Use of Visualization Tools to Improve Financial Knowledge: An Experimental Approach

Michael G. Kothakota[a] and D. Elizabeth Kiss[b]

This study examined the use of data visualization to improve financial literacy in adults. Using financial knowledge questions as test items this study used an experimental approach. Poisson regression was conducted on responses from 1,797 participants to an online survey via SurveyMonkey. Approximately one-third of respondents were assigned to a text-only group explaining a financial concept, one-third to a group that received a visualization plus text explanation of the concept, and one-third to a control group with no intervention. The findings suggest visualization of data assist in assimilation of financial knowledge compared to no intervention and to text interventions. The study has implications for financial education programs attempting to implement interventions in order to improve financial knowledge.

Keywords: data visualization, financial counseling, financial education, financial planning, personal finance

Financial independence is at the heart of healthy adult life. Basic numeracy and foundational financial knowledge are required for financial independence, yet many adults struggle with acquiring and maintaining financial independence. This can lead to a host of personal problems ranging from evictions and divorce to costly expenses associated with poor credit histories (Lusardi & Mitchell, 2007b).

Public concern about general levels of adult financial knowledge was highlighted in relation to the use of interest-only mortgages prior to the financial crisis (Seay, Preece, & Le, 2017). That crisis resulted in part from consumers' beliefs that they could sustain the payments on mortgages approved by their lender without understanding the underwriting process or the terms of the mortgages they were obtaining (Nguyen & Pontell, 2010).

Consumers also need a minimum level of financial knowledge and numeracy in order to make informed decisions about other financial products including credit cards (Robb & Sharpe, 2009) and personal loans as well as investments such as stocks, bonds, or annuities. Only when the general public has a solid foundation of basic financial knowledge, can the gap between those who have and those who do not be reduced.

Life involves many financial decisions (Martin, 2002). At the same time, financial tools and products, and the markets in which they operate, are increasingly complex. Yet, many in the general public lack the financial knowledge and literacy required to be good consumers of these tools (Byrne, 2005). Too many find simple financial and numeracy tasks such as a computing interest difficult (Lusardi & Mitchell, 2007a, 2011). In recent studies, only 18% of participants were able to compute compound interest (Lusardi & Mitchell, 2008) and only 33% were able to demonstrate they understood investment risk diversification (Lusardi & Mitchell, 2007b). The lack of basic financial literacy skills can contribute to financial problems and anxiety about financial security (Lusardi, Mitchell, & Curto, 2010).

While financial education programs are available, they are time-intensive and may not be easily accessible for those consumers who need it most. Also, although business leaders may recognize the importance of a financially literate workforce, they often do not invest in work-place financial education programs (Prawitz & Garman, 2009). Finally,

[a] *PhD in Personal Financial Planning, Kansas State University, 220 Kinney Glenn Court, Durham, NC 27713. E-mail: mkothakota@ksu.edu*
[b] *Associate Professor, Department of Personal Financial Planning, Kansas State University, 303 Justin Hall, 1324 Lovers Lane, Manhattan, KS 66506. E-mail: dekiss4@k-state.edu*

http://dx.doi.org/10.1891/JFCP-18-00070

while an assessment of a program in California illustrated financial literacy programs increase perception of knowledge (Xu, 2018), many financial education programs may have limited efficacy or have effects that are short-lived (Kim, Gutter, & Spangler, 2017; Schuchardt et al., 2009; Willis, 2009).

Literacy and education programs focusing on personal finance are important to an informed public for several reasons. Improving the delivery of financial education is important, and the effects should be significant, and include positive behavior change (Lyons, Chang, & Scherpf, 2006; Mandell & Klein, 2009; Xiao & O'Neill, 2016; Xiao & Porto, 2017). Financial educators should always seek to improve the quality of instruction (Schuchardt et al., 2009) and evaluate the impact of programs over time (White et al., 2018). In addition, financial planners are better able to assist clients with financial plans when their clients understand basic financial information. Financial therapists and counselors can address client problems more efficiently if the clients are able to understand financial concepts (Moreland, 2018). Finally, policy makers working with an informed public can craft legislation that will keep regulations less onerous if the public has a stronger financial foundation. What can be done?

Modern instructional design techniques combined with the visual display of financial information may improve consumers' comprehension of financial concepts. This study explored whether or not financial information represented visually can increase financial knowledge. With software advances and increased computing power, the construction of visual representations of financial data is easier than in the past. Using modern tools, appropriately constructed visual information as part of financial education instructional design can be helpful in transmitting information to learners.

Human pattern recognition and visual information research can be used to conduct studies on what would work to improve financial knowledge. The overarching research question for this study was: do visual plus text-based financial literacy interventions improve financial knowledge? A second research questions follows from the first: are these interventions superior to text-only interventions? This study contributes to the literature by suggesting that the science of applied data visualization may help improve financial literacy among adults. Specifically, that using empirically validated visual techniques can help improve societal understanding of financial concepts.

Literature Review

There is little practical information or empirical research on the use of data visualizations in financial literacy education and financial decision-making. Some thought leaders in the field of data visualization have presented examples of personal finance visualizations, but they are limited and lack empirical support (Azzam, Evergreen, Germuth, & Kistler, 2013). Much of the literature describes opinions on "best practices" and has been popularized with the increased focus on Big Data and data science academic programs. Emerging evidence indicates visual representation of data can assist with processing of information and has been increasingly included in software development (Ware, Hui, & Franck, 1993; Ware, Neufeld, & Bartram, 1999).

Thought Leaders

Tufte, Few, and Evergreen are among the thought leaders who regularly publish on data visualization best practices. Tufte has published many books and articles but most of his work describes his opinions on what is aesthetically pleasing (design principles), and less on cognitive processing (Tufte, 2006; Tufte & Graves-Morris, 1983; Tufte & Weise Moeller, 1997). Few (2012) posits why many visualizations fail, and what role neuroscience plays in how humans interpret information. Examples in his book, *Show Me the Numbers* (Few, 2012), illustrate why three-dimensional graphics are rarely appropriate and why pie charts are never appropriate. These principles are reiterated by Tufte, who expands on the fact that pie charts are not effective because humans do not perceive angles well (Tufte, 2006).

Practical applications using open source tools for creating visualizations have helped businesses. Evergreen (2016) uses research-based methods for visualizing data as it relates to quantitative information. She further expands on the use of Excel-based graphics and the use of statistical programming languages to produce these visuals. She pushes back against the absolute negation of pie charts.

Foundational Research

Work on visual limitations and cognitive load has been done at the Visual Cognition Laboratory at Northwestern University in Evanston, IL (Liverence & Franconeri, 2015).

They apply cognitive load theory (CLT) as a basis for applying a "simplest is best" framework to visual information representations. Their research has described the bounds of visual attention and working memory. Their work has highlighted how visual perception is limited and provides a hypothesis on how making the visual easily accessible can reduce cognitive load. Using simple visuals in conjunction with text may allow the visual attention resource to filter "necessary" information, and visual working memory to store the relevant information.

Given the mathematical nature of financial knowledge, research conducted in mathematical problem-solving is foundational and helpful. Evidence from studies of teachers using interactive visualization for math problems is promising (Gomez-Chacon, 2013). In addition, researchers have tested the ability of teachers to solve more advanced math problems using spatial visualizations (Sevimli & Delice, 2011). Further research in psychology indicates a relationship between visualization and working memory as it relates to problem-solving (Cornoldi, Carretti, Drusi, & Tencati, 2015).

Personal Finance Visualizations

Financial information using box and whisker plots in economic supply and demand graphs can help students process the information better (Siluvairajah, 2011), as these types of graphs are able to illustrate average ranges and demonstrate how outliers may have outsized influence. Connected scatterplots presenting time series asset pricing have been shown to cause the viewer to inspect the data more closely than with traditional scatterplots (Haroz, Kosara, & Franconeri, 2015). Typical financial visualizations, such as those in personal finance software, often use pie or "donut" charts in asset allocation; however, evidence from multiple objects research suggests that bar charts would be more appropriate in these cases (Franconeri, Jonathan, & Scimeca, 2010).

Most financial visualizations appear to be in the business context and include bar, pie, and time series charts associated with business financial metrics. One published book in this area focuses on complex investment instruments and avoids personal finance (Rodriguez & Kaczmarek, 2016). No peer-reviewed empirical research could be located that investigated the effect of visualization on basic personal financial knowledge and understanding. Advanced visuals for competent financial professionals can be important, but combating financial illiteracy is a larger problem.

Theoretical Framework

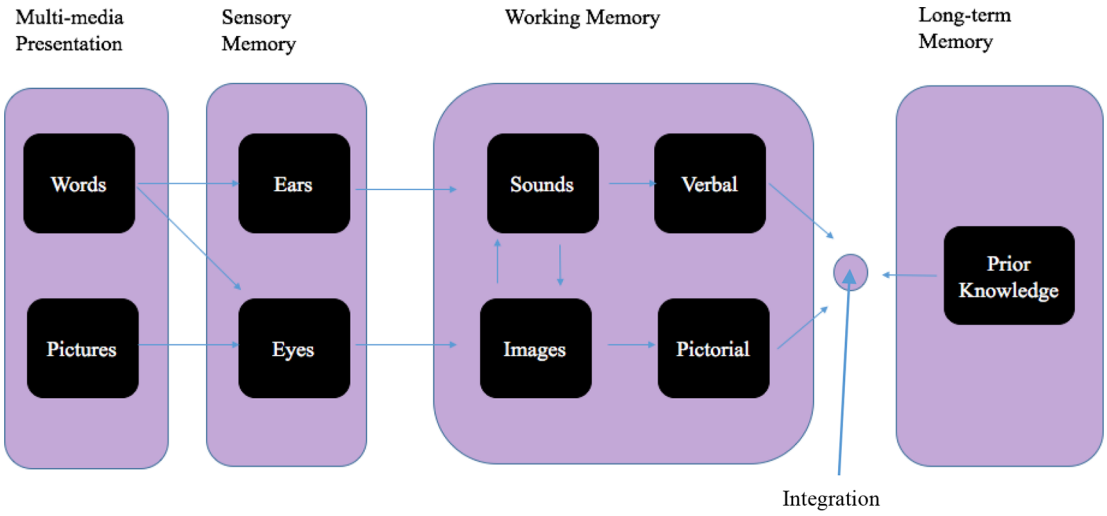
Education and learning theories should be included in any attempt to increase financial knowledge. One common misconception is that individuals possess "learning styles." That is, persons may be more inclined to learn visually, in an auditory fashion, or kinesthetically. However, the evidence does not bear this out (Pashler, McDaniel, Rohrer, & Bjork, 2008). Multiple studies have been unable to find any evidence where an individual learning style should be catered to (Knoll, Otani, Skeel, & Van Horn, 2017; Kraemer, Rosenberg, & Thompson-Schill, 2009; Rogowsky, Calhoun, & Tallal, 2015).

More likely is the notion that the subject matter determines the best way to learn (Howard-Jones, 2014). Thus, if an individual is attempting to perfect a foreign accent, then they would need to hear (auditory) that accent. Many tasks must be learned using multiple instructional techniques. For example, playing a score on a violin requires both listening for the right sound (auditory) and placing fingers and bow in the right place (kinesthetic). Financial knowledge may be best acquired with multiple instructional techniques as well.

The cognitive theory of multi-media learning (CTML) posits that the human brain uses dual-pathways to develop working memory and long-term memory (Mayer, 1997). In particular, this dual-processing is a way to combat heavy cognitive load. Using a combination of sounds other than words, verbal speech, images, and pictorial representations are a way to reduce the load in one channel or share the load, which will aid in processing (see question on Figure 1). There is evidence that when words are read, the person "hears" the word, placing load on the auditory channel (Pilotti, Gallo, & Roediger, 2000). One study found that using visual information in conjunction with text increased long-term memory over words alone by 92% (Brady, Konkle, Alvarez, & Oliva, 2008). Integration of existing knowledge, visual cues, and auditory information can reduce cognitive load, resulting in faster processing and retention of knowledge.

CLT also applies to visual research. Researchers in instructional design concur that reducing cognitive load, particularly visual working memory, assists in learning

Figure 1. Cognitive theory of multi-media learning.



Adapted from The Theory of Multi-Media Learning (Mayer, 1997).

(Kirschner, Ayres, & Chandler, 2011). Because the CTML uses CLT, these theories are often examined in conjunction with one another. Applying research in CLT on limits of cognitive load, CTML can suggest ways to reduce the load in any one channel if applied appropriately (Liverence & Franconeri, 2015).

Hypotheses

Given the research questions, two hypotheses were investigated. They were:

> H1: Respondents who receive financial knowledge interventions with text-only explanations will have higher financial knowledge scores, as defined by five common financial questions, than those who receive no intervention.
> H2: Respondents who receive text-based financial knowledge interventions combined with a visual explanation will have higher financial knowledge scores, as defined by five common financial questions, than respondents who receive text-only interventions or no intervention at all.

Method

Data

This study examined the financial knowledge of persons aged 18–65, representing the adult population. Previous studies have utilized various age cohorts, but the group used here allowed the researchers to examine the population across ages. Subjects received this survey via online survey administration through SurveyMonkey. Subjects were recruited and were compensated by SurveyMonkey. The survey was designed to take no longer than 10 minutes, in accordance with best practices in survey design (Fowler, 2013).

Survey Design

The use of financial knowledge questions in research was pioneered by Lusardi and Mitchell (Xiao & O'Neill, 2016) and has been used by others (e.g., Mimura, Koonce, Plunkett, & Pleskus, 2015). This study also used financial knowledge questions. These consisted of five, multiple-choice questions (see Appendix). Three groups were surveyed and answered these questions and additional demographic questions. One group, prior to seeing each financial knowledge question, received an explanation of concepts contained within the question and then answered the question. A second group received a visual and a text explanation and then answered the financial knowledge question. The third group received no intervention and simply answered the questions.

An estimated 10–15 minutes was required to complete this survey. In addition, respondents were required to read and e-sign an honor code statement at the beginning and end of the survey signifying that they used no external sources (persons, internet search, etc.) to answer the questions.

This has been shown to reduce cheating from 79% to 37% (Shu, Mazar, Gino, Ariely, & Bazerman, 2012). Data were cleaned and incomplete observations (<5% of all responses) were deleted from the combined dataset. This method of list-wise deletion is shown to have virtually no effect when trying to analyze any data (Allison, 2012).

Measurements

This study was quantitative in nature and only post-test answers were collected. Because the purpose of the study was to test whether or not a visual intervention prior to receiving a question provides a higher financial knowledge score the response or dependent variable was the financial knowledge score. The independent variable of interest was the actual intervention. That is, no intervention (control group), a text explanation of the concept prior to answering the question, or a visual representation of the concept with explanatory text. Additional independent variables included were (a) age, (b) level of education, (c) relationship status, (d) race and ethnicity, (e) whether or not they have taken one or more financial classes in the past year, (f) biological sex, and (g) income.

Respondents were asked to enter their year of birth to assess age. Relationship status, ethnicity, biological sex, and level of education were asked. Whether or not someone had taken financial classes was asked as well. Respondents responded yes or no to the question, but the timeframe of when such a class might have been taken had to have been within a year. The reasoning behind this was to determine if recent learning may have reduced the difficulty in accessing knowledge (Mayer, 1997). However, random assignment and the power of the sample eliminated the need to use this control (Jaynes, 2003). The final demographic question detailed respondents' individual personal income (not household income). The participants were asked to enter the numerical value of their annual income (e.g., $50,000).

Research Design

This quantitative randomized control trial contained two intervention conditions: (a) text-only presentation of a financial concept, (b) text plus visual explanation of financial concept, and c) a control condition (i.e., no intervention). Consenting participants were randomly assigned to one of these three conditions. Those in the intervention condition were presented one of the two interventions. The random control trial controls for internal threats to validity associated with repeated testing that may be present if a pre-post quasi-experimental design were used (Jaynes, 2003).

Results

Descriptive sample statistics are detailed in Table 1. Data were analyzed by performing multiple bi-variate tests across age cohorts, income, racial, and gender characteristics as well as multi-variate regression. Cursory examination of the means revealed the mean financial knowledge score for the control group was 3.29, for the text-only condition it was 3.57, and for the text plus visualization it was 3.87. Analysis of variance (ANOVA) for a between groups comparison was conducted and the difference in means was significant at the 0.01 level (see Table 2).

Data were examined visually and it was determined that the data formed a Poisson distribution, as each correct answer is independent of the others. Count data such as interval scores is more appropriately modeled using a Poisson regression (Hutchison & Holtman, 2007). Ordinary Least Squares (OLS) treats count data as continuous and assumes the data is multi-variate normal and by definition is non-discrete. Therefore, it is inappropriate to use linear regression to model these type of data. Results from the Poisson model, including the control, and both treatments are shown in Table 3.

Treatment was shown to be significant at the .01 level for both the text-only and the text plus visualization. Poisson regression output is interpreted in two ways. The first is using the coefficients as a function of the log of expected counts and the second is using the Incident Rate Ratio (IRR) (Hutchison & Holtman, 2007). Given there is not a time component applied to this analysis, the log of expected counts interpretation is the most appropriate. The coefficients can thus be interpreted as for every one unit change in the predictor variable, the difference in the log of expected counts (e.g., the log difference in scores) of outcome variable (i.e., financial knowledge score) changes by that predictor variable, all other predictor variables being held constant. Specifically, there is a 0.11 difference in the log of expected counts between the text intervention and the control group, while there is a 0.86 difference in the log of expected counts between the visual plus text intervention and the control group.

TABLE 1. Descriptive Statistics (*N* = 1,797)

Variable		Percent	Count
Treatment			
	Control	33.61	604
	Text-only	33.22	597
	Visualization plus text	33.17	596
Biological Sex			
	Female	53.31	958
	Male	44.91	807
	Prefer not to answer	1.78	32
Race and Ethnicity			
	Black	6.91	124
	Hispanic	5.01	90
	Asian/Pacific Islander	4.23	76
	White	79.78	1432
	Other	4.07	73
Education			
	High school dropout	2.67	48
	High school grad	10.35	186
	Some college	29.60	532
	College grad	26.54	477
	Some graduate	8.51	153
	Graduate school	16.53	297
	Professional degree (JD, MD) or PhD	5.79	104
Financial Class			
	Yes	93.32	1677
	No	6.68	120
Age			
	18–29	21.15	380
	30–44	27.60	496
	45–59	31.94	574
	60+	19.31	347
	Continuous variables		
Annual Income			
	Mean	$72,000.00	
	Median	$50,000.00	

Being male was significant at the .01 level and there was a 0.13 difference in the log of expected counts between male respondents versus female respondents. White respondents demonstrated a difference in the log of expected counts of 0.31, when compared to other race and ethnic groups. Having a graduate or professional degree corresponded to a 0.27 and 0.25 difference respectively compared to those who did not complete high school.

Discussion, Limitations, and Implications

Previous research on financial literacy suggests most interventions are very helpful in improving financial knowledge

TABLE 2. Tukey's HSD Results for Multiple Comparisons ANOVA

	Diff	Lower Bound	Upper Bound	*p* (adj)
Text-Control	0.28	0.1	0.47	.0012***
Viz-Control	0.58	0.39	0.77	<.001***
Viz-Text	0.29	0.10	0.48	<.001***

Note. ANOVA = analysis of variance; HSD = honestly significant difference.
Mean scores: Control = 3.29, Text = 3.57, Visual plus text = 3.87.
*p < .10. **p < .05. ***p < .01.

(Carpena, Cole, Shapiro, & Zia, 2011) though few comparisons between techniques have been evaluated (Lusardi & Mitchell, 2014; Lusardi, Mitchell, & Curto 2010). Text-only interventions use only a single type of learning, and financial information can be complicated, inhibiting the ability to learn the information.

Recent research in neuroscience indicates training with visual aids assists in communication of information (Grisham, Lom, Lanyon, & Ramos, 2016). Brain scans indicate visual stimulation results in an increase in white matter within the brain structure, consistent with a marked gain in mathematical ability, as well as language and memory (Fields, 2011). Language in the form of new terms associated with financial concepts, and retention of key ideas is important in financial knowledge. Computation is helpful in understanding interest. In financial planning, neuroscience research has been conducted on how to better understand how clients process information (James, 2013). In other professions, visual images have been shown to assist with understanding risk (Garcia-Retamero & Galesic, 2010).

Based on the analysis reported here, there appears to be an effect when using text and visual plus text interventions. Results suggest cognitive load is lessened and performance improves when information is applied in the visual plus text intervention. The visual plus text intervention outperforms the text-only. Both outperform the control.

This research suggests there is a positive effect in using visualizations in financial education. Although foundational in nature, this research could be the catalyst for future research involving varying visuals for the same item, resulting in even larger improvements. Preliminary findings within groups assessed in this study suggest different demographic groups respond differently to the two interventions. Wagner (2019) examined the relationship between financial education and financial literacy for people with lower education and income. Additional types of visual stimuli not used in this study may produce different results.

Limitations

As this study took place at one moment in time, there is no way to measure retention of information. Future studies may explore a pre- and post-test experimental design to determine if there is a change in financial knowledge score using a questionnaire with no intervention and then using the intervention to determine if a score improves. These post-tests could be given at different time intervals to determine the rate of knowledge decay.

Despite the honor code requirement and timed responses, cheating may still occur which may bias the financial knowledge score reported herein upward. A study where the survey is administered in person with a proctor may help to reduce cheating. Restrictions to not bring smartphones into the testing area and a survey program that prevented web searches could mostly eliminate cheating.

Not all colors used in visualizations were color-blind friendly. While blue and orange are typically colors used in visualizations to differentiate, the gray used in the diversification question is not. In addition, the disconnected legend may have caused some confusion to the viewer.

Finally, while these particular financial knowledge questions have been used frequently and have been found to be both valid and reliable (Lusardi & Mitchell, 2014), this was the first time these specific interventions were used. The visuals used may not have been the best or the text explanation insufficient. Use of other types of visuals drawn from other academic research may assist in perhaps dialing-in the "best" interventions.

This study is experimental. The participants knew they were participating in academic research and responses are not necessarily indicative of real-world responses. Since the number of questions was limited, there should be little experimental fatigue. As this was a post-test only type survey, there is no threat via testing effects. Effort was made to construct the experiment in such a way that the

TABLE 3. Poisson Regression Results for all Variables Predicting Financial Knowledge Scores

Variable		Coefficient	*SE*	Z	Pr(>|z|)
Income		0.00000015	9E–10	1.81	.07*
Gender Male		0.13	0.025	5.2	<.001***
Treatment					
	Text	0.11	0.031	3.62	<.001***
	Visual	0.86	0.03	6.04	<.001***
Education					
	High school	–0.064	0.12	–0.534	.06*
	Some college	0.13	0.11	1.1	.27
	Bachelors	0.22	0.11	1.93	.05*
	Some graduate	0.20	0.12	1.63	0.1
	Masters	0.27	0.12	2.31	.02**
	Professional	0.25	0.12	2.06	.04**
Race					
	White	0.31	0.07	5.28	<.001***
	Hispanic	0.062	0.08	0.73	.46
	Asian/Pacific Islander	0.11	0.09	1.32	.19
	Other	0.093	0.09	1.05	.29
Intercept		0.67	0.13	5.316	

*$p < .10$. **$p < .05$. ***$p < .001$.

researcher did not influence the outcome. Visual designs were constructed using previous best practices and a theoretical model was followed to reduce bias.

Controlling for whether a participant had recently participated in a financial class helped to reduce maturation effects since having a recent class could influence the participants' knowledge and possibly inflate their score. As the survey was administered online, there was no way to pull out shorter-term maturation effects. Randomization and sample size should have eliminated most effects of selection bias. The internal validity threat of repeated testing was avoided with the between group comparison. The statistical method used reduces issues with construct validity as there is not a measurement of "financial knowledge" and the number of correct responses was used. Some previous issues with the financial knowledge questions are noted. Further, as in studies related to financial knowledge, it may have been useful to control for statistical literacy, which this study did not do.

Given the sample size of 1,797 and rough inter-group homogeneity, the nature of the study allows for some generalization. However, SurveyMonkey participants self-select into participating in panels, and there may be unobserved idiosyncrasies that make the sample different from the general population. There is the potential that due to the medium used by the participant in taking the test, there is some threat to generalizability (Babbie, 2016). Participants were able to take the survey using a mobile device or a computer and viewing the visualizations or reading the text may have had an effect on the number of correct questions. In a real-world test where homogeneity of format is controlled, generalizability would have been easier to achieve. Some further issues arise in interpretation of certain demographic coefficients, as certain subgroups were not represented enough for statistical validity.

Despite these limitations, this research is a starting point for the inclusion of visuals in financial education programs and products. A strong visual component may lessen the cognitive load of consumers and students who may already be depleted from either work or other school subjects. New avenues of both research and financial education can be explored using visualization to boost individual financial knowledge.

Implications

With further confirmatory research, policy makers and government agencies such as the Consumer Financial Protection Bureau can use the results in public service announcements and legislative drafts. In an effort not to obfuscate information that otherwise may not be readily understood by consumers, ways of presenting information to consumers can be mandated of financial organizations. A more informed public could actually lead to a need for less regulation and oversight as financial knowledge can provide them with skills and confidence, making them less likely to be taken advantage of through predatory practices.

Applying these findings to retirement planning, persons will have a better grasp of their financial situation when speaking to financial planners and may be better able to assist in securing their retirement. This can reduce the cost of constructing a financial plan and maintaining it, as advisors can use visual concepts in their practices to reduce the time spent teaching financial concepts. Further, this can be viewed as effective communication because the person receiving the information is able to decode and synthesize the information. This can help create trust in financial professionals (Sharpe, Anderson, White, Galvan, & Siesta, 2007). Financial therapists and counselors can spend less time explaining financial information and more time treating financial problems by incorporating visuals into their practices.

Educational programs and financial educators can benefit from this research. Increasing the efficacy of such programs by applying the insights from this research can assist with program development and continued delivery. Programs that rely on private donations will be able to illustrate how their programs work. Those that rely on public funding would be able to make a case for monies to be provided to their program. Empirical evidence on the efficacy of visual methods could provide the needed push to make financial education a priority in public primary and secondary schools. If students can be shown to benefit from such interventions, educators can use them to assist in preparing students for post-school life.

References

Allison, P. D. (2012). *Logistic regression using SAS: Theory and application*. Cary, NC: SAS Insititute.

Azzam, T., Evergreen, S., Germuth, A. A., & Kistler, S. J. (2013). Data visualization and evaluation. In T. Azzam & S. Evergreen (Eds.), *Data visualization, part 1. New directions for evaluation* (Vol. 139, pp. 7–32).

Babbie, E. (2016). *The practice of social research*. Boston, MA: Cengage Learning.

Brady, T. F., Konkle, T., Alvarez, G. A., & Oliva, A. (2008). *Visual long-term memory has a massive storage capacity for object details*. *Proceedings of the National Academy of Sciences*, *105*(38), 14325–14329. https://doi.org/10.1073/pnas.0803390105

Byrne, K. (2005). How do consumers evaluate risk in financial products? *Journal of Financial Services Marketing*, *10*(1), 21–36. https://doi.org/10.1057/palgrave.fsm.4770171

Carpena, F., Cole, S., Shapiro, J., & Zia, B. (2011). *Unpacking the causal chain of financial literacy,* pp. 9–14. The World Bank.

Cornoldi, C., Carretti, B., Drusi, S., & Tencati, C. (2015). Improving problem solving in primary school students: The effect of a training programme focusing on metacognition and working memory. *British Journal of Educational Psychology*, *85*(3), 424–439. https://doi.org/10.1111/bjep.12083

Evergreen, S. (2016). *Effective data visualizations*. Thousand Oaks, CA: Sage.

Few, S. (2012). *Show me the numbers: Designing tables and graphs to enlighten*. El Dorado Hills, CA: Analytics Press.

Fields, R. D. (2011). Image learning: The search for a memory trace. *The Neuroscientist*, *17*(2), 185–196. https://doi.org/10.1177/1073858410383696

Fowler, F. J. (2013). *Survey research methods*. Thousand Oaks, CA: Sage.

Franconeri, S. L., Jonathan, S. V., & Scimeca, J. M. (2010). Tracking multiple objects is limited only by objects spacing, not by speed, time, or capacity. *Psychological Science*, *21*(7), 920–925. https://doi.org/10.1177/0956797610373935

Garcia-Retamero, R., & Galesic, M. (2010). How to reduce the effect of framing on messages about health. *Journal of General Internal Medicine*, *25*, 1323–1329. https://doi.org/10.1007/s11606-010-1484-9

Gomez-Chacon, I. M. (2013). Prospective teachers' interactive visualization and affect in mathematical problem-solving. *The Mathematics Enthusiast*, *10*(1), 61–86.

Grisham, W., Lom, B., Lanyon, L., & Ramos, R. (2016). Proposed training to meet challenges of large-scale data

in Neuroscience. *Frontiers in Neuroinformatics*, *10*, 28. https://doi.org/10.3389/fninf.2016.00028

Haroz, S., Kosara, R., & Franconeri, S. L. (2015). The connected scatterplot for presenting paired time series. *Transactions on Visualization and Computer Graphics*, *22*, 2174–2186. https://doi.org/10.1109/TVCG.2015.2502587

Howard-Jones, P. A. (2014). Neuroscience and education: Myths and messages. *Nature Reviews Neuroscience*, *15*(12), 1–8. https://doi.org/10.1038/nrn3817

Hutchison, M. K., & Holtman, M. C. (2007). Analysis of count data using Poisson regression. *Research in Nursing & Health*, *28*(5), 408–418. https://doi.org/10.1002/nur.20093

James, R. N. (2013). Brain activity suggests planning designation helps calm investors. *Journal of Financial Planning*, *26*(2), 52–57.

Jaynes, E. T. (2003). *Probability theory: The logic of science*. Cambridge, UK: Cambridge University Press.

Kim, J., Gutter, M. S., & Spangler, T. (2017). Review of family financial decision making: Suggestions for future research and implications for financial education. *Journal of Financial Counseling and Planning*, *28*(2), 253–267. https://doi.org/10.1891/1052-3073.28.2.253

Kirschner, P. A., Ayres, P., & Chandler, P. (2011). Contemporary cognitive load theory research: The good, the bad and the ugly. *Computers in Human Behavior*, *27*(1), 99–105. https://doi.org/10.1016/j.chb.2010.06.025

Knoll, A. R., Otani, H., Skeel, R. L., & Van Horn, K. R. (2017). Learning style, judgements of learning, and learning of verbal and visual information. *British Journal of Psychology*, *108*(3), 544–563. https://doi.org/10.1111/bjop.12214

Kraemer, D. J., Rosenberg, L. M., & Thompson-Schill, S. L. (2009). The neural correlates of visual and verbal cognitive styles. *Journal of Neuroscience*, *29*(12), 3792–3798. https://doi.org/10.1523/JNEUROSCI.4635-08.2009

Liverence, B. M., & Franconeri, S. L. (2015). Resource limitations in visual cognition. In R. Scott & S. Kosslyn (Eds.), *Emerging trends in the social and behavioral sciences*. Hoboken, NJ: John Wiley.

Lusardi, A., & Mitchell, O. S. (2007a). Baby boomer retirement security: The roles of planning, financial literacy, and housing wealth. *Journal of Monetary Economics*, *54*(1), 205–224. https://doi.org/10.1016/j.jmoneco.2006.12.001

Lusardi, A., & Mitchell, O. S. (2007b). Financial literacy and retirement preparedness: Evidence and implications for financial education. *Business Economics*, *42*(1), 35–44. https://doi.org/10.2145/20070104

Lusardi, A., & Mitchell, O. S. (2008). *Planning and financial literacy: How do women fare?* (No. w13750). Cambridge, MA: National Bureau of Economic Research.

Lusardi, A., & Mitchell, O. S. (2011). Financial literacy around the world: An overview. *Journal of Pension Economics and Finance*, *10*(04), 497–508. https://doi.org/10.1017/S1474747211000448

Lusardi, A., & Mitchell, O. S. (2014). The economic importance of financial literacy: Theory and evidence. *Journal of Economic Literature*, *52*(1), 5–44. https://doi.org/10.1257/jel.52.1.5

Lusardi, A., Mitchell, O. S., & Curto, V. (2010). Financial literacy among the young. *Journal of Consumer Affairs*, *44*(2), 358–380. https://doi.org/10.1111/j.1745-6606.2010.01173.x

Lyons, A. C., Chang, Y., & Scherpf. (2006). Translating financial education into behavior change for low-income populations. *Journal of Financial Counseling and Planning*, *17*(2), 27–45.

Mandell, L., & Klein, L. S. (2009). The impact of financial literacy education on subsequent financial behavior. *Journal of Financial Counseling and Planning*, *20*(1), 15–24.

Martin, R. (2002). *Financialization of daily life*. Philadelphia, PA: Temple University Press.

Mayer, R. E. (1997). Multimedia learning: Are we asking the right questions? *Educational Psychologist*, *32*(1), 1–19. https://doi.org/10.1207/s15326985ep3201_1

Mimura, Y., Koonce, J., Plunkett, S. W., & Pleskus, L. (2015). Financial information source, knowledge, and practices of college students from diverse backgrounds. *Journal of Financial Counseling and Planning*, *26*(1), 63–78. https://doi.org/10.1891/1052-3073.26.1.63

Moreland, K. A. (2018). Seeking financial advice and other desirable financial behaviors. *Journal of Financial Counseling and Planning*, *29*(2), 198–207. https://doi.org/10.1891/1052-3073.29.2.198

Nguyen, T. H., & Pontell, H. N. (2010). Mortgage origination fraud and the global economic crisis. *Criminology & Public Policy*, *9*(3), 591–612. https://doi.org/10.1111/j.1745-9133.2010.00653.x

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest*, *9*(3), 105–119. https://doi.org/10.1111/j.1539-6053.2009.01038.x

Pilotti, M., Gallo, D. A., & Roediger, H. L. (2000). Effects of hearing words, imaging hearing words, and reading on auditory implicit and explicit memory tests. *Memory & Cognition*, *28*(8), 1406–1418. https://doi.org/10.3758/BF03211841

Prawitz, A. D., & Garman, E. T. (2009). It's time to create a financially literate workforce to improve the bottom line. *Benefits Compensation Digest*, *46*(4), 1.

Robb, C. A., & Sharpe, D. L. (2009). Effect of personal financial knowledge on college students' credit card behavior. *Journal of Financial Counseling and Planning*, *20*(1), 25–43.

Rodriguez, J., & Kaczmarek, P. (2016). *Visualizing financial data*. Hoboken, NJ: Wiley.

Rogowsky, B. A., Calhoun, B. M., & Tallal, P. (2015). Matching learning style to instructional method: Effects on comprehension. *Journal of Educational Psychology*, *107*(1), 64–79. https://doi.org/10.1037/a0037478

Schuchardt, J., Hanna, S., Hira, T., Lyons, A. C., Palmer, L., & Xiao, J. J. (2009). Financial literacy and education research priorities. *Journal of Financial Counseling and Planning*, *20*(1), 84–95.

Seay, M. C., Preece, G. L., & Le, V. C. (2017). Financial literacy and the use of interest-only mortgages. *Journal of Financial Counseling and Planning*, *28*(2), 168–180. https://doi.org/10.1891/1052-3073.28.2.168

Sevimli, E., & Delice, A. (2011). The influence of teacher candidates' spatial visualization ability on the use of multiple representations in problem solving of definite integrals: A qualitative analysis. *Research in Mathematics Education*, *13*(1), 93–94. https://doi.org/10.1080/14794802.2011.550750

Sharpe, D. L., Anderson, C., White, A., Galvan, S., & Siesta, M. (2007). Specific elements of communication that affect trust and commitment in the financial planning process. *Journal of Financial Counseling and Planning*, *18*(1), 2–17.

Shu, L. L., Mazar, N., Gino, F., Ariely, D., & Bazerman, M. H. (2012). Signing at the beginning makes ethics salient and decreases dishonest self-reports in comparison to signing at the end. *Proceedings of the National Academy of Sciences*, *109*(38), 15197–15200. https://doi.org/10.1073/pnas.1209746109

Siluvairajah, M. (2011). Supply and demand vs. price driven graphs financial data visualization. *International Journal on Computer Science and Engineering*, *3*(8), 2935.

Tufte, E. R. (2006). *Beautiful evidence*. New York, NY: Graphics Press LLC, Cheshire, CT.

Tufte, E. R., & Graves-Morris, P. R. (1983). *The visual display of quantitative information* (Vol. 2, No. 9). Cheshire, CT: Graphics Press.

Tufte, E. R., & Weise Moeller, E. (1997). *Visual explanations: Images and quantities, evidence and narrative* (Vol. 36). Cheshire, CT: Graphics Press.

Wagner, J. (2019). Financial education and financial literacy by income and education groups. *Journal of Financial Counseling and Planning*, *30*(1), 132–141. https://doi.org/10.1891/1052-3073.30.1.132

Ware, C., Hui, D., & Franck, G. (1993, October). Visualizing object-oriented software in three dimensions. In *Proceedings of the 1993 conference of the centre for advanced dtudies on collaborative research: Software engineering* (Vol. 1, pp. 612–620). Durham, NH: IBM Press.

Ware, C., Neufeld, E., & Bartram, L. Visualizing causal relations. *Proceedings of IEEE Information Visualization*, *99*(1) 39–42.

Willis, L. E. (2009). Evidence and ideology in assessing the effectiveness of financial literacy education. *San Diego Law Review*, *46*, 415.

White, N. D., Packard, K. A., Flecky, K. A., Kalkowski, J. C., Furze, J. A., Ryan-Haddad, A., . . . Qi, Y. (2018). Two year sustainability of the effect of a financial education program on the health and wellbeing of single, low-income women. *Journal of Financial Counseling and Planning*, *29*(1), 68–74. https://doi.org/10.1891/1052-3073.29.1.68

Xiao, J. J., & O'Neill, B. (2016). Consumer financial education and financial capability. *International Journal of Consumer Studies*, *40*(6), 712–721. https://doi.org/10.1111/ijcs.12285

Xiao, J. J., & Porto, N. (2017). Financial education and financial satisfaction: Financial literacy, behavior, and capability as mediators. *International Journal of Bank Marketing*, *35*(5), 805–817. https://doi.org/10.1108/IJBM-01-2016-0009

Xu, X. (2018). Assessing a community-based financial literacy program: A case study in California's Silicon Valley. *Journal of Financial Counseling and Planning*, *29*(1), 142–153. https://doi.org/10.1891/1052-3073.29.1.142

Disclosure. The authors have no relevant financial interest or affiliations with any commercial interests related to the subjects discussed within this article.

Acknowledgments. An earlier version of this work was presented as a poster at the 2017 Annual AFCPE Research and Training Symposium. An abstract was published in the 2017 Proceedings. The citation is:

Kothakota, M., & Kiss, E. (2017). Visualization and financial knowledge. In V. J. Anderson & D. E. Kiss (Eds.), *Proceeding of the Association for Financial Counseling Planning and Education, 2017 Annual Research and Training Symposium* (p. 30).

IRB #8614 approved on 2/1/2017.

Funding. The author(s) received no specific grant or financial support for the research, authorship, and/or publication of this article.

Appendix
Financial Knowledge Questions

1. 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?
   a. More than $102
   b. Exactly $102
   c. Less than $102
   d. Do not know
2. Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, would you be able to buy more than, exactly the same as, or less than today with the money in this account?
   a. More than today
   b. Exactly the same as today
   c. Less than today
   d. Do not know
3. Do you think that the following statement is true or false? "Buying a single company stock usually provides a safer return than a stock mutual fund."
   a. True
   b. False
   c. Do not know
4. Suppose you had $100 in a savings account and the interest rate is 20% per year and you never withdraw money or interest payments. After 5 years, how much would you have on this account in total?
   a. More than $200
   b. Exactly $200
   c. Less than $200
   d. Do not know
5. If the interest rate falls, what should happen to bond prices?
   a. Rise
   b. Fall
   c. Stay the same
   d. Do not know

Visualizations of financial concepts

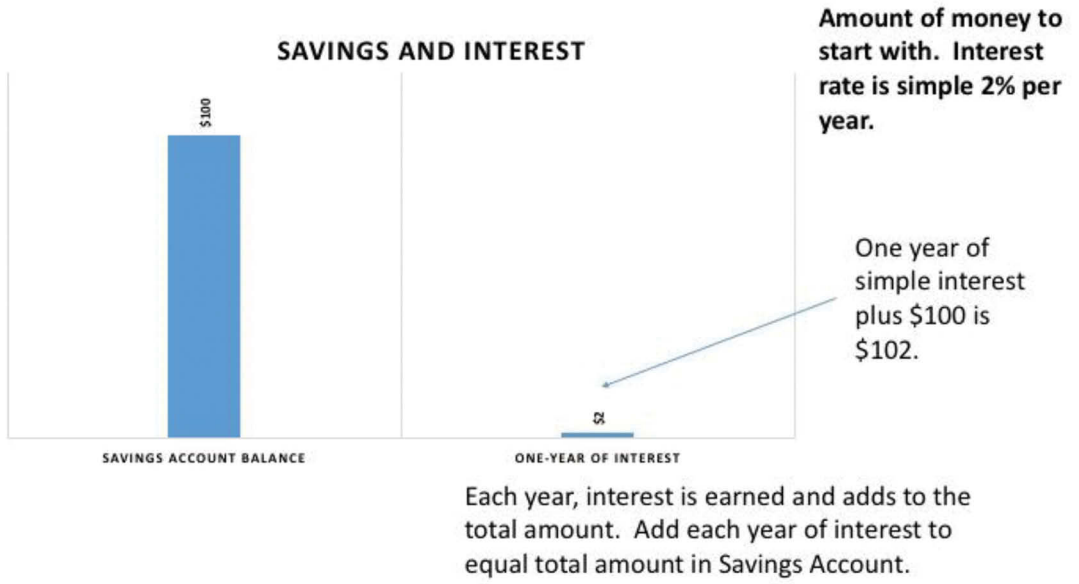


Figure A1. Visualizations of financial concepts.

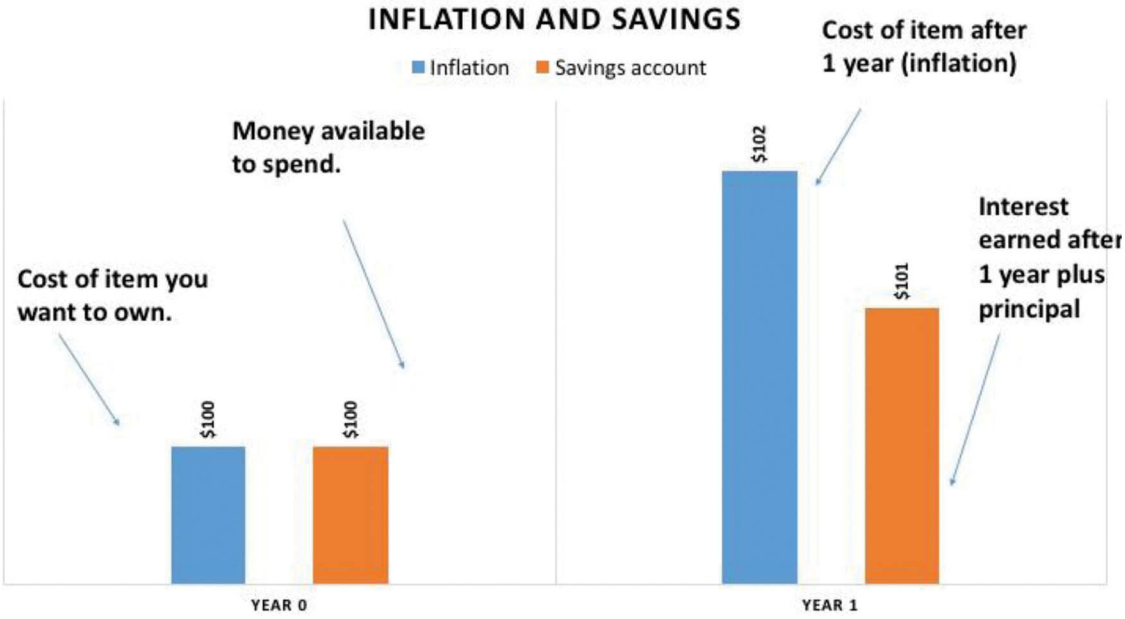


Figure A2. Inflation and savings.

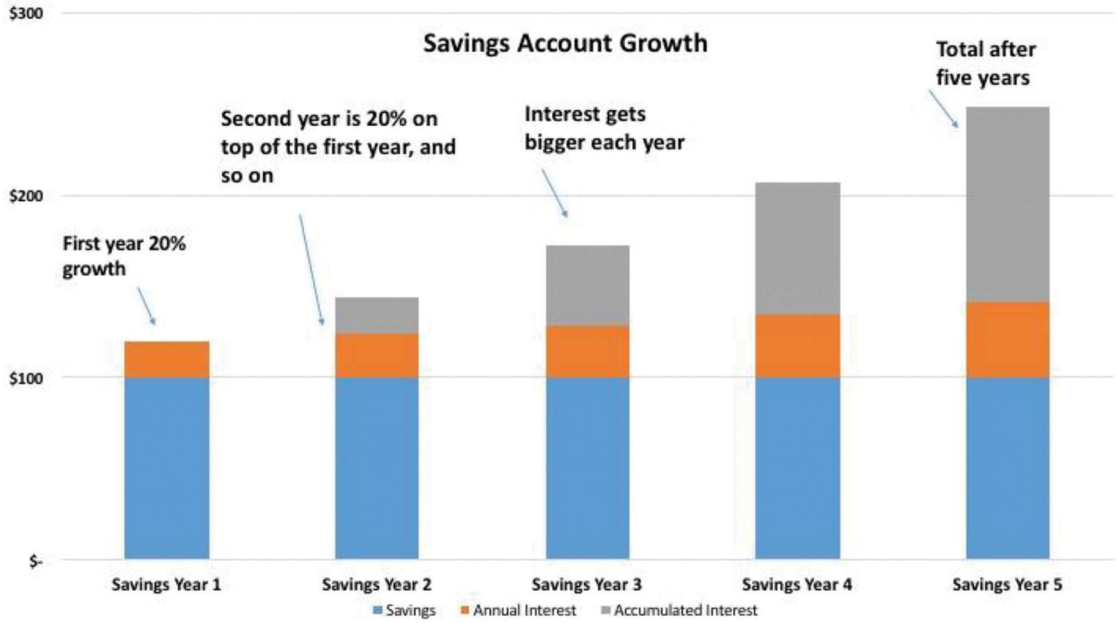


Figure A3. Savings account growth.

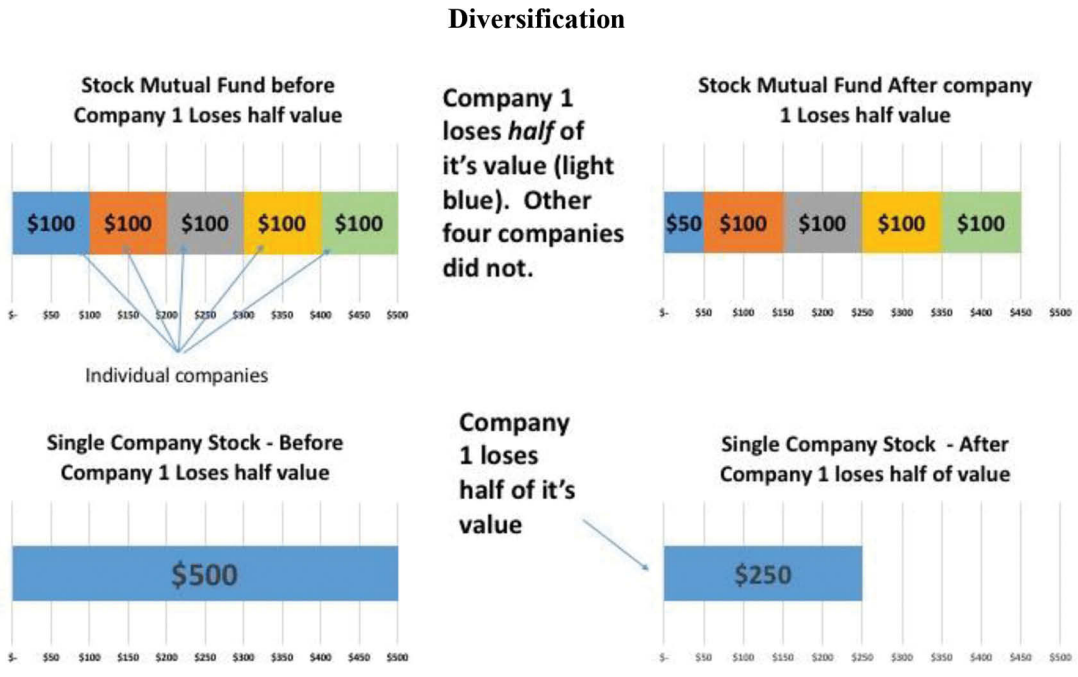


Figure A4. Diversification.

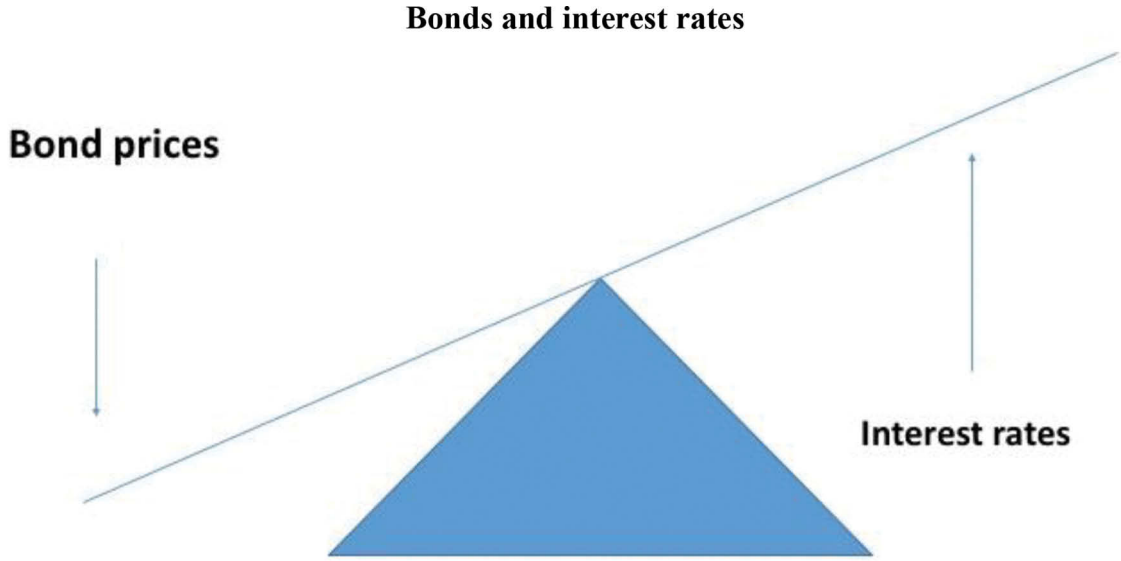


Figure A5. Bonds and interest rates.