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Unintended consequences of minimum annuity laws: An experimental study ☆

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ABSTRACT

The need to ensure that people have adequate savings for retirement has prompted debate among regulators and academics. Certain countries have implemented or are considering implementing mandatory minimum annuity laws (e.g., Singapore and Israel), whereas others have repealed or are considering repealing such legislation (e.g., the U.K.). We investigate the introduction as well as the repeal of a regulatory change—specifically, a mandatory minimum annuity rule—using a laboratory experiment and two surveys. Our results indicate that imposing a mandatory minimum may create an anchoring effect to the threshold level. Furthermore, our results suggest that the mandatory requirement may have unintended consequences: Such laws may fail to provide an increase in the demand for annuities and may even reduce it for certain individuals. The outcome is sensitive to the relation between the level of the mandatory minimum and anticipated consumption (i.e., future financial need). Moreover, we provide novel evidence about the consequences of a repeal of mandatory minimum annuity laws and suggest that it may not restore the demand for annuities to the pre-law level.

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1. Introduction

The combined trends of higher life expectancy, occupational instability, and the steady erosion of government support for retirement plans raise many concerns related to ensuring adequate retirement resources. An important decision that individuals make upon retirement is whether to annuitize some of their long-term savings. An annuity is a product designed to insure against longevity risk, paying a monthly (or yearly) pension for the rest of a retiree's life. Although annuities provide insurance against longevity risk, the academic empirical evidence documenting their use is very limited.[1] This may change, however. A potential market failure may call for a regulatory intervention, such as imposing a minimum annuity law.

Some regulators have indicated their desire to increase the demand for annuities. However, different regulators around the globe disagree on how to do so. One controversial policy is to mandate (typically partial) annuitization. The United Kingdom had a minimum annuity law that was repealed in 2014. In contrast, Israel adopted a mandatory minimum annuity in 2008. Other countries have a range of policies regarding the decumulation phase; for instance, in Singapore, a combination of a lump sum and a deferred annuity (provided by the government) is mandatory (Fong et al., 2011). India mandates annuitization of at least 40% of pension accumulations. Other countries such as the United States[2] and Denmark have no restrictions on retirees' lump-sum withdrawals, allowing a full lump-sum cash-out at retirement.[3] In Australia, there is a longstanding debate regarding the proper policy for increasing the annuitization rate. This variety of approaches prompted us to investigate the demand for annuities as a result of regulatory changes in minimum annuity laws. Whereas substantial attention has been devoted to studying the direct connection between behavioral biases and the choice of an annuity, our focus is on behavioral biases that may result from regulatory intervention.

We investigate these behavioral biases in both the initiation and the repeal of a mandatory minimal annuity law in a comparable way. Specifically, we use two comprehensive surveys (with both students and representative populations) and a laboratory experiment with performance-dependent incentives to study individuals' responses to an initiation (repeal) of minimum mandatory laws and the factors affecting their response.

We find that the initiation of mandatory annuitization laws shifts the total distribution of chosen annuities toward higher levels. Regardless of whether the participants were students or retirement-age adults, our results suggest that the mandatory minimum annuity was used as a signal, leading to an anchor that on average increases the annuity amounts chosen, given the parameters we use. We also provide evidence of unintended consequences in the form of a decrease in annuitization rates among high-income (consumption perception) individuals,[4] and we assess the results of a repeal in mandatory annuity laws and find that the distribution of annuities does not shift back to original levels.

Our paper contributes to the literature that investigates the effect of regulatory changes, long-term savings decisions and annuity choices, and behavioral biases and individuals' long-term savings decisions, specifically anchoring.[5] Our findings also link to a broader literature on regulations' unintended consequences related to different regulatory interventions. For example, Sharkey (2005) studies the consequences of malpractice damage caps, Murphy (2013) discusses unintended consequences of regulating banking bonuses, Jensen et al. (2015) examine climate policies, Kennedy et al. (1998) discuss disclosure of contingent environmental liabilities, Robbennolt (2002) studies punitive damage caps, and Mugerman and Ofir (2019) provide evidence of anchoring on regulatory limits in the mortgage market. The relevant literature suggests that regulators are either unaware of or underestimate the effect of behavioral biases on the effectiveness of regulation. As our findings show, people exhibit behavioral biases both when regulations are introduced and when they are repealed. In the context of pension regulation, such consequences can have detrimental effects on retirees' welfare.

To the best of our knowledge this is the first research to study both the effect of implementing a regulation and the effect of its repeal. Regulations may be repealed for a variety of reasons, ranging from political pressure to a change in the economic fundamentals. Often regulations are repealed because their implementation was meant to be temporary in the first place, and they were merely used as pilots. Typically, regulators view a regulatory policy as perfectly reversible; that is, repealing it would restore the economy to the same state that prevailed before its implementation. Such a view would make regulators comfortable with the experimentation of policies that can be repealed if found ineffective or counterproductive.

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[1] Starting with Yaari's (1965) theoretical work, a vast literature suggests that annuities have substantial value, and under some assumptions, retirees would use annuities on retirement, in contrast to empirical findings that many retirees prefer the lump sum in practice (e.g., Benartzi et al., 2011). Several reasons for not choosing an annuity in favor of a lump sum have been identified, such as the complexity of the decision (Brown, 2007; Brown et al., 2017), acquiescence and default biases (Bütler and Teppa, 2005; Agnew et al., 2008), difficulty in making irreversible decisions (Brown and Warshawsky, 2001), framing (Benartzi et al., 2011; Beshears et al., 2014; Brown et al., 2008; Goldstein et al., 2016), difficulty parting with accumulated money (Benartzi et al., 2011), mental accounting (Benartzi et al., 2011; Brown, 2007), ambiguity regarding one's own life expectancy (d'Albis and Thibault, 2012; Smith et al., 2001; Payne et al., 2013), and heuristics such as "insurance is only for bad events" (Brown, 2007).

[2] Many American employees are covered by the Social Security Administration (SSA), which essentially pays a life annuity (Brown and Nijman, 2012). However, we should distinguish SSA annuitization from mandatory annuitization in the private schemes discussed in this paper—there is no minimum level of annuitization in the SSA scheme and it does not cover all American employees.

[3] A review of annuitization policies worldwide is available at Mitchell et al. (2011).

[4] Previous literature, such as Fuster et al. (2008) and Brown (2003), examines mandatory annuitization and suggests that it benefits most households.

[5] The anchoring effect (Tversky and Kahneman, 1974) refers to an estimation heuristic in which a person's final estimation of some value is biased by starting from an initial salient value (the "anchor"), possibly derived from the formulation of the problem or from a partial calculation, and then not adjusting sufficiently away from that anchor. The economics literature contains many illustrations of the anchoring effect, for example, in negotiation, stock prices, acquisition activities (Baker et al., 2012), and 401(k) pension investment choices (Choi et al., 2004).

Our finding suggests that this view is rather optimistic. Because of the anchoring effect, the repeal of a policy may leave a memory trace, and the effect of the policy may persist.

This paper continues as follows: in Section 2 we describe our methodology and design, in Section 3 we present our surveys, in Section 4 we describe our laboratory experiment and its results, and in Section 5 we discuss our results.

2. Methodology and design

To investigate a regulatory change such as a mandatory annuity under various conditions, there are several potential methodologies: (1) data analysis, (2) field experiment, (3) survey, and (4) laboratory experiment. Yet, the lack of a satisfactory set of data that covers the entire individual portfolios of a sample of retirees during a period covering initiation and repeal of a law supports the use of an alternative methodology. Specifically, our study builds on a controlled laboratory experiment and two surveys. Surveys offer several advantages that other methodologies lack. They allow us to (1) gather information regarding perceptions; (2) recruit a substantial number of participants; (3) verify a representative sample of the population who are close to retirement, an important point given the complexity of the annuitization decision; and (4) compare two populations: one group far from retirement and another closer to it.

The laboratory experiment was aimed at better understanding the mechanism of the decision to annuitize. Its advantages, beyond those of surveys, include the following: (1) we could better control the information conditions and the exogenous stochastic processes. Specifically we could capture the effect of anticipated consumption (i.e., future financial need) on the choices; (2) it enabled us to validate some of the previous survey results using a different research method and reveal the driving force behind some of the decisions that participants express in the survey; (3) it allowed us to repeat the decision dilemma, for the same individual, to test for a possible learning effect; and (4) we could offer monetary rewards related to the performance to create a more authentic decision environment.[6] For both research methods (survey and laboratory experiment), we used a between-subjects design, in which each subject was exposed to only one of six conditions. In both methods, causal estimates were obtained by comparing the behavior of participants across the conditions.

We now discuss the tasks that participants were presented with in each of the two methodologies we used.

3. Surveys

3.1. Detailed design

The questionnaire was administered twice—once with a student sample and once with a representative sample of 50- to 70-year-olds, a group close to retirement.[7] All respondents were asked to divide a (virtual) sum of money that was saved for retirement between a monthly annuity and a lump sum to be paid immediately upon retirement. Participants were randomly assigned to one of three conditions. In Condition 1, the control condition, respondents were asked to split their (virtual) funds between an annuity and a lump sum with no restriction. In Conditions 2 and 3 we added information regarding a regulatory requirement: a mandatory minimum annuity law that was in force (Condition 2) or had been repealed (Condition 3). All participants were asked to allocate their retirement savings, which they were told amounted to NIS 2 million.[8] We also specified a monthly conversion factor of 200 (a conversion factor is the value that determines how much annuity a retiree is able to purchase from a certain lump sum; it is generally specified in terms of either years or months).[9]

We asked participants in Condition 1 the following question:

> *At retirement, a retiree can generally choose between an **annuity** and **a lump-sum** withdrawal from his or her pension savings, with respect to each retiree's conversion factor. Assume that you have saved NIS 2 million and your conversion factor is 200. What does 200 mean? It means that if you choose an annuity of NIS 1000[10] a month, the accumulation required for the annuity is 1,000*200 = 200,000 and the remainder can be withdrawn as a lump-sum amount of NIS 1.8 million (2000,000−200,000). In these terms, what is the **monthly** annuity you would choose if you were to retire today (you would receive the remaining amount as a lump sum today)?* _____

[6] For a discussion about the use of financial incentives in the laboratory, see Camerer et al. (1999).

[7] Previous studies such as Heimer et al. (2015) demonstrated differences in perception of life expectancy in different age groups, hence motivating us to examine perceptions separately for students and an older population.

[8] New Israeli Shekels, equal to approximately U.S. $500,000; we chose the amount according to an analysis of the average household wage and reasonable long-term rates of return.

[9] In Israel conversion factors are specified in terms of months. A monthly conversion factor of 200 equals a yearly conversion factor of 16.67. In practice, annuity factors vary widely according to the pension product and pension fund calculations. An individual may have an annuity factor of 160 (and in some rare cases even lower) while another may have a factor of about 240. We chose the parameter 200 after consulting with Israeli insurance experts and with the aim to simplify the calculation for the subjects. In line with Hurwitz and Sade (2019), we also asked all participants in the survey to answer a question regarding their life expectancy (lower than, equal to, or higher than the average in the population). The effect of the mandatory annuity and repeal conditions was similar for the low- and high-life-expectancy participants, suggesting that people are affected by such regulatory requirements regardless of their different perceptions about longevity.

[10] One can argue that the specific example we provided in the instructions could influence choices. If that is indeed the case, we expect that it will influence all three manipulations. Relatively few subjects, 3.27% of the representative sample and 3.31% of the students, chose exactly 1000. Further, in the lab experiment we offered a range of different examples.

Table 1
Summary statistics by condition: student sample.

Condition	*N*	Gender (% male)	% Age below 20 years	% Age 21–30 years	% Age 31–40 years	% Age above 40 years	Mean education (years)	% Married	% With good or very good health
1	109	50	0	97.25	1.83	0.92	14.10	12.8	98
2	118	56	0	84.75	15.35	0	14.98	23.7	99
3	135	49	2.22	94.82	1.48	1.48	13.71	8.15	100

Note. Condition 1 had no specific manipulation. In Condition 2 participants were informed about a mandatory minimum annuity required by law, and in Condition 3 participants were informed about a mandatory minimum annuity regulation that was recently repealed. Gender represents the proportion of male participants in the sample. Married is the proportion of participants who defined themselves as married. The proportion of good and very good health was derived from a question in our survey in which participants were asked to assess their health condition as very good, good, not so good, or not good at all.

Table 2
Summary statistics by condition: representative sample.

Condition	*N*	Gender (% male)	% Age 50–60 years	% Age 61–70 years	% With academic education	% Married	% With good or very good health
1	324	41	54	46	47	76	89
2	258	46	57	43	50	72	87
3	304	42	58	42	51	70	88

Note. Condition 1 had no specific manipulation. In Condition 2 participants were informed about a mandatory minimum annuity required by law, and in Condition 3 participants were informed about a mandatory minimum annuity regulation that was recently repealed. Gender represents the proportion of male participants in the sample. Age 50–60 and age 61–70 represent the proportions of participants in those age ranges. The percentage with academic education was derived from a question in which participants were asked to assess their education level (categories: high school education, post-secondary or academic education. Married is the proportion of participants who defined themselves as married. The proportion of good and very good health was derived from a question in our survey in which participants were asked to assess their health condition as very good, good, not so good, or not good at all.

In Condition 2 we added the following statement: "*According to State of Israel laws, there is a mandatory minimum annuity of NIS 4000 a month.*" The rest of the wording was the same as in Condition 1. In Condition 3 we added the sentence "*In the past, State of Israel laws stated a mandatory minimum annuity of NIS 4000 a month; these laws were recently repealed.*" Again, the rest of the wording remained the same as in Condition 1.

In addition, we asked participants about their own life expectancy estimations and collected demographic and self-assessed health information (including smoking). Most of the questions were multiple choice but some were open ended (e.g., occupation), and some included a scale of responses (i.e., probabilities).

3.2. Participants

The student sample consisted of 362 students ($n = 109$ in Condition 1; $n = 118$ in Condition 2; $n = 135$ in Condition 3; $M_{age} = 26.14$ years, $SD = 3.46$, range 19–54 years; 51% male, 49% female) who were recruited from the Hebrew University of Jerusalem and the College of Management Academic Studies in Israel.[11] To assess how seriously the respondents treated the questionnaire, they were asked to answer questions regarding life expectancy in Israel. The mean estimated life expectancy (for both males and females) was 79.6 years ($SD = 6.9$) and the median answer was 80 years. The proximity of the estimated values to the real-life expectancy at birth in Israel according to the Central Bureau of Statistics (men: 80.3 years, women: 83.9 years) can be an indicator that the survey respondents took the survey seriously and paid attention to the questions.

The age-representative sample was drawn from respondents to an online survey conducted by a research company of 886 Israeli residents aged 50–70 years ($n = 324$ in Condition 1; $n = 258$ in Condition 2; $n = 304$ in Condition 3; 56% aged 50–60 years; 44% aged 61–70; 43% male; 57% female) in November 2016.[12] With regard to income, 30% reported that they earned more than the average income of the population, 32% earned the same as the average, and 38% earned less than the average.

This sample was also asked to estimate the mean life expectancy in Israel. Respondents' mean estimates were 76.9 years for women and 76 years for men ($Mdn = 84.5$ and 81 years, respectively); the actual life expectancy at age 60 reported by the Central Bureau of Statistics is 83 years for men and 85.5 years for women.

Table 1 displays the characteristics of the student sample and Table 2 the characteristics of the representative sample, by condition. The subgroups were very similar, both in demographic parameters and health perception (in the students' survey, Condition 2 was slightly older than the other groups).

[11] A paper-and-pencil survey, administered during class time.

[12] The survey was administered by Geocartography using an online panel of voluntarily registered potential participants with a wide residential age distribution.

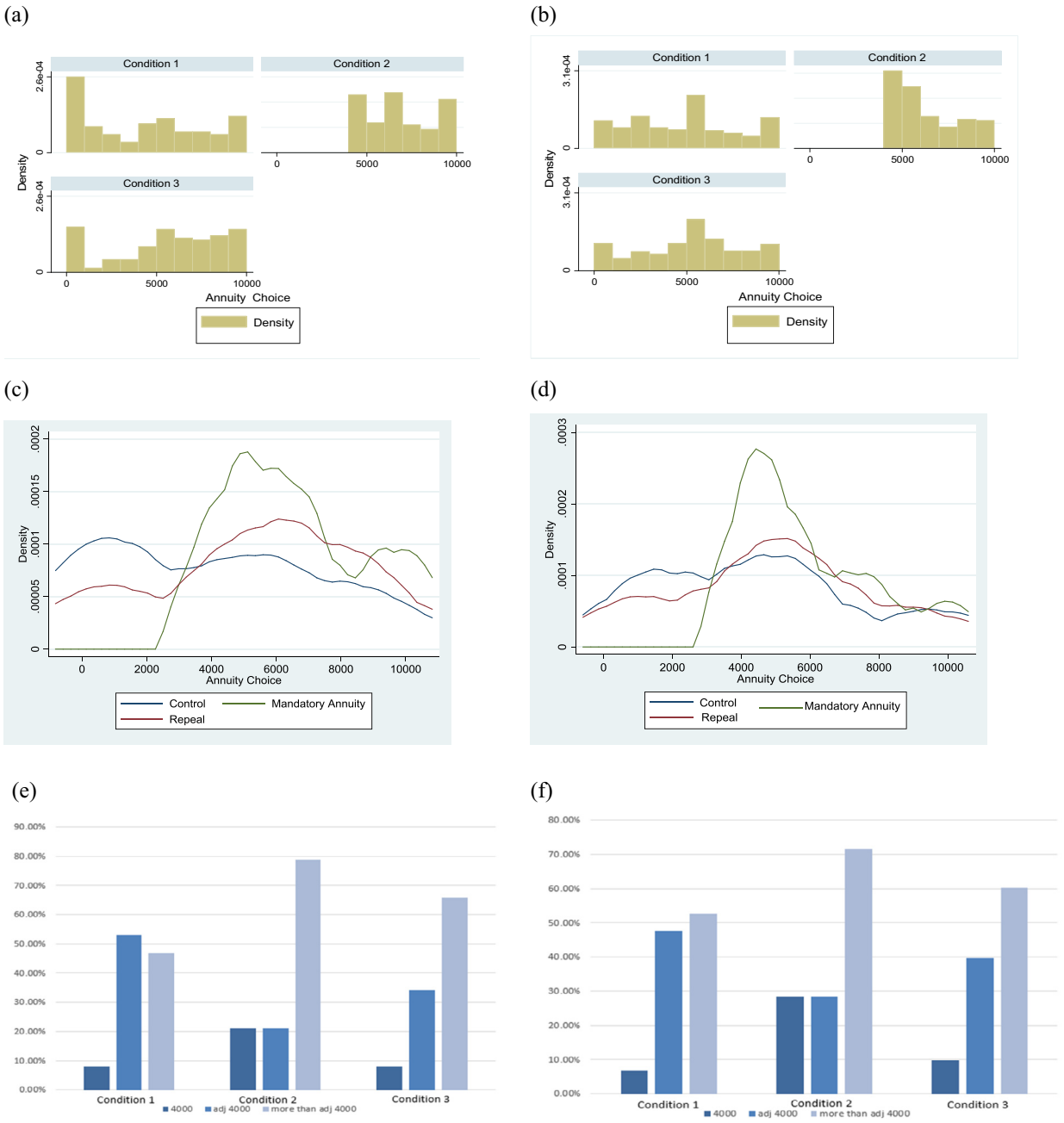

Fig. 1. Annuity distributions by conditions for (a) the student sample and (b) the representative sample; kernel densities for (c) the students sample and (d) the representative sample; and the proportion of participants who chose either an annuity of NIS 4000, adjusted 4000 (i.e., lower or equal to 4000), or higher than adjusted 4000 for (e) the student sample and (f) the representative sample.

3.3. Results

3.3.1. The anchoring effect

Fig. 1(a) and (b) shows the distribution of chosen annuities in the different conditions for the student sample and the representative sample. Participants chose higher annuities in Condition 2 (mandatory minimum annuity) and Condition 3 (mandatory minimum annuity repealed) than in Condition 1 (control group). Furthermore, Fig. 1(c) and (d) present kernel densities summarizing the distribution of chosen annuities in the various conditions in the student survey and the representative sample. The kernel density plot for the mandatory law (Condition 2) is shifted up and to the right of the kernel

Table 3
Percentage of student sample choosing annuities of different values.

Condition	*N*	Monthly annuity value (new Israeli shekels)					
		0	4000	Adjusted 4000[a]	10,000	Mean	Median
1	109	18.35%	8.26%	52.29%	10.09%	4116.97	4000
2	118	0%	21.19%	21.19%	19.49%	6572.03	6000
3	135	11.11%	8.15%	34.07%	12.59%	5346.22	6000

*Note. Condition 1 had no specific manipulation. In Condition 2 participants were informed about a mandatory minimum annuity required by law, and in Condition 3 participants were informed about a mandatory minimum annuity regulation that was recently repealed. As expected, the mean annuity was highest in the condition that introduced an anchor (Condition 2), while the medians in Conditions 2 and 3 were equal. Choosing the exact amount of 4000 that was introduced as the minimum annuity (the anchor) was highest in Condition 2. Nevertheless, the proportion of small annuities that were lower than or equal to 4000 (*i.e., *adjusted 4000) were lowest in Condition 2 (in which the lowest could only be 4000), implying a shift in the entire distribution toward higher annuities. Moreover, the proportion of participants who chose an annuity lower than or equal to 4000 was higher in Condition 3 than in Condition 2 but not as high as in Condition 1.*

[a] *Any value between NIS 1 and 4000 was adjusted to 4000.*

Table 4
Percentage of representative sample choosing annuities of different values.

Condition	*N*	Monthly annuity value (new Israeli shekels)					
		0	4000	Adjusted 4000[a]	10,000	Mean	Median
1	324	7%	6.79%	47.5%	12.3%	4479.9	5000
2	258	0%	28.3%	28.3%	10.8%	5922.5	5000
3	304	7.5%	9.86%	39.8%	9.54%	4871.2	5000

*Note. Condition 1 had no specific manipulation. In Condition 2 participants were informed about a mandatory minimum annuity required by law, and in Condition 3 participants were informed about a mandatory minimum annuity regulation that was recently repealed. As expected, the mean annuity was highest in the condition that introduced an anchor (Condition 2) while the median was the same in all conditions. Nevertheless, the proportion of small annuities that were lower than or equal to 4000 (*i.e., *adjusted 4000) were lowest in Condition 2 (in which the lowest could only be 4000), implying a shift in the entire distribution toward higher annuities. Moreover, the proportion of participants who chose an annuity lower than or equal to 4000 was higher in Condition 3 compared to Condition 2 but not as high as in Condition 1.*

[a] *Any value between NIS 1 and 4000 was adjusted to 4000.*

density plot for the control group (Condition 1) and the repeal condition (Condition 3).[13] Tables 3 and 4 show the proportion of participants in each sample who chose an annuity of NIS 0, NIS 4000 (the mandatory minimum annuity), and NIS 10,000 (the maximum possible annuity). We also show the "adjusted 4000," in which all the annuities that were between NIS 1 and 4000 were set to 4000 (Conditions 1 and 3). This was done because one could argue that the difference between conditions 1 and 2 is not surprising and may have resulted from the technical fact that anyone who wanted to choose a value below the mandatory minimum in Condition 2 had to choose a higher value—at least the minimum—because of the minimum annuity law that was introduced. To test whether this drove the results, we conducted an additional test. If there is no other effect, one would expect that the only observed difference would be that those who might have wanted an annuity with a value below the mandatory minimum would have to choose the minimum value. Hence, for comparison, in the unconstrained condition, we assigned the minimum value for each observation that had a value below the minimum ("adjusted treatment"). If, for example, the choice was a value of NIS 2000, we assigned it the value of NIS 4000, the minimum annuity by law constraint. We call this value "adjusted 4000." We compared the adjusted treatment to the treatment with the actual constraint introduced by the minimum annuity law.

As seen in Table 3 and Fig. 1(e) and (f), the proportion of student participants who chose an annuity of NIS 4000 was significantly higher in Condition 2 (mandatory minimum annuity) than in the other conditions. Again, note that in Condition 2, choices were lower bounded at the value of 4000, and hence for the comparison all choices between NIS 0 and 4000 were taken into account (adjusted 4000 in Table 3), and that Condition 1 (control group) had a higher proportion of participants choosing that amount than Conditions 2 and 3. The mean annuity was highest in Condition 2. The median annuity was equal in Conditions 2 and 3 and higher than in Condition 1. The proportion who chose the maximum allowed annuity (in this questionnaire, NIS 10,000) was also highest in Condition 2, followed by Condition 3 and then Condition 1. The difference between Conditions 1 and 2 is statistically significant and so is the difference between Conditions 1 and 3.

The mean results presented in Table 4 are similar. The proportion of the representative sample who chose an annuity between NIS 0 and 4000 (adjusted 4000 in Table 4) was highest in Condition 1, followed by Condition 3 and then Condition 2. The mean annuity was highest in Condition 2, followed by Condition 3 and then Condition 1. The difference between Conditions 1 and 2 is statistically significant while the difference between Conditions 1 and 3 is not statistically significant.

[13] In the representative sample, a Kolmogorov–Smirnov test of the hypothesis that the empirical distributions for the control and mandatory annuity conditions come from the same population distribution rejects the null hypothesis. The same test was conducted to compare the empirical distributions of the control and repeal groups. Here again, we rejected the null hypothesis (both p values are lower than 0.05). We did not conduct a Kolmogorov–Smirnov test for the students survey due to the sample size.

These results suggest that there was a shift of both students and retirement-age adults in Conditions 2 and 3, as the mandatory minimum annuity created an anchoring and adjustment process, with the anchor being the regulatory signal that led to higher annuities. To better understand the determinants of the decision to annuitize and to test the hypothesis that a mandatory minimum annuity law may become an anchor that will shift the distribution of annuities, we further investigated the effects found in the questionnaire, using various specifications (including logit, probit, and ordinary least squares regression analyses and different dependent variables; since there was no significant difference, we present only the logit specifications) and controlling for both demographic and socioeconomic variables (e.g., age, gender,[14] marital status,[15] and income) and for relevant health conditions (such as smoking in the present or past and health perceptions[16]).

Eq. (1) describes the potential main characteristics that might affect the decision of individual i to choose an annuity that is less than or equal to NIS 4000 (the mandatory minimum)[17]:

$$\begin{aligned}\text{annuity}_{\leq 4{,}000_i} = {} & \alpha + \beta_1 \text{Condition2} + \beta_2 \text{Condition3} + \beta_4 \text{age}_{61-70i} + \beta_5 \text{male}_i + \beta_6 \text{single}_i \\ & + \beta_7 \text{married}_i + \beta_8 \text{divorced}_i + \beta_9 \text{widowed}_i + \beta_{10} \text{smoker}_i + \beta_{11} \text{chance85}_i \\ & + \beta_{12} \text{chance95}_i + \beta_{13} \text{income}_i + \beta_{14} \text{good and very good health}_i + \epsilon_i \end{aligned} \quad (1)$$

where $\text{annuity}_{\leq 4{,}000_i}$ is a dummy variable for a chosen annuity that is less than or equal to NIS 4000 ($\text{annuity}_{\leq 4{,}000} = 1$ if chosen annuity is lower than or equals 4000); Condition 2 is the mandatory minimum annuity manipulation and Condition 3 is the repealed mandatory minimum annuity manipulation (Condition 1, the control group, is the reference category); age_{61-70i} is a dummy variable that equals 1 if the respondent's age was between 61 and 70 years; single_i, married_i, divorced_i, and widowed_i are dummy variables for marital status; smoker_i indicates smoking activity; chance85_i and chance95_i are the subjective probabilities of reaching age 85 and 95, respectively; income_i represents reported income above the mean income in Israel; and $\text{good and very good health}_i$ is respondents' self-reported health status.

The version of the questionnaire used in Condition 2 indicating the mandatory minimum annuity significantly affected the propensity to annuitize. As shown in Table 5, personal characteristics are not significantly related to the annuitization decisions for the representative sample. Gender, income, and health condition are significantly related to the decision to annuitize in some estimations; male participants tend to choose higher annuities; and income and good health also predict higher propensity to annuitize.

Moreover, the results presented in Table 5 (regression analysis) illustrate that the mandatory minimum annuity affects participants' decisions in the representative sample. We find that the likelihood of choosing an annuity of strictly more than NIS 4000 is significantly higher in the constrained conditions (Conditions 2 and 3) than in the unconstrained (control) condition. Participants who were informed about a mandatory minimum annuity requirement that was repealed (Condition 3) are less likely to choose an annuity of less than or equal to NIS 4000 compared to participants who were not informed of the mandatory minimum annuity (Condition 1; see Table 5, columns 2 and 3). The effect of the mandatory minimum annuity (Condition 2) is much stronger for participants who were less educated (less than a high school diploma).

For robustness, we further investigate the results of a censored regression on the value of NIS 4000 (Table 5, column 5; see Table 6, column 34, for the student sample). We show that participants in the mandatory annuity and repeal conditions choose higher annuities compared to participants in the control group (the effect of the repeal is significant only in the students survey).

As in the representative sample, personal characteristics do not affect the tendency to annuitize in the student sample. When we test for the influence of the mandatory minimum annuity law (both its introduction and its repeal) on the tendency to choose an annuity less than or equal to NIS 4000 (Table 6, columns 2 and 3), the effect of both manipulations is statistically significant, meaning that the entire distribution of chosen annuities changes as a result of the regulation. Whether participants were told that the mandatory minimum annuity law was in effect (Condition 2) or repealed (Condition 3), their demand for annuities is higher compared to the control group (Condition 1). As these results are similar to those presented in Table 5, the manipulation appears to have affected students and older participants in similar directions.

3.3.2. Repeal of the regulatory requirement

We are interested in studying the effect of the repeal of the mandatory minimum annuity law. As shown in Table 3, for the student participants in Condition 3 where the law was repealed, the chosen annuities are still higher than when there was no anchor at all (Condition 1). In particular, the median annuity in both the mandatory minimum annuity and the repealed mandatory minimum annuity conditions (Conditions 2 and 3) is higher than the median annuity in the control condition (Condition 1). Moreover, the average annuity in Condition 3 is higher than in Condition 1. Table 6 reports the analysis of the factors affecting their annuitization decisions. Interestingly, similar results were obtained in the representative sample.

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[14] For example, Bütler and Teppa (2005) found a relation between gender and annuity choice.

[15] Previous research provides evidence of a relation between marital status and the annuitization decision (e.g., Poterba and Warshawsky, 2000; Kotlikoff and Spivak, 1981; Cappelletti, Guazzarotti, and Tommasino, 2013).

[16] Hurwitz and Sade (2019) presented evidence that medical condition affects annuitization decisions, while smoking status does not.

[17] Variables chosen according to the annuity vs. lump sum choices in the empirical literature. For further discussion see Hurwitz and Sade (2019).

Table 5
Representative sample: logit models of the factors affecting the choice of an annuity less than or equal to NIS 4000 and Tobit model (censored) for chosen annuity.

Variable	Less than or equal to NIS 4000				Chosen annuity
	Total sample ($N = 886$) Logit		Less educated sample[a] ($N = 216$) Logit		Total sample ($N = 886$) Tobit
	Estimate	Odds ratio	Estimate	Odds ratio	
Condition 2	−0.833***	0.435***	−1.373***	0.253***	912.3***
	(0.181)	(0.0786)	(0.379)	(0.0960)	(256.1)
Condition 3	−0.321*	0.725*	−0.848**	0.428**	388.3
	(0.165)	(0.120)	(0.352)	(0.151)	(248.3)
Age 61–70 years	0.191	1.211	−0.0229	0.977	47.82
	(0.144)	(0.175)	(0.308)	(0.301)	(210.3)
Male	−0.374**	0.688**	−0.158	0.854	656.8***
	(0.149)	(0.103)	(0.317)	(0.271)	(215.1)
Single	0.354	1.425	−0.149	0.862	−405.0
	(0.653)	(0.931)	(1.271)	(1.095)	(941.9)
Married	0.478	1.612	−0.302	0.740	−127.3
	(0.576)	(0.929)	(1.042)	(0.770)	(832.5)
Divorced	0.546	1.726	−0.267	0.766	−540.8
	(0.595)	(1.026)	(1.087)	(0.833)	(861.2)
Widowed	0.282	1.326	−0.627	0.534	−169.3
	(0.665)	(0.882)	(1.353)	(0.723)	(958.1)
Smoker	0.247	1.280	−0.0707	0.932	−359.4
	(0.225)	(0.288)	(0.412)	(0.383)	(335.9)
Subjective chance of reaching age 85	0.00183	1.002	0.0306	1.031	21.39
	(0.0439)	(0.0440)	(0.0878)	(0.0905)	(64.79)
Subjective chance of reaching age 95	−0.00532	0.995	−0.0635	0.938	0.0180
	(0.0344)	(0.0343)	(0.0745)	(0.0699)	(50.13)
Income	−0.254	0.776	−0.271	0.762	627.7***
	(0.163)	(0.127)	(0.426)	(0.325)	(229.9)
Good and very good health	−0.623***	0.537***	−0.697	0.498	909.4**
	(0.231)	(0.124)	(0.457)	(0.227)	(353.7)
Constant	0.110	1.116	1.384	3.989	3267***
	(0.628)	(0.701)	(1.147)	(4.576)	(920.3)
Pseudo R^2	0.0395	0.0395	0.0728	0.0728	0.0046

Note. N = Number of observations in the models. Standard errors in parentheses. Dependent variables are either choosing an annuity that is less than or equal to NIS 4000 (columns (1)-(4) or chosen annuity (column (5). Main explanatory variables are gender, marital status, smoking decisions, subjective survival probability, income, and health.

* $p < 0.1$.

** $p < 0.05$.

*** $p < 0.01$.

[a] *Participants with less than a high school diploma.*

The effect of repealing the mandatory minimum annuity (Condition 3) is negative and significant in the specifications above (Tables 5 and 6), reflecting a lower tendency to choose annuities less than or equal to NIS 4000. This result suggests that, in our framework, a regulation that was repealed still has an impact on individuals' decisions. Specifically, the annuity amounts are still higher in the repeal condition (Condition 3) than in the control condition in which the participants were not informed about the regulation at all (Condition 1).[18]

3.3.3. Income and effects of a mandatory minimum annuity law

Our survey results indicate that the effect of the initiation of a mandatory minimum annuity law is not significantly diminished by the law's repeal. One might ask whether this effect differs for people with different demographics. For instance, one might expect smaller effects for people with lower expectations regarding their future consumption (i.e., financial need).

To explore this question, we compare annuity choices between participants in the representative sample who reported having a very high income and those who reported a very low income.[19] Fig. 2 reveals that for low-income participants, the mandatory minimum annuity indeed increases the mean chosen annuity, whereas for high-income participants, the "anchor" of a mandatory minimum annuity has little effect. Furthermore, in the low-income group, individuals are affected

[18] Furthermore, the difference between Condition 2 (mandatory law) and Condition 3 (repeal) is also statistically significant (in both the students sample and the representative sample). This implies that the repeal condition was not as strong as the regulation in place but still increased the tendency to choose higher annuities.

[19] In the survey we used reported income as a parameter for economic status. Recent research has claimed that during the process of predicting financial slack, people are driven by expected changes in income and tend to ignore changes in expected consumption (Berman et al., 2016). We approached future consumption more directly in our laboratory experiment.

Table 6
Student sample: logit model of the factors affecting the choice of an annuity less than or equal to NIS 4000 and Tobit model (censored) for chosen annuity.

Variable	Less than or equal to NIS 4000($N = 345$) Logit		Chosen annuity ($N = 345$) Tobit
	Estimate	Odds ratio	Estimate
Condition 2	−1.486***	0.226***	1650***
	(0.323)	(0.0732)	(439.2)
Condition 3	−0.788***	0.455***	1251***
	(0.281)	(0.128)	(419.7)
Age	−0.0517	0.950	105.1**
	(0.0433)	(0.0411)	(52.56)
Male	0.188	1.207	−449.9
	(0.244)	(0.295)	(337.7)
Single	0.282	1.326	−238.7
	(0.385)	(0.510)	(486.1)
Smoker	0.450	1.569	−552.3
	(0.320)	(0.501)	(460.2)
Subjective chance of reaching age 85	−0.0526	0.949	−66.57
	(0.0766)	(0.0727)	(105.9)
Subjective chance of reaching age 95	0.0770	1.080	−75.26
	(0.0638)	(0.0689)	(88.51)
Income	0.486	1.626	388.9
	(0.339)	(0.552)	(456.1)
Good and very good health	−1.144	0.318	2455
	(1.282)	(0.408)	(2047)
Constant	2.125	8.372	454.3
	(1.798)	(15.06)	(2566)
Pseudo R^2	0.0756	0.0756	0.008

Note. N = Number of observations in the models. Standard errors in parentheses. Dependent variables are either choosing an annuity that is less than or equal to NIS 4000 (columns 2 and 3) or chosen annuity (column 4). Main explanatory variables are gender, marital status, smoking decision, subjective survival probability, income, and health.
*$p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

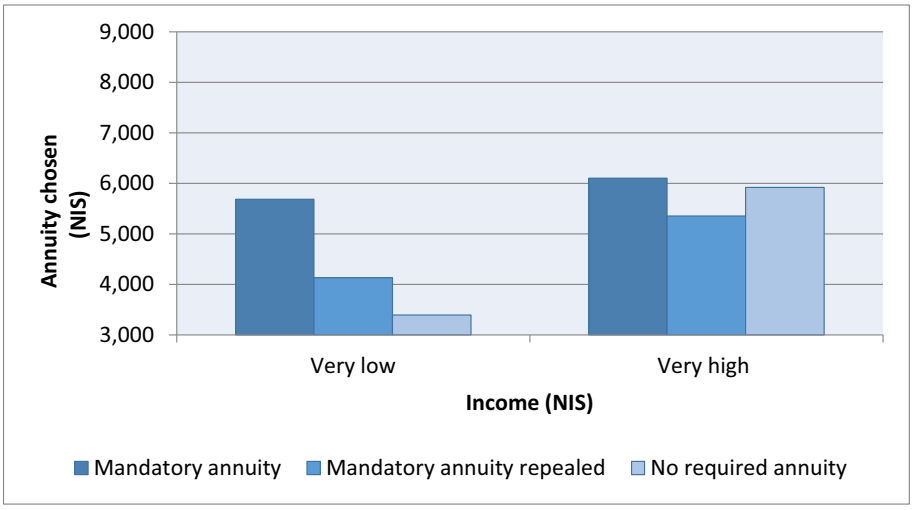

Fig. 2. Mean annuity amount chosen by the representative sample for different incomes and annuity requirements. NIS = New Israeli shekels.

by the anchor regardless of education level, whereas in the high-income group, the anchor does not affect the educated participants as much as the less-educated participants.

It should be noted that in the student survey, 80.61% of the participants declared that their income was much lower than or equal to the average of the population; hence it is not surprising that on average they behave similarly to the low-income representative survey participants. This finding led us to investigate the relation between consumption perceptions and annuity choice in a laboratory setting.

4. Laboratory experiment

4.1. Design details

The experiment consisted of two rounds of a computerized task that involved the distribution of money between an annuity and a lump sum (where the conversion factor was 200). Participants, students of the Hebrew University of Jerusalem and the College of Management Academic Studies, Israel,[20] first were given verbal instructions and then read a scenario in which they learned they were at the stage of life just before retirement and had saved an amount of ZUZ[21] 2000,000. Furthermore, participants were told that a computer would draw their life expectancy from a set ranging from 0 to 360 months with an average of 200 months.[22] They were informed that the outcome of the draw would be revealed only after they chose their annuity. Thus, they did not know the exact amount they would need before choosing the annuity. Participants were given two examples of the task to ensure that they understood the instructions. They provided demographic details before proceeding with the task.

Participants ($N = 277$) were randomly assigned to one of two consumption groups in one of three conditions ($n = 99$ in Condition 1; $n = 89$ in Condition 2; $n = 89$ in Condition 3). Condition 1 was a control condition; participants received no additional information beyond what we describe above. In Condition 2, participants were told that regulators in the State of Israel had stipulated a mandatory minimum annuity in the amount of ZUZ 4000 monthly. To reflect the situation of a recent repeal of a mandatory minimum annuity law, in Condition 3 participants were given additional information stating that a previous mandatory minimum annuity of ZUZ 4000 had recently been repealed. Participants in the high-consumption groups were told that their monthly consumption would be ZUZ 8000, 9000, or 10,000 (evenly distributed); participants in the low-consumption group were told that their monthly consumption would be ZUZ 3000, 4000, or 5000 (also evenly distributed). The participants' task was to decide how to split their (virtual) accumulated funds between an annuity that would pay every period according to the realized longevity and a lump sum. During the experiment, we computed the monthly balance in the participants' account according to their choices and the realization of the variables. In the case of a surplus, it was accumulated each month and in the case of a deficit the shortfall was taken from the lump sum, if possible.[23]

The participants were paid for their participation, receiving a show-up fee of NIS 27 (equivalent to the hourly minimum wage in Israel) and NIS 20 in addition if they had no deficit in their account. This was meant to simulate the real-life situation in which retirees who perceive annuities as a consumption tool are more likely to purchase annuities (Brown et al., 2008). Moreover, if there was a monthly surplus or a lump sum not needed for consumption, it was added to the participants' payment (explained to participants in detail at the beginning of the experiment). The aim of this part of the compensation scheme was to take into consideration bequest motives known to influence annuity choices (Friedman and Warshawksy, 1990; Inkmann et al., 2010). Given that being an elderly person with no income or savings is a very undesirable outcome, participants were told that if they consumed all of the lump sum and the annuity was insufficient for living expenses, they would receive the show-up fee only. Each participant took part in the experiment twice (same manipulation), to test for potential learning effects (for further description of the payment mechanism, see Appendix 1).

4.2. Results

We compare the chosen annuity in each of the conditions and in the two rounds that we conducted. The general trend is presented in Fig. 3. [24]

The results show a clear treatment effect in the high-consumption groups and a less substantial effect in the low-consumption groups. In the low-consumption groups, the mandatory minimum annuity increased the mean chosen annuity as expected (above the level in the control group), but in the high-consumption groups, the mandatory minimum annuity led to a decrease. Similar to the simulation we performed for the surveys, we again computed the adjusted 4000 annuity

[20] Participants were recruited through advertisements at the University and College and emails from the academic staff.

[21] ZUZ was a virtual currency that was converted (for payment) into new Israeli shekels at a ratio of ZUZ 50,000 to NIS 1.

[22] We designed the experiment in such a way that a risk-neutral individual would be indifferent between the annuity and the lump-sum for each of the consumption values (given our aim is to focus on the effect of the law and its repeal). To derive an optimization exercise, one should assume a specific structure of risk preferences, which we do not assume. We assume that since the subjects were randomly assigned, there is no significant difference in the risk aversion of the different treatments and groups.

[23] The decision made in this experiment takes into account some important real-life considerations related to the withdrawal phase, such as longevity risk (uncertainty about the number of periods in the experiment), financial shocks (uncertainty about expected consumption), and bequest motives (the payment mechanism includes the cumulative difference between income and expenses as we will further describe). Alas, the experiment is still abstract and does not take into account all real-life considerations, such as large financial shocks early in retirement (which can lead to a possible preference for a lump sum), interest rates, inflation, and tax considerations. However, as the aim of the experiment is not to explain the reasons for low demand in many annuity markets but rather to study the consequences of initiation and repeal of mandatory annuitization laws, and since the above considerations were identical in all the conditions, the abstraction does not affect the external validity of our results.

[24] We should first note that since all participants were given ZUZ 2 million, participants in the low-consumption group are expected on average to choose lower annuities than the high-consumption group. In fact, we find that the mean chosen annuity in the control group is higher in the high-consumption group compared to the low-consumption group, which implies that on average participants understood the task. Hence, our focus is on a comparison of the choices and the effect of the mandatory annuity law within each consumption group and not on the comparison of the level of the chosen annuitization between the two consumption groups.

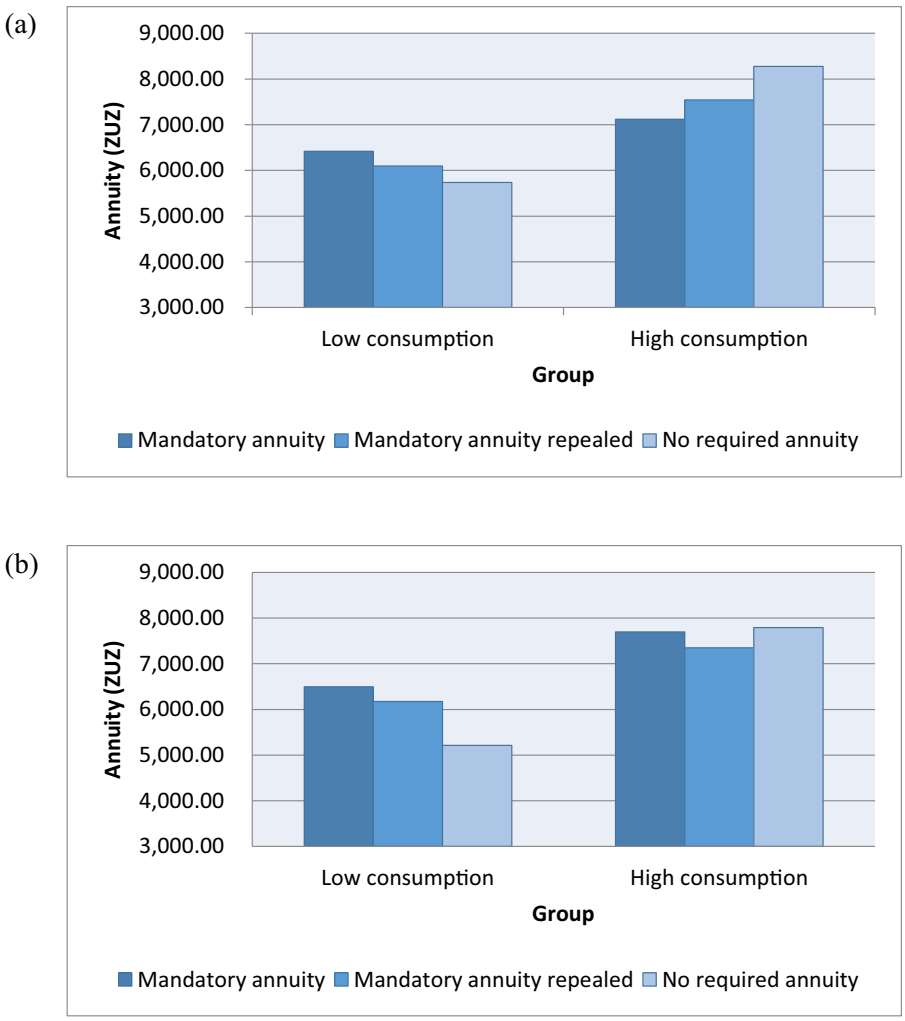

Fig. 3. Mean annuity amount chosen by participants in the high- and low-consumption groups in (a) Round 1 and (b) Round 2 of the experiment. ZUZ = Experimental currency.

(in which we assigned each participant who chose an annuity value that was lower than 4000 a level of 4000). In the high-consumption group, the proportion of participants who chose an annuity equal to 4000 or less is 2.17% in Condition 1 (the control group), increases to 7.5% in Condition 2 (mandatory annuity), and to 11.11% in Condition 3 (the repeal treatment). In the low-consumption group, the proportion is 22.64% in Condition 1, 8.16% in Condition 2, and 15.91% in Condition 3. Table 7 displays detailed statistics regarding the mean annuity choices for each condition for each group in each round.

Results show that the consumption group mattered for the mean chosen annuity in both rounds. Moreover, in both low- and high-consumption groups and in both the first and second round, we find a difference between Conditions 1 and 2. Interestingly, the direction of the difference between the conditions is different for participants with low versus high consumption.

In the low-consumption groups, participants in Condition 2 (mandatory annuity) had a higher mean chosen annuity (in both rounds) than participants in Condition 1 (control); for high-consumption groups, participants in Condition 1 had a higher mean chosen annuity (in both rounds) than participants in Condition 2.

Additionally, there is a smaller difference between Conditions 2 (mandatory annuity) and 3 (repeal). In both rounds, participants in the low-consumption group in Condition 2 had a higher mean chosen annuity than participants in the low-consumption group in Condition 3. For the high-consumption groups, the mean chosen annuity in Condition 3 was higher than the mean chosen annuity in Condition 2 in Round 1 but lower in Round 2.

To determine the significance of the differences between the mean chosen annuity in Conditions 1 and 3 (in both the low- and high-consumption groups), we conducted a *t*-test followed by a nonparametric test (Kruskal–Wallis). For the *t*-test, the difference between the means of Conditions 1 and 2 in the low-consumption groups is statistically significant at the 10%

Table 7
Mean chosen annuity in each condition and in each round of the laboratory experiment.

Condition	High-consumption group			Low-consumption group		
	Mean	*SD*	*N*	Mean	*SD*	*N*
Round 1						
1. No manipulation (control)	8275.54	1847.77	46	5739.28	2772.02	53
2. Mandatory minimum annuity	7120.35	1691.81	40	6421.86	1372.48	49
3. Mandatory minimum annuity repealed	7543.53	2782.83	45	6097.73	1724.58	44
Round 2						
1. No manipulation (control)	7791.30	2364.72	46	5215.79	2819.58	53
2. Mandatory minimum annuity	7700.25	1830.90	40	6500.00	1555.63	49
3. Mandatory minimum annuity repealed	7351.11	3120.83	45	6176.14	2164.18	44

Note. All amounts are in the experimental currency, ZUZ. Shown is mean chosen annuity in each condition and in each round (participants were required to perform the same task twice). High-consumption groups consisted of participants who were told that their future consumption would be ZUZ 8000, 9000, or 10,000. Low-consumption groups consisted of participants who were told that their future consumption would be ZUZ 3000, 4000, or 5000.

level in Round 1 and at the 5% level in Round 2. In the high-consumption groups the difference in the means is statistically significant at the 5% level in Round 1 but not statistically significant in Round 2.

We used a Kruskal–Wallis test because of different variances between the groups.[25] The test results indicate that for the low-consumption groups, there is a statistically significant difference in chosen annuities between the mandatory minimum annuity condition (Condition 2) and the control condition (Condition 1) in Round 2 but not in Round 1, ($\chi^2_{\text{round2}} = 4.579,\ p_{\text{round2}} = 0.0324,\ \chi^2_{\text{round1}} = 0.724,\ p_{\text{round1}} = 0.395$, respectively). In the high-consumption group, the test results indicate a statistically significant difference between the groups in Round 1 but not in Round 2, $\chi^2_{\text{round1}} = 9.608,\ p_{\text{round1}} = 0.0019$ and $\chi^2_{\text{round2}} = 0.474,\ p_{\text{round2}} = 0.4913$, respectively).

These results highlight the difference between high- and low-income individuals in the representative sample. For low-consumption participants, the results indicate that the mandatory minimum annuity increased the mean chosen annuity (consistent with the survey results for respondents with low income). For high-consumption participants, the opposite occurred.

For robustness, we also pooled the results of both rounds of the experiment to estimate a logit model assessing the propensity to choose annuities lower than or equal to 4000 by condition (mandatory annuity and repeal) and controlling for personal characteristics (clustered at the respondent level; Table 8). We find that in the low-consumption group participants in both the initiation and the repeal condition choose significantly lower levels of annuities that are lower than or equal to 4000 compared to the control group, while in the high-consumption group the effect is negative for the initiation condition and positive for the repeal condition, but alas, neither effect is significant.

Our results suggest that repealing a mandatory minimum annuity law does not immediately convert the distribution of annuities back to its original shape. This result is consistent across all of the measurements in this project, including two surveys (a student survey, an online representative survey) and a laboratory experiment.

The result is consistent with an anchoring effect. We conjecture that in this complex situation, participants used the regulatory constraint as a signal. In particular, under the veil of ignorance (no information), participants had to choose their annuity merely based on their beliefs regarding future consumption and life expectancy. Since the decision of how much to annuitize is complex, the regulatory message served as a signal on which participants anchored when making their decisions. Hence, for participants in the high-consumption group the new signal pushed beliefs about the amount of annuity needed downward, whereas in the low-consumption group, the signal pushed the beliefs upward. In the repeal condition, the signal was weaker but apparently still influenced the decision to annuitize. Hence, the distribution of annuities did not immediately revert to its original shape.

5. Discussion

We have demonstrated, using a laboratory experiment and two surveys, that mandatory minimum annuity laws influence individual decisions and choices. Our results suggest that the introduction of a mandatory minimum annuity shifted the entire distribution of chosen annuities, presumably due to a process of anchoring and adjustment, with the anchor being the regulatory signal (minimum annuity). By contrast, information about repeal of such a regulation did not entirely shift the distribution back again. Interestingly, the effect differed between people with different income and consumption levels, suggesting that careful investigation is needed before regulators use a mandatory minimum annuity to increase annuity choices to any given minimum level.

[25] Instead of the more common Wilcoxon test used in experimental economics (Siegel and Castellan, 1988). The obtained results remain when using a Wilcoxon test. Specifically, comparing the mandatory annuity condition and control group, for the low-consumption group alone, in the first round (second round) $p = 0.393$ ($p = 0.031$), and for the high-consumption group alone, in the first round (second round) $p = 0.0018$ ($p = 0.486$).

Table 8
Experimental results: logit models of the factors affecting the choice of an annuity of less than or equal to NIS 4000 (clustered at respondent level).

Variable	Low consumption ($N = 292$)	High consumption ($N = 246$)
Round1	−0.369	−0.727**
	(0.267)	(0.338)
Condition 2	−1.344**	−0.292
	(0.586)	(0.757)
Condition 3	−0.889*	0.905
	(0.526)	(0.876)
Age	−0.376***	−0.0454
	(0.136)	(0.116)
Male	−0.525	−0.285
	(0.470)	(0.629)
Single	−0.448	–
	(1.477)	
Smoker	−1.270	1.028
	(1.009)	(0.728)
Education years	−0.247	−0.522**
	(0.219)	(0.260)
Subjective chance of reaching age 85	−0.235	−0.0689
	(0.150)	(0.204)
Subjective chance of reaching age 95	0.201	0.124
	(0.146)	(0.169)
Unwillingness to get older with no assets	−0.193**	−0.107
	(0.0857)	(0.115)
High and very high income	2.033***	1.101
	(0.595)	(0.677)
Very good health	−0.691	−0.726
	(0.569)	(0.745)
Risk preferences	−0.000150	0.000498
	(0.000139)	(0.00109)
Time preferences	−0.000954	0.0302
	(0.00149)	(0.0185)
Constant	15.84***	7.221
	(5.122)	(5.164)
Observations	292	246

Note. N = Number of observations in the models. Robust standard errors in parentheses. Dependent variables are choosing an annuity that is less than or equal to NIS 4000. Main explanatory variables are round of the experiment, experimental condition, age, education, subjective unwillingness to get older with no assets, and income.

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

In particular, a mandatory minimum annuity will not necessarily increase the annuity amount people choose. Specifically, in some conditions (e.g., when income and consumption are high), mandatory minimum annuities may result in a decrease in the annuity amount chosen. In our experimental framework, high-consumption individuals naturally believed that they would need to withdraw a major part of their assets as an annuity. For these people the constraint of a NIS 4000 minimum annuity sent a signal that pushed beliefs about the funds needed for living downward, in contrast to individuals in the low-consumption group, for whom there was an opposite effect. Furthermore, our results suggest that a repeal of the constraint can be expected to weaken the effect but not necessarily to cancel it.

Our study is the first to explore the behavioral effects of both initiation and repeal of mandatory annuity laws in the same research in a comparable manner. It contributes to the literature that investigates the effect of regulatory changes, unintended consequences of regulatory changes and caps, long-term savings decisions and annuity choices, and behavioral biases (specifically anchoring) and individuals' long-term savings decisions. Our findings are also relevant for policy discussions, in particular for cases in which regulators impose constraints that limit individuals' choices for the purpose of protecting them. Such regulations vary widely. For instance, regulators impose speed limits that may in reality signal a recommended level. A similar mechanism may be related to health recommendations, alcohol consumption limits, and others.

We conjecture that merely mentioning a minimum annuity level as a recommended level for withdrawal, rather than imposing it as a regulation, might be sufficient to create behavioral change. We leave testing this for future research. We also leave for future research and additional investigation the following questions: What is the appropriate level of mandatory annuity for a given population with specific characteristics? Is it socially acceptable to mandate an increase in annuities for some individuals while understanding that this regulation may cause other individuals to choose smaller annuities?

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jebo.2019.11.008.

Appendix: Payment function

The following is a formal description of the payment function in our experiment. Participants did not receive this description and the instructions were explained using text and numerical examples only.

$$P = 27 + 20 * f(a_{ri}, c_{ri}, t_{ri}) + \frac{[\sum_{r=1}^{2} \max\{a_{ri} * t_{ri} + l_{ri} - c_{ri} * t_{ri}, 0\}]}{50,000}$$

where:

P = *payment*
27 – Show up fee
r = *round*
i = *individual*
a_{ri} = *chosen annuity in round "r" by individual i*
$l_{ri} = 2,000,000 - a_{ri} * 200$
c_{ri} = *consumption for individual i in round r; drawn from the values described above.*
t_{ri}=*realized longevity(in months) for individual i in round r; drawn from the values described above.*

$$f(a_{ri}, c_{ri}, t_{ri}) = \begin{cases} 0, & \sum_{r=1}^{2} \max\{a_{ri} * t_{ri} + l_{ri} - c_{ri} * t_{ri}, 0\} = 0 \\ 1, & otherwise \end{cases}$$

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