, there could be concern about learning effects. We can test for learning by comparing the group of respondents who participated in the July module only (N = 445) with the group who participated in both modules (N = 1,532). The former group of respondents answered only the questions without the DK option. If we were to find a higher probability of correctly answering the financial literacy questions among the participants who participated twice, we could attribute the difference to having seen the questions before. The results of this exercise are shown in Table A.2.1, panel B, in the Online Appendix. There are no significant differences in the responses of those two groups. We also split the sample by gender and do not find learning effects for men or women. Thus, learning effects are not confounding our results.

2.2. Comparing Answers Across Modules

In Table 1, we present the answers to the three financial literacy questions for both the May and July modules separately for men and women.

Looking at the question that assesses understanding of compound interest (the "interest question"), which is the simplest question of the Big Three, we find that men are significantly more likely than women to answer correctly (91.9% versus 84.4%, see Table 1, panel A) in the May module. The gender gap for this question is 7.5 percentage points. There is a higher share of women reporting incorrect answers, but women also more often report DK answers compared with men. Whereas 6.7% of the women reply DK to this question, only 2.8% of the men choose the DK option. We compare the distribution of answers across answer options between men and women using a χ^2-test and find that the differences in answer patterns are statistically significant. In the July module, we ask the same question, this time without the DK option. The number of correct answers increases to 94.7% for men and 91.2% for women (again, the distribution of answers differs significantly between men and women). The number of incorrect answers also increases. However, overall, the gender difference shrinks by half, to 3.5 percentage points (the change is statistically significantly different from zero). Interestingly, when we look at the responses to this question in July for those who chose DK in May (see Table 2), we find that the majority of respondents are able to provide the correct answer. Around 70% of both men and women who responded DK to this question in the May module are, in fact, able to correctly answer the question in the July module. A test against random guessing shows that both men and women are significantly more often choosing the correct answer compared with what would have occurred if they had chosen a random answer.[12]

The question that measures respondents' knowledge of the workings of inflation (the "inflation question") is somewhat more difficult for respondents to answer. The number of correct answers is lower than for the previous question, and the gender gap is now larger, at more than nine percentage points (see Table 1, panel B). The DKs again drive two-thirds of the gender gap, and the number of incorrect answers is also somewhat higher among women. Comparing the answering behavior of men and women reveals significantly different answer patterns. When forced to answer, that is, when the DK option is taken away, the gender gap diminishes from nine to six percentage points. This is again because those who responded DK to this question in the May module are, in fact, often able to provide the correct answer when forced to make a choice.

Table 1. Answers to the Financial Literacy Questions in the Two Modules

		May module			July module	
Financial literacy questions and responses	Men	Women	All	Men	Women	All
Panel A: Interest						
More than 102 euro[a]	91.9	84.4	88.6	94.7	91.2	93.1
Exactly 102 euro	3.0	4.0	3.5	3.7	6.0	4.7
Less than 102 euro	2.0	3.9	2.8	1.6	2.8	2.2
Do not know	2.8	6.7	4.5	—	—	—
Refuse	0.3	1.0	0.7	—	—	—
Total	100	100	100	100	100	100
p-value χ^2-test	<0.001			<0.001		
Panel B: Inflation						
More	2.1	2.4	2.2	2.2	2.7	2.4
Exactly the same	3.3	5.4	4.2	4.1	9.8	6.6
Less[a]	89.8	80.6	85.8	93.7	87.5	91
Do not know	4.6	10.7	7.3	—	—	—
Refuse	0.2	0.9	0.5	—	—	—
Total	100	100	100	100	100	100
p-value χ^2-test	<0.001			<0.001		
Panel C: Risk diversification						
Incorrect "right"	7.5	9.7	8.5	17.7	27	21.7
Correct "false:[a]	61.9	34.4	49.9	82.3	73	78.3
Do not know	30.1	54.7	40.9	—	—	—
Refuse	0.5	1.2	0.8	—	—	—
Total	100	100	100	100	100	100
p-value χ^2-test	<0.001			<0.001		
Panel D: No. of correct answers						
0	3.6	6.6	4.9	0.5	0.7	0.6
1	7.3	16.8	11.5	3.3	6.9	4.8
2	31	47.2	38.1	21.4	32.3	26.2
3	58.1	29.4	45.5	74.9	60.1	68.4
p-value χ^2-test	<0.001			<0.001		

Notes. Data from the DNB Household Panel. Surveys on financial literacy were fielded in May and July 2012. In the July module, the DK option was not offered. We report percentages of total number of respondents. Number of observations: men: 861; women: 671; total: 1,532. The p-value of a χ^2-test refers to a test on the difference in the distribution of responses between men and women.
[a]Correct answers.

Table 2. Answers in the July Module Conditional on Answers in the May Module

	Men			Women		
July module\May module	Incorrect	Correct	Do not know	Incorrect	Correct	Do not know
Panel A: Interest						
Incorrect	23.3	3.5	29.6	28.3	5.0	30.8
Correct	76.7	96.5	70.4	71.7	95.0	69.2
Total	100	100	100	100	100	100
Panel B: Inflation						
Incorrect	41.3	2.7	33.3	30.8	7.0	38.5
Correct	58.7	97.3	66.7	69.2	93.0	61.5
Total	100	100	100	100	100	100
Panel C: Risk diversification						
Incorrect	38.5	10.3	27.4	47.7	12.6	32.3
Correct	61.5	89.7	72.6	52.3	87.4	67.7
Total	100	100	100	100	100	100

Notes. Data from the DNB Household Panel. Surveys on financial literacy were fielded in May and July 2012. In the July module, the DK option was not offered. We report the percentage of correct and incorrect answers given in the July module, depending on the responses given in the May module for each of the financial literacy questions. Number of observations: men: 861; women: 671; total: 1,532.

The test against random answering is rejected; both men and women are significantly more likely to choose the correct answer (see Online Appendix A.2). Nevertheless, within the DK group, men more often than women provided a correct answer when forced to make a choice (67% for men versus 62% for women; see Table 2, panel B).

The third question assesses knowledge of the workings of risk diversification (the "risk" question). For this question, the proportion of DK answers is much higher for both men and women, but especially for women. In the May module, more than half of the women indicate that they do not know the answer to this question (54.7%) compared with 30.1% of the men; again, the differences in answer patterns between men and women are statistically significant (see Table 1, panel C). The gender gap for this question is as high as 27.5 percentage points. Strikingly, in the July module, the gap shrinks to nine percentage points. The majority of women and men who chose DK in the May module are, in fact, able to answer this question correctly in the July module. As before, the increase in correct responses is significantly higher compared with what would have occurred if respondents had chosen randomly (see Online Appendix A.2). Again, the proportion of correct answers is higher for men than for women (72.6% versus 67.7%; see Table 2, panel C).

Table 1, panel D, shows the number of correct answers to the Big Three. The probability of answering all three questions correctly increases from 58.1% to 74.9% for men and from 29.4% to 60.1% for women between the May and the July modules. The gender gap shrinks by about half, from 29 to 15 percentage points.

To summarize, we confirm a gender gap in financial literacy. This is due in part to women more often stating they do not know the answer—when given the option to do so—to the financial literacy questions. When respondents are forced to answer, the gender gap decreases substantially (but does not disappear). The DK answers may signal that respondents are not sure of being correct, even though there is a high likelihood that they are. Indeed, conditional on responding DK in the May module, both men and women are, in fact, likely to give a correct answer to each of the three questions in the July module.

2.3. Confidence in Knowledge

When the DK option is taken away, respondents are asked to rank their confidence in their answers on a scale from 1 (not confident at all) to 7 (completely confident). Average scores for all three questions for men and women are reported in Table 3. Overall, the results confirm that women are significantly less confident in their answers than men. A large fraction of men are very confident in their answers (ratings of 6 or 7), but this is not true for women, who report much lower levels of confidence. Comparing the average ratings for the three questions shows that respondents are fairly confident in their answers to the interest and inflation questions, which are relatively simple questions. Subjective confidence ratings for the more difficult risk question are lower.

We turn next to evaluate the confidence levels from the July module, conditional on the respondent's answers to the same questions in the May module. Conditional on giving a correct answer in the May

Table 3. Confidence in Financial Literacy

	All			Men			Women		
Confidence and financial literacy	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD
Panel A: Interest									
Overall confidence	1,532	6.34	1.35	861	6.52	1.24	671	6.11	1.44
Conditional on incorrect	96	5.45	1.74	43	5.47	1.86	53	5.43	1.66
Conditional on correct	1,357	6.52	1.15	791	6.64	1.11	566	6.35	1.19
Conditional on "do not know"	79	4.39	1.88	27	4.81	1.62	52	4.17	1.98
Panel B: Inflation									
Overall confidence	1,532	5.97	1.58	861	6.34	1.36	671	5.49	1.72
Conditional on incorrect	98	4.87	1.91	46	4.96	1.99	52	4.79	1.86
Conditional on correct	1,314	6.25	1.34	773	6.53	1.15	541	5.84	1.49
Conditional on "do not know"	120	3.83	1.69	42	4.33	1.56	78	3.56	1.70
Panel C: Risk diversification									
Overall confidence	1,532	4.82	1.73	861	5.33	1.60	671	4.15	1.66
Conditional on incorrect	130	4.85	1.48	65	5.34	1.31	65	4.35	1.48
Conditional on correct	764	5.55	1.47	533	5.84	1.35	231	4.90	1.53
Conditional on "do not know"	638	3.93	1.64	263	4.31	1.63	375	3.66	1.60

Notes. Data from the DNB Household Panel. Respondents report confidence levels on a Likert scale from 1 to 7 after each question in the July module. We report the overall confidence levels for each question and confidence conditional on the answers given in the May module for each of the financial literacy questions. Number of observations: men: 861; women: 671; total: 1,532.

module, we find that women are significantly less confident than men in their answers in the July module for all questions. Thus, even when they pick the correct answer, women are not confident in their knowledge. Conditional on answering DK in the May module, women are again less confident in their answers in the July module compared with men. The difference is not statistically significant for the first two questions (potentially because of the much lower number of DK responses), but it is statistically significant for the risk diversification question. Moreover, respondents who selected a DK answer in the May module are, on average, much less confident compared with those who chose an answer, whether correct or incorrect, in the May module.[13] Overall, women are less confident than men, irrespective of their answers in the May module.

One potential interpretation of the observed pattern is that men are overconfident in their financial literacy. This could make them more willing to guess, that is, not choose the DK response option in the May module and rate themselves high on the subjective confidence scale in the July module. However, in that case, the pattern of answers in the July module, when no DK option is available, should look different. If men (or women) are overconfident but in fact do not know the answers to the financial literacy questions, we would expect that the likelihood of selecting the correct answers does not differ significantly from random guessing. What we find instead is a significantly higher number of correct answers after taking away the DK option compared with what would have occurred had respondents picked the answers at random. We test this formally by comparing actual responses with variables that take a probability of being correct conditional on a DK response of 1/3 for the interest question, 1/3 for the inflation, and 1/2 for the risk question, respectively, depending on the available answer options.[14] We report the results in Online Appendix 2. Moreover, if men are more willing to guess, then conditional on giving an answer (not selecting the DK option) in May, men should be more likely to give inconsistent answers across the two surveys. To check if this is the case, we ran χ^2-tests on the difference in the distribution of the answering patterns between men and women. Online Appendix 2 reports how consistent the answers are across the two surveys for men and women. Results show that for all three questions, there is a significant difference in the answering patterns between men and women. However, contrary to the hypothesis that men are overconfident and thus would more often report inconsistent answers, we find a lower fraction of inconsistent answers among men. Overall, men are not more likely to guess, and such guessing behavior can be ruled out as a major driver for the response patterns that we find. We will investigate this further in Section 5.

In summary, the financial literacy scores in the May module reflect both knowledge and confidence. The financial literacy measure resulting from the July module, in which respondents were forced to pick an answer, is not confounded by confidence. At the same time, the July measure is likely to contain measurement error and to be upward biased because respondents without knowledge may simply guess the correct answer. Thus, taking away the DK option does not necessarily lead to a better measure of financial literacy or provide a superior way to measure financial knowledge. In the next section, we use information from both survey modules and develop an LCM to estimate a measure of "true" financial literacy.

3. Modeling "True" Financial Literacy

To get a measure of "true" financial literacy, we estimated each respondent's probability of truly knowing the answer to the financial literacy question, depending on the structure of their responses to the question in the two survey modules and the response to the confidence question. For this purpose, we set up an LCM.

The descriptive statistics reported above show that respondents, particularly women, are inclined to pick the DK option when they are not confident in their knowledge, even if they may actually know the correct answer. This leads to a systematic bias with respect to gender in the measurement of financial literacy. On the other hand, some respondents seem to pick answers randomly. Thus, answers may be correct simply because of random guessing. Therefore, just counting the number of correct answers, as it is usually done in the literature (including our own previous work), creates noisy financial literacy measures.

The main contribution of the LCM is to disentangle "true" knowledge to be able to calculate a financial literacy index with minimal measurement error. For this purpose, we derive a measure of "true" financial knowledge based on the structure of the two survey modules, using respondents' confidence in their answers to correct for guessing. Based on this information, we predict the probability that a respondent truly knows the correct answer. Our new financial literacy index is the sum of these probabilities for the three individual financial literacy questions (rather than simply using a value of zero or one, as in the count of correct answers commonly used in the literature). As in the standard measure, these probabilities take the value of one if a respondent knows the correct answer for certain and take the value of zero if the respondent does not know the correct answer for certain. However, for some respondents, these probabilities now take values between zero and one; this is the case, for example, for respondents who chose DK in the May survey but do in fact know the answer with some degree of confidence. As we will show in the next

section, providing a good measure of financial literacy has implications for assessing its impact on financial behavior.

We define for each of our three financial literacy questions the following latent variable for "true" knowledge:

$\tilde{y}_{ik} = 1$ if respondent i truly knows the correct answer to financial literacy question k $(k = 1, 2, 3)$,

$\tilde{y}_{ik} = 0$ otherwise.

We do not observe $\tilde{y}_{ik}$, but we do observe some proxies for this variable; let y_{ik}^m be the individual's i answer to literacy question k in May (superindex m). Notice that y_{ik}^m can take on the following three values: 0 (incorrect answer), 1 (correct answer), or 2 (do not know/refusal). Because the July module does not allow for a DK option, the variable y_{ik}^j (the answer of individual i to question k in July j) can only take on the values 0 and 1. As previously noted, instead of the DK option, the July module has a follow-up question that measures the level of confidence in the response on a Likert scale (from 1 to 7), represented by the variable $conf_{ik}^j$. We can use the information provided by a vector of background characteristics $\boldsymbol{x}_i$ and the variables y_{ik}^m, y_{ik}^j, and $conf_{ik}^j$ to predict the probability that a respondent truly knows the answer to financial literacy question k. In other words, for each respondent in our sample and for each of our three financial literacy questions, we will compute the following conditional probability:

$$P(\tilde{y}_{ik} = 1 | y_{ik}^m, y_{ik}^j, \boldsymbol{x}_i, conf_{ik}^j);\ k = 1, 2, 3 \tag{1}$$

Second, we construct an index measure of financial literacy by adding up the probabilities of knowing (i.e., having "true" knowledge of) the three financial literacy questions:

$$finlit_i = \sum_{k=1}^{3} P(\tilde{y}_{ik} = 1 | y_{ik}^m, y_{ik}^j, \boldsymbol{x}_i, conf_{ik}^j). \tag{2}$$

In the next subsection, we present an LCM that can be used to predict the probability (see Equation 1) that the respondent truly knows the answer to the financial literacy question k $(k = 1, 2, 3)$.

3.1. The Latent Class Model

We start by defining a random variable, g_{ik}, that summarizes the answers we observe in the May and July modules into all possible combinations of answers: $g_{ik} = 3 \cdot y_{ik}^j + y_{ik}^m$. In other words, this multinomial variable can take on six different values (from 0 to 5), depending on the combination of answers given in the two modules. For example, $g_{ik} = 0$ if respondent i answers question k incorrectly in both modules, and $g_{ik} = 4$ if the respondent answers correctly in both modules. The log-likelihood of our LCM is based on the conditional multinomial probability of g_{ik}: $P(g_{ik} = g | \boldsymbol{x}_i, conf_{ik}^j)$. This conditional probability can be written as a weighted average of two multinomial probabilities $P(g_{ik} = g | \tilde{y}_{ik} = 1, \boldsymbol{x}_i, conf_{ik}^j)$, that is, the probability of observing answer pattern $g_{ik} = g$ given true knowledge $(\tilde{y}_{ik} = 1)$, and $P(g_{ik} = g | \tilde{y}_{ik} = 0, \boldsymbol{x}_i, conf_{ik}^j)$, that is, the probability of observing answer pattern g_{ik} given a lack of true knowledge $(\tilde{y}_{ik} = 0)$, where the probabilities for having or not having true knowledge, that is, $P(\tilde{y}_{ik} = 1 | \boldsymbol{x}_i, conf_{ik}^j)$ and $P(\tilde{y}_{ik} = 0 | \boldsymbol{x}_i, conf_{ik}^j)$, serve as weights,

$$\begin{aligned} P(g_{ik} = g | \boldsymbol{x}_i, conf_{ik}^j) &= P(g_{ik} = g, \tilde{y}_{ik} = 1 | \boldsymbol{x}_i, conf_{ik}^j) \\ &\quad + P(g_{ik} = g, \tilde{y}_{ik} = 0 | \boldsymbol{x}_i, conf_{ik}^j) \\ &= \alpha_g^1(\boldsymbol{x}_i, conf_{ik}^j) P(\tilde{y}_i = 1 | \boldsymbol{x}_i, conf_{ik}^j) \\ &\quad + \alpha_g^0(\boldsymbol{x}_i, conf_{ik}^j) P(\tilde{y}_i = 0 | \boldsymbol{x}_i, conf_{ik}^j), \end{aligned} \tag{3}$$

where the conditional multinomial probabilities are defined as

$$\alpha_g^1(\boldsymbol{x}_i, conf_{ik}^j) = P(g_{ik} = g | \tilde{y}_{ik} = 1, \boldsymbol{x}_i, conf_{ik}^j)$$
$$\alpha_g^0(\boldsymbol{x}_i, conf_{ik}^j) = P(g_{ik} = g | \tilde{y}_{ik} = 0, \boldsymbol{x}_i, conf_{ik}^j).$$

We assume that, conditional on background characteristics $\boldsymbol{x}_i$, true knowledge is independent of confidence. This means

$$P(\tilde{y}_{ik} = 1 | \boldsymbol{x}_i, conf_{ik}^j) = P(\tilde{y}_{ik} = 1 | \boldsymbol{x}_i). \tag{4}$$

In other words, only the answers g_{ik} are influenced by confidence, but whether a respondent truly knows the correct answer or not is independent of confidence. In addition, we assume that the probability in Equation (4) can be modeled by means of a probit specification so that the conditional probability that respondent i truly knows the answer to literacy question k is equal to

$$P(\tilde{y}_{ik} = 1 | \boldsymbol{x}_i) = \Phi(\boldsymbol{x}_i' \boldsymbol{\beta}_k), \tag{5}$$

where $\Phi(.)$ denotes the cumulative distribution function of the standard normal distribution. We also assume that $\alpha_g^1(\boldsymbol{x}_i, conf_{ik}^j) = \alpha_g^1(conf_{ik}^j)$ and $\alpha_g^0(\boldsymbol{x}_i, conf_{ik}^j) = \alpha_g^0(conf_{ik}^j)$; thus, the observed answer pattern depends on true knowledge and confidence but not on any additional background characteristics. The following two probabilities are modeled by using a multinomial logit specification $(I(conf_{ik}^j = l) = 1$ if $conf_{ik}^j = l$ and $I(conf_{ik}^j = l) = 0$ otherwise),[15]

$$\alpha_g^1(conf_{ik}^j; \boldsymbol{\gamma}_k^1) = \frac{\exp\left(\sum_{l=1}^{7} \gamma_{kgl}^1 I(conf_{ik}^j = l)\right)}{\sum_{h=0}^{5} \exp\left(\sum_{l=1}^{7} \gamma_{khl}^1 I(conf_{ik}^j = l)\right)} \tag{6a}$$

$$\alpha_g^0(conf_{ik}^j; \boldsymbol{\gamma}_k^0) = \frac{\exp\left(\sum_{l=1}^{7} \gamma_{kgl}^0 I(conf_{ik}^j = l)\right)}{\sum_{h=0}^{5} \exp\left(\sum_{l=1}^{7} \gamma_{khl}^0 I(conf_{ik}^j = l)\right)}, \tag{6b}$$

where $\boldsymbol{\gamma}_k^1 = (\boldsymbol{\gamma}_{k01}^1, \ldots, \boldsymbol{\gamma}_{k07}^1, \ldots, \boldsymbol{\gamma}_{k51}^1, \ldots, \boldsymbol{\gamma}_{k57}^1)'$ and $\boldsymbol{\gamma}_k^0 = (\boldsymbol{\gamma}_{k01}^0, \ldots, \boldsymbol{\gamma}_{k07}^0, \ldots, \boldsymbol{\gamma}_{k51}^0, \ldots, \boldsymbol{\gamma}_{k57}^0)'$. Assumptions (4), (5), and (6) imply that the probability described in (3) can

be rewritten as follows:

$$P(g_{ik}=g|\boldsymbol{x}_i,conf_{ik}^j)=\alpha_g^1(conf_{ik}^j;\gamma_k^1)\Phi(\boldsymbol{x}_i'\boldsymbol{\beta}_k)+\alpha_g^0(conf_{ik}^j;\gamma_k^0)\Phi(-\boldsymbol{x}_i'\boldsymbol{\beta}_k). \quad (7)$$

We base the log-likelihood function on the conditional probability function (7). Notice that there is an identification problem; the parameter vector $(\boldsymbol{\gamma}_k^{1'},\boldsymbol{\gamma}_k^{0'},\boldsymbol{\beta}_k')'$ is observationally equivalent with $(\boldsymbol{\gamma}_k^{0'},\boldsymbol{\gamma}_k^{1'},-\boldsymbol{\beta}_k')'$ in the sense that they both result in the same probability distribution of observable data.[16] We address this identification problem by making the following assumptions:

$$P(g_{ik}=0|\tilde{y}_{ik}=1,conf_{ik}^j=z)=P(y_{ik}^m=0,y_{ik}^j=0|\tilde{y}_{ik}=1,conf_{ik}^j=z)=0,z=1,\ldots,7 \quad (8a)$$

$$P(g_{ik}=1|\tilde{y}_{ik}=1,conf_{ik}^j=z)=P(y_{ik}^m=1,y_{ik}^j=0|\tilde{y}_{ik}=1,conf_{ik}^j=z)=0,z=1,\ldots7 \quad (8b)$$

$$P(g_{ik}=2|\tilde{y}_{ik}=1,conf_{ik}^j=z)=P(y_{ik}^m=2,y_{ik}^j=0|\tilde{y}_{ik}=1,conf_{ik}^j=z)=0,z=1,\ldots,7 \quad (8c)$$

$$P(g_{ik}=3|\tilde{y}_{ik}=1,conf_{ik}^j=z)=P(y_{ik}^m=0,y_{ik}^j=1|\tilde{y}_{ik}=1,conf_{ik}^j=z)=0,\ z=1,\ldots,7 \quad (8d)$$

$$P(g_{ik}=4|\tilde{y}_{ik}=0,conf_{ik}^j=z)=P(y_{ik}^m=1,y_{ik}^j=1|\tilde{y}_{ik}=0,conf_{ik}^j=z)=0,\ z=6,7 \quad (8e)$$

These assumptions can be explained as follows: First, regardless of the confidence level, if a respondent truly knows the answer to a financial literacy question, he or she will not pick a wrong answer twice (see Equation 8a). Second, conditional on true knowledge, respondents will answer consistently in both modules; that is, they will not answer correctly in May and incorrectly in July or vice versa (see Equations 8b and 8d). Moreover, we exclude the possibility that individuals with true knowledge would pick a DK response in May and answer incorrectly in July (see Equation 8c). Thus, given true knowledge, the only possible answer patterns are to provide the correct answer twice or answer DK in May and provide the correct answer in July. In other words, respondents who are truly knowledgeable do not randomly pick an answer or make mistakes.

The assumption in Equation (8e) refers to the structure we impose conditional on lack of knowledge. Given that the respondent does not know the answer ($\tilde{y}_{ik}=0$) and that he or she is very confident in his or her answer in July (i.e., $conf_{ik}^j=6$ or $conf_{ik}^j=7$), the probability of guessing the correct answer twice (in May and July) is zero. However, in the case when the respondent does not know the answer ($\tilde{y}_{ik}=0$) and that he or she is not very confident (i.e., $conf_{ik}^j<5$), we do not impose any restriction. In other words, we allow for the possibility of random guessing by respondents who do not know the answer ($\tilde{y}_{ik}=0$), but we do not allow for guessing for individuals who do know the correct answer ($\tilde{y}_{ik}=1$). The estimation results of the LCM (see Equation 7) are presented in Online Appendix A.3.

3.2. A Summary Estimate for Respondents' Financial Literacy Based on the LCM

Once we have estimated the relevant parameters, we can compute for each financial literacy question the probability $P(\tilde{y}_{ik}=1|g_{ik}=g,\boldsymbol{x}_i,conf_{ik}^j)$ (see Equation 1) as follows (Vermunt 2010):

$$P(\tilde{y}_{ik}=1|g_{ik}=g,\boldsymbol{x}_i,conf_{ik}^j)=\frac{\alpha_g^1(conf_{ik}^j;\boldsymbol{\gamma}_k^1)\Phi(\boldsymbol{x}_i'\boldsymbol{\beta}_k)}{\alpha_g^1(conf_{ik}^j;\boldsymbol{\gamma}_k^1)\Phi(\boldsymbol{x}_i'\boldsymbol{\beta}_k)+\alpha_g^0(conf_{ik}^j;\boldsymbol{\gamma}_k^0)\Phi(-\boldsymbol{x}_i'\boldsymbol{\beta}_k)} \quad (9)$$

Note that this probability can be thought of as the posterior probability of having true knowledge (our latent variable) after updating the prior probability using additional information from the two surveys (Bayes' rule).

Thus, for each respondent, we predict the probability of truly knowing the correct answer to a given financial literacy question. This probability depends on the responses given in the May and July modules (i.e., $g_{ik}=g$) and on the respondents' reported level of confidence in the July module. The higher the estimated posterior probability, the more knowledge the individual has. Notice that the posterior distribution of $\tilde{y}_{ik}$ is degenerate if the following conditions are met:

$$P(\tilde{y}_{ik}=1|g_{ik}=g,\boldsymbol{x}_i,conf_{ik}^j)=1 \text{ if } \alpha_g^0(conf_{ik}^j;\boldsymbol{\gamma}_k^0)=0$$

$$P(\tilde{y}_{ik}=1|g_{ik}=g,\boldsymbol{x}_i,conf_{ik}^j)=0 \text{ if } \alpha_g^1(conf_{ik}^j;\boldsymbol{\gamma}_k^1)=0$$

Because of the assumptions (see Equations 8a–8e) presented in the previous subsection, the posterior distribution of $\tilde{y}_{ik}$ is degenerate in many cases; that is, $\tilde{y}_{ik}=0$ with certainty if (a) respondents answer inconsistently over time (once correctly, once incorrectly), (b) answer incorrectly two times, or (c) pick the DK answer in the May module and an incorrect answer in the July module. The respondent truly knows the correct answer ($\tilde{y}_{ik}=1$) with certainty if he or she answers the financial literacy questions correctly two times (irrespective of the confidence level). For respondents who provide a DK answer in the May module and a correct answer in the July module, the LCM is used to predict the probability of true knowledge, $P(\tilde{y}_{ik}=1|g_{ik}=5,\boldsymbol{x}_i,conf_{ik}^j)$, which could take on a value between 0 and 1 (see Equation 9 and Table A.5 in the Online Appendix). In Section 6, we argue that these respondents are "under-confident," because they likely have knowledge ($P(\tilde{y}_{ik}=1|g_{ik}=5,\boldsymbol{x}_i,conf_{ik}^j)>0$) yet they have selected the DK response option.

In Online Appendix A.3, we report the estimation results of the LCM. Figure A.1 in the Appendix displays the distribution of our estimated (posterior) probabilities of true knowledge for each of the Big Three. The probability of truly knowing the answer to the

interest question is 0 for 12.4% of respondents and 1 for 87.6%; we do not observe probabilities between 0 and 1. The probability of truly knowing the answer to the inflation question is 0 for 13.1% of the sample and 1 for 85.2% of the sample; 1.7% of respondents have values in between. The probability of truly knowing the answer to the risk diversification question is 0 for 28.9% of respondents and 1 for 44.4% of respondents; 26.7% are assigned probabilities between 0 and 1. These findings are as expected considering that the first two questions are rather simple and intuitive whereas the third question is, by design, more difficult.

We compute a measure of respondents' level of financial literacy by summing up the estimated probabilities for each question (see Equations 2 and 9). Unlike current financial literacy indicators, which simply sum up the number of correct answers (giving a value of 1 to the correct answers and 0 to the incorrect answers and DK responses), this new measure recognizes that respondents who select the DK option may actually know the answer. In the next section, we will compare the financial literacy measures for individual respondents based on the observed number of correct answers in the May and July modules and the results from the LCM. We will then use our new measure of financial literacy to estimate the relationship between financial literacy and stock market participation and compare it with estimates using traditional measures of financial literacy.

4. Estimation Results

4.1. Comparing Measures of Financial Literacy

We present our measures of financial literacy in Table 4. The results for the May measure are provided in panel A, and the results for the July measure are in panel B. In panel C, we present our measure of "true" financial literacy based on the LCM (see Equations 1 and 2).

Because the standard way of measuring financial literacy includes the DK option, we compare the May measure to the LCM estimates. The average probability of a correct answer to the interest question is slightly lower in the LCM (87.6%) than in the May survey module (88.6%), which indicates that there is some (correct) guessing in the May survey. The pattern is reversed for the other two questions. According to the LCM, the average probability that respondents truly know the answer to the inflation question is 86.3%, whereas only 85.8% of respondents correctly answered this question in the May module. The average probability that respondents truly know the answer to the risk diversification question is 61.6%, whereas only about half of respondents (49.9%) gave a correct answer to this question in May. The average value of "true" financial literacy is 2.35, which is slightly above the May measure of 2.24.

We also display the gender gap in financial literacy based on the May module and the LCM. When considering "true" knowledge, the gender gap is smaller for all three financial literacy questions. Specifically, whereas the gender gap indicated by correct answers to the standard interest (inflation/risk) question is 7.5 (9.2/27.5) percentage points, the estimated difference in "true" knowledge is 5.7 (8.8/16.1) percentage points. Thus, when interpreting gender differences in financial literacy based on responses to the standard set of questions, which include the DK option, one has to bear in mind that women are more likely to select the DK option,

Table 4. Share and Average Number of Correct Answers Across Financial Literacy Measures

Financial literacy	Men	Women	Gender difference (men-women)	Total
Panel A: May measure				
Interest	91.9	84.4	7.5	88.6
Inflation	89.8	80.6	9.2	85.8
Risk	61.9	34.4	27.5	49.9
Financial literacy measure	2.44	1.99	0.44	2.24
Panel B: July measure				
Interest	94.7	91.2	3.5	93.1
Inflation	93.7	87.5	6.2	91.0
Risk	82.3	73.0	9.3	78.3
Financial literacy measure	2.71	2.52	0.19	2.62
Panel C: "true" financial literacy				
Interest	90.1	84.4	5.8	87.6
Inflation	90.2	81.3	8.8	86.3
Risk	68.6	52.5	16.1	61.6
Financial literacy measure	2.49	2.18	0.31	2.35

Notes. In panels A and B, financial literacy refers to the observed percentage of respondents who answered a specific question correctly. The financial literacy measure refers to the sum of the correctly answered questions. In panel C, the probabilities of giving a correct answer are estimated from our LCM. The gender difference is the difference between the averages of men and women. Number of observations: men: 861; women: 671; total: 1,532.

making their financial literacy levels appear lower than men's.

We also run ordinary least-squares regressions to show the relationship between the different financial literacy measures and gender. Table 5, panel A, reports the results. The financial literacy gender gap, excluding controls, is 0.442 for the May measure and 0.307 for the LCM. Thus, the gender gap in "true" knowledge predicted by the LCM is smaller than the gender gap based on responses to the standard questions. In other words, slightly more than 30% ((0.442 − 0.307)/0.442 = 0.305) of the financial literacy gender gap identified in the May module can be attributed to differences in confidence. The estimation results in Table 5 show that the estimated effects in all three specifications (the May measure, July measure, and "true" financial literacy measure) are significantly different from each other.

Next, we include background variables (Table 5 panel B); specifically, we control for education, marital status, income, and age. The *adjusted* R^2 of the regressions is 0.156 for the May measure, 0.157 for the LCM measure, and 0.094 (much lower) for the July measure. For all three measures, we find that women still score worse than men. However, not surprisingly, the gender difference becomes smaller when including sociodemographic variables; for example, women, on average, have lower education and income than men. All control variables show the usual patterns reported in the literature. However, our main findings are similar to the univariate estimates; 32% of the gender difference based on the traditional May measure can be explained by differences in confidence rather than differences in knowledge. Again, the test statistics show that the estimated effects in the three regressions are significantly different from each other.

We performed an extensive set of robustness checks (see Online Appendix A.6). Most importantly, we estimated the LCM based on a reduced set of questions (just the inflation and interest questions) and an extended set of questions (the Big Three with one additional question on bond prices). Our results persist using these alternative sets of questions. Moreover, we added measures of risk aversion and interest in finance, and we restricted the sample to financial respondents, that is, those responsible for making financial decisions in the households, and we used general rather than question-specific confidence scales. We also ran robustness checks relaxing the assumptions made in Equations 8b and 8d. This gives some more flexibility to the model but does not change the results substantially (see Online Appendix A.6 for details). Overall, our results are robust to these changes.

4.2. Financial Literacy and Stock Market Participation

It is important to measure financial literacy properly because many studies have shown that financial literacy is related to financial behavior (see Lusardi and Mitchell 2014 for a review). We focus next on stock market participation because of the importance of investment and portfolio choices for household well-being, in particular now that individuals are more responsible for their retirement savings. We assess whether and the extent to which the measures of financial literacy we have developed lead to different findings regarding the relationship between financial literacy and stock market participation. Previous studies, using traditional measures of financial literacy, have shown a strong link between financial knowledge and stock market participation (see Lusardi and Mitchell 2014 for a review and Van Rooij et al. 2011 for evidence on Dutch data). However, the evidence in this paper shows that those measures of financial literacy reflect both "true" knowledge and confidence. Therefore, the existing estimates of the relationship between literacy

Table 5. OLS Regression: Financial Literacy

Variables	(1) May	(2) July	(3) True financial literacy	(4) Under-confidence
Panel A: Only controlling for gender				
Female	−0.442	−0.190	−0.307	0.164
	(0.0386)	(0.0291)	(0.0354)	(0.0243)
Adjusted R^2	0.067	0.024	0.040	0.029
Panel B: Controlling for marital status, age, education, income				
Female	−0.361	−0.147	−0.245	0.141
	(0.0394)	(0.0301)	(0.0362)	(0.0252)
Adjusted R^2	0.156	0.094	0.157	0.043

Notes. A: *p*-values of tests: (1) H0: b-female_may=b-female_july: 0.000; (2) H0: b-female_may=b female-true_financial_literacy: 0.000; (3) b-female_july=b-female_true_financial _literacy: 0.000. B: *p*-values of tests: (1) H0: b-female_may=b-female_july: 0.000; (2) H0: b-female_may=b female-true_financial_literacy: 0.000; (3) b-female_july=b-female_true_financial _literacy: 0.000. Results from OLS regressions in which the dependent variable is the number of correctly answered financial literacy questions in the May module (column 1), in the July module (column 2), and estimated from the LCM (column 3). In column 4, the dependent variable is a measure for under-confidence. In panel A, we include only gender as an explanatory variable. In panel B, we add controls for marital status, age, education, and income. Robust standard errors clustered at the household level in parentheses. Number of observations: 1,532.

and stock market participation likely reflect a mix of both.

Below, we investigate what the use of different financial literacy measures says about the relationship between financial literacy and stock market participation. Our objective is to check how our true measure of financial literacy performs in these estimations and what we can learn about the potential bias affecting the existing estimates. First, we run a regression using the standard measure of financial literacy (May measure), and then we compare the results with regressions based on the LCM financial literacy measure. In discussing the results, we focus on the financial literacy coefficient estimate as well as the gender coefficient estimate because both are likely to be impacted, as explained below.

Following the example of previous studies, we define a dummy for stock market participation that equals 1 if the respondent holds investments in stocks and/or mutual funds and 0 otherwise. As reported in Table 6, there is a strong negative correlation between gender and stock market participation; 33.9% of men in our sample own stocks versus 20.3% of women. If we control for the usual set of background characteristics and the traditional financial literacy measure (the May measure), we find a strong positive relationship between financial literacy and stock market participation.[17] Although the gender coefficient becomes much smaller than in column 1, it is still statistically significant (column 2). Compared with men, women have a 4.61 percentage point lower chance of owning stocks after controlling for a set of background variables, including income, education, etc. Moreover, a one-standard-deviation higher level of financial literacy implies a 9.01 percentage point higher probability of owning stocks (comparable to the effect found in the literature). This is a sizeable effect, but note that this coefficient estimate reflects both confidence and knowledge.

Next, we run a regression using the financial literacy measure from the July module, which should be unconfounded by confidence (Table 6, column 3). Although still significant, the financial literacy effect reduces to a 5.49 percentage point higher likelihood of investing in the stock market for a one-standard-deviation higher level of literacy. Note that the female coefficient estimate becomes more negative compared with the estimate in Table 6, column 2, because it is now likely to pick up part of the confidence effect; being less confident, women are less likely to invest in stocks. Recall that the July measure for financial literacy is affected by measurement error because of guessing because respondents are forced to pick an answer. As a result, the financial literacy coefficient may be biased toward zero. Indeed, once we use the predicted measure of "true" financial literacy, the financial literacy coefficient is somewhat higher (Table 6, column 4). We estimate a 6.65 percentage point higher likelihood of investing in the stock market for a one-standard-deviation higher level of "true" financial literacy and a smaller effect of being female. In other words, both the estimates for the effect of financial literacy and the effect of gender are impacted by the financial literacy measures used in the estimation. We report *p*-values of cross-specification tests at the bottom of Table 6. All tests show that the estimated coefficients differ significantly from each other.

Risk aversion is not included among the explanatory variables in our baseline specification (our sample is much smaller when using this variable). Yet risk aversion has been shown to differ between men and women and is an important determinant of stock market participation. As a sensitivity analysis, we reran all regressions, including a measure of risk aversion; the estimated financial literacy coefficients are qualitatively and quantitatively the same.[18]

Moreover, measurement error in financial literacy may not be the only factor leading to biases in the

Table 6. OLS Regression: Stock Market Participation and Financial Literacy

Variables	(1)	(2) May	(3) July	(4) True financial literacy
Financial literacy		0.0901	0.0549	0.0687
		(0.0105)	(0.0097)	(0.0103)
Female	−0.136	−0.0461	−0.0715	−0.0626
	(0.0207)	(0.0212)	(0.0213)	(0.0213)
Controls	—	x	x	x
Observations	1,532	1,532	1,532	1,532
Adjusted R^2	0.0221	0.137	0.117	0.123

Notes. *p*-values of tests: (1) H0: b-female_may = b-female_july: 0.000; (2) H0: b-female_may = b female-true_financial_ literacy: 0.000; (3) b-female_july=b-female_true_financial _literacy: 0.0021; *p*-values of tests: (1) H0: b-finlit_may=b-finlit _july: 0.0026; (2) H0: b- finlit _may=b finlit -true_financial_literacy: 0.0086; (3) b- finlit _july=b- finlit _true_ financial _literacy: 0.0576. Results from OLS regressions in which the dependent variable is a dummy for stock market participation. In column (1), we control only for gender. In columns (2)–(4), we add financial literacy measures and controls for marital status, age, education, and income. The financial literacy measures in models (2), (3), and (4) differ; we normalize them by subtracting the mean and dividing them by the standard deviation. We use the number of correct answers to the three financial literacy questions in May (column 2), in July (column 3), and estimated from the LCM (column 4). Robust standard errors clustered at the household level in parentheses. Number of observations: 1,532.

estimates of the effect of financial literacy on stock market behavior. The regression estimates could also be biased because of omitted variables (e.g., cognitive ability) and reverse causality (e.g., increased knowledge due to investing in the stock market). Therefore, in several studies, researchers have also performed instrumental variables (IV) estimation (see, e.g., Van Rooij et al. 2011). We present and discuss instrumental variables estimation in Online Appendix A.5.

One may also wonder whether the results extend to more financial behaviors than stock market participation. To address this, we provide estimations using retirement planning as a dependent variable in Online Appendix A.4. We obtain the same pattern of estimates as in the stock market participation results.

5. Confidence

An additional question we turn to is whether we can get an estimate of the degree of confidence and whether confidence matters for financial decisions. More specifically, we are interested in the role of under-confidence. By *under-confidence*, we mean that respondents can be financially literate; that is, they may know the answers to the financial literacy questions even though they selected the DK option. Thus, we assume that under-confidence is present only among those who respond to questions in the May module with DK ($y^m_{ik} = 2$) and answer the July questions correctly ($y^j_{ik} = 1$), that is, $g_{ik} = 5$. In other words, respondents are under-confident if they truly know the correct answer to question k and respond with DK nevertheless. The probability of this event is equal to $P(\tilde{y}_{ik} = 1|g_{ik} = 5, \boldsymbol{x}_i, conf^j_{ik})$.

People who responded with DK in May but provided an incorrect answer in July ($y^j_{ik} = 0$) cannot be under-confident according to our LCM model because we have assumed that

$$P(g_{ik} = 2|\tilde{y}_{ik} = 1, conf^j_{ik}) = P(y^m_{ik} = 2, y^j_{ik} = 0|\tilde{y}_{ik} = 1, conf^j_{ik}) = 0$$

(see assumptions in Section 3.1). Consequently, those respondents (a) cannot be financially knowledgeable, that is, $P(\tilde{y}_{ik} = 0|g_{ik} = 2, \boldsymbol{x}_i, conf^j_{ik}) = 1$, and (b) cannot be underconfident. According to our definition, those who do not choose a DK response in May do not face the problem of under-confidence; that is, the under-confidence measure is equal to zero.

As before, we compute an overall measure of under-confidence by summing up the estimated probabilities for the individual questions

$$Und\_conf_i = \sum_{k=1}^{3} P(\tilde{y}_{ik} = 1|g_{ik} = 5, \boldsymbol{x}_i, conf^j_{ik}) \cdot I(g_{ik} = 5)$$

where $I(.)$ denotes an indicator function that is 1 if $g_{ik} = 5$ and 0 otherwise.[19]

In Table 7, we show the mean probability of being under-confident for women and men. According to our measures and as we expected, there are more under-confident women than men for all questions. The fraction of under-confident women and men is higher for the more difficult questions and, in particular, for the risk diversification question. Overall, average under-confidence is equal to 0.179 for men and 0.343 for women. When we run regressions for under-confidence (see Table 5, column 4), the gender difference in under-confidence is between 0.164 and 0.141.

Table 7. Under-Confidence by Gender

	Under-confidence		
Financial literacy	Men	Women	Total
Interest question	0.015	0.042	0.027
Inflation question	0.028	0.064	0.044
Risk question	0.135	0.238	0.180
Under-confidence score	0.179	0.343	0.251

Notes. The table shows the share of under-confident respondents by financial literacy question and the under-confidence score. The probabilities of being under-confident are estimated from the LCM; the under-confidence score is defined according to $\sum_{k=1}^{3} P(\tilde{y}_{ik} = 1|g_{ik} = 5, \boldsymbol{x}_i, conf^j_{ik}) \cdot I(g_{ik} = 5)$. Number of observations: 1,532.

Next, we include under-confidence as an additional explanatory variable in the stock market regression (see Table 8, column 2); for ease of comparison, we also report the results from the regression of stock market participation on financial literacy using "true" financial literacy (Table 8, column 1) and the May measure of financial literacy (Table 8, column 3). All variables are standardized so that their point estimates can be compared across specifications. Controlling for "true" financial literacy, stock market participation is lower for under-confident respondents. Interestingly, the estimated coefficient of under-confidence has about the same order of magnitude as the coefficient of true financial literacy, and the financial literacy coefficient is almost unaffected (see the estimates in Table 8, columns 1 and 2). According to Hayashi (2000), in the case of an omitted variable, the difference in the estimated coefficients of a variable of interest (in our case, financial literacy) and the omitted variable (here, under-confidence) is low if either the coefficient of the omitted variable is small or if the correlation between the variable of interest and the omitted variable is low (see section 3.9 in Hayashi 2000). The estimated coefficient of under-confidence is not small. However, under-confidence is almost uncorrelated with true financial literacy estimated from the LCM (correlation coefficient of −0.0085).

Turning to the gender coefficient, the estimate becomes about 30% smaller in Table 8, column 2 compared with column 1. The reason for this is that under-confidence and gender are highly correlated. In a regression of under-confidence on gender, financial literacy, and various control variables, gender turns out to be the most important variable.[20] Comparing

Table 8. OLS Regression: Stock Market Participation, Financial Literacy, and Under-Confidence

Variables	(1) True financial literacy	(2) True financial literacy	(3) May	(4) May
Financial literacy	0.0687	0.0714	0.0901	0.0666
	(0.0103)	(0.0102)	(0.0105)	(0.0187)
Under-confidence		−0.0607		
		(0.00912)		
DK (May)				−0.0279
				(0.0170)
Female	−0.0626	−0.0437	−0.0461	−0.0443
	(0.0213)	(0.0212)	(0.0212)	(0.0213)
Observations	1,532	1,532	1,532	1,532
R^2	0.133	0.150	0.147	0.148
Adjusted R^2	0.123	0.140	0.137	0.138

Notes. Results from OLS regressions in which the dependent variable is a dummy for stock market participation. Additional controls for marital status, age, education, and income are included. The financial literacy measures and under-confidence measure in columns (1) and (2) are based on the LCM. The financial literacy measures and the DK measure in columns (3) and (4) are based on the May module. We normalize the financial literacy measures, under-confidence, and the DK variable by subtracting the mean and dividing them by the standard deviation. Robust standard errors clustered at the household level are in parentheses. Number of observations: 1,532.

the size of the gender coefficient between columns 2 and 3 in Table 8 shows that the gender coefficient, when controlling for true financial literacy and under-confidence, has about the same order of magnitude as the gender coefficient in the regression when using the May financial literacy measure (Table 8, column 3). In summary, the regression results show that it is important to control for both financial literacy and under-confidence when explaining stock market participation.

6. Making Use of the "Do Not Know" Answers

Measuring true financial literacy and under-confidence is quite difficult. Here, we propose a simple way to proxy for confidence. Recall that DK responses and under-confidence are highly correlated. Accordingly, in Table 8, column 4, we regress stock market participation on the May financial literacy measure (which is the measure commonly available in most surveys) and the number of DK responses to the three financial literacy questions. In that regression, the point estimate of the May financial literacy measure is rather close to the point estimate when using true financial literacy (compare columns 1 and 2 with column 4 in Table 8). Moreover, the point estimate of the female dummy is similar to the point estimate in column 2, where we account for under-confidence. Thus, controlling for the number of DK responses when using the tradition measure of the Big Three can potentially fix the problem caused by not controlling for under-confidence explicitly. However, note that the number of DK responses is an imperfect proxy for under-confidence; that is, the coefficient is biased toward zero and insignificant in the regression reported in column 4. Thus, although using this proxy does not provide a good estimate of under-confidence, it does help to get an estimate of financial literacy that is closer to the measure of "true" financial literacy.[21] Based on these findings, we recommend using the DK responses in financial literacy surveys when investigating the relationship between financial literacy and financial decision-making; that is, use information on both the correct answers and the DK answers in the empirical work.

7. Conclusion

The central result of our paper is that when it comes to financial literacy, women know less than men, but they know more than they think they know. Using the Big Three financial literacy questions, we find that 30% of the gender gap in financial knowledge can be attributed to differences in confidence and the remainder to differences in knowledge. Crucially, both financial literacy and confidence matter for stock market participation, and it is important to distinguish between the two. In our methodological framework, we provide a way to estimate both true knowledge and confidence. We find that response behavior differences directly impact financial literacy measurement and thereby how results have to be interpreted. In our setting, this applies to several results: the observed gender difference in financial literacy, the relationship of gender to stock market participation, and the relationship between financial literacy and under-confidence, respectively, and stock market participation.

Disentangling confidence from knowledge matters greatly for policy. First and foremost, our paper shows that there is a substantial gender gap in financial knowledge even after correcting for differences in confidence. Thus, although financial education programs are generally useful, programs targeting women may be better at closing the knowledge gap (see Driva et al. 2016 and Bottazzi and Lusardi 2021).[22]

Second, if differences in confidence persist between women and men, boosting knowledge may not be enough. Filippin and Paccagnella (2012) showed that confidence plays an important role in the accumulation of human capital. Small initial differences in confidence can result in large differences in human capital accumulation. The same applies to financial literacy and wealth; small initial differences in confidence may lead to large differences in accumulated financial literacy and well-being. Particularly in the context of long-term financial decisions related to investment, retirement savings, wealth accumulation, lower levels of confidence can be detrimental to women. And the effect may be exacerbated because women, on average, have a longer life expectancy than men.

Given our findings, it seems crucial not only to support individuals in acquiring financial knowledge but also to instill confidence in their knowledge. To draw conclusions about effective financial education interventions, future research should test interventions that convey knowledge, confidence, or both and measure their impact on knowledge, confidence, and behavior. An interesting example in this context is the stock trading experiment by Jha and Shayo (2024).

The need to boost female confidence is represented prominently by the *Fearless Girl* statue, which motivated the title of this paper. *Fearless Girl*—a bronze statue of a girl that was placed in front of the *Charging Bull* on Wall Street on March 7, 2017 (one day before International Women's Day)—was an initiative that received a lot of attention. The intent was to raise awareness and encourage women's leadership. Its symbolic placement sparked a debate about women's roles, particularly in financial professions, and pointed to the importance of confidence, especially in the fields of finance and investing. However, although raising public awareness is a useful first step, more research is needed to know what can be done to make women more knowledgeable and more fearless when it comes to finance. This might be important in lowering the gender inequality in not only financial literacy but also wealth accumulation and financial inclusion, including access to formal credit and high-quality financial advice.

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Endnotes

[1] Notable exceptions are Van Rooij et al. (2011), who performed factor analysis, including indicators of correct and DK responses. Von Gaudecker (2015) dealt with DK answers by imputing the probability of having a correct answer when random guessing (see the online appendix to Von Gaudecker 2015). Anderson et al. (2017) treated DK as incorrect responses in their main analyses but presented robustness checks using alternative approaches (treating DK as the correct response, control for DK indicator in regressions).

[2] Note that there are some surveys that measure financial literacy based on survey questions without an explicit DK option; see, e.g., the PISA data used in Bottazzi and Lusardi (2021) and Davoli (2023). Results from our survey indicate that this method also has shortcomings.

[3] Financial literacy now has its own JEL classification code: G53.

[4] Proposed reasons for such behavior are related to differences in the willingness to compete (Niederle and Versterlund 2010), confidence in male-specific tasks, and willingness to contribute to tasks that are outside the gender-specific domain (Coffman 2014b).

[5] See, for example, reviews by Blau and Kahn (2017) and Goldin and Mitchell (2017).

[6] Jordà et al. (2019) showed that there is a large equity premium using historical returns of 16 advanced economies over more than a century.

[7] For more information, see www.centerdata.nl.

[8] See also Van Rooij et al. (2024).

[9] For a detailed discussion of these questions, see Lusardi and Mitchell (2014).

[10] Note that there is also the option to "refuse to answer," which is chosen by a very small fraction of respondents and is therefore irrelevant. In the remainder of the paper, we include the refusals in the group of DK responses.

[11] The two financial literacy modules were part of larger surveys. We find that 21 respondents had at least one missing answer in the first survey and 11 respondents in the second survey, corresponding to a total number of 30 unique respondents with incomplete answers in the financial literacy modules, which we drop from the analysis.

[12] See Online Appendix A.2 for the test against random answering. The difference between the actual answers and random answers is significantly different from zero at the 10% level among men and 5% level among women.

[13] We also ran regressions with DK responses as the dependent variables and confidence levels (as well as sociodemographic variables such as gender, age, income, education, and marital status) as explanatory variables. We find a negative relationship between higher confidence levels and DK responses. The relationship is particularly strong for the risk diversification question. Results are available upon request.

[14] This is very similar to an approach suggested by Von Gaudecker (2015) in the online appendix of his paper.

[15] We assume without loss of generality that $\gamma^1_{k4l} = 0$, $l = 1, \ldots, 7$ (i.e., for the "$\tilde{y}_{ik} = 1$ multinomial logit model," the reference group consists of individuals who give a correct answer in both surveys) and $\gamma^0_{k0l} = 0$ (for the "$\tilde{y}_{ik} = 0$ multinomial logit model," the reference group has given an incorrect answer in both surveys).

[16] Because the reference group consists of individuals for which $g_{ik} = 4$, we can impose the condition $P(g_{ik} = 0|\tilde{y}_i = 1, conf^j_{ik}) = 0$ (see Equation 8a) a priori by assigning the parameters γ^1_{k0l} ($l = 1, \ldots, 7$) a very small value (cf. Equation 6a). In the empirical application, we impose the following restriction: $\gamma^1_{0kl} = -22$. Assumptions mentioned in Equations (8b), … , (8e) are imposed in an analogous way.

[17] The financial literacy variables are standardized, which facilitates the comparison of the regression results across specifications.

[18] The risk measure used is taken from the annual DHS survey and based on the following question: "The following statements concern saving and taking risks. Please indicate for each statement to what extent you agree or disagree. I am prepared to take the risk to lose money, when there is also a chance to gain money." After merging these data, our sample is reduced to 1,449 respondents. Results are included in Online Appendix Table A.8.

[19] We also used a more restrictive definition of under-confidence by imposing that respondents report confidence levels below the threshold level 6. This reduces the share of under-confident respondents slightly but does not change our conclusions.

[20] These additional regressions are available upon request.

[21] Note that, as an alternative shortcut, we also estimated a model using the July measure and an aggregate measure of confidence (on a scale from 1 to 7), as implemented in the July survey. The coefficient of the July measure is downward biased because of measurement error due to guessing, even if we control for confidence. Results are available upon request.

[22] For evidence on the effectiveness of financial education, see Frisancho (2020) and the review in Kaiser et al. (2022).

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