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ARTICLE

Automatic enrollment with a 12 percent default contribution rate

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Abstract

We study a retirement savings plan with a default contribution rate of 12 percent of income, which is much higher than previously studied defaults. Twenty-five percent of employees had not opted out of this default 12 months after hire; a literature review finds that the corresponding fraction in plans with lower defaults is approximately one-half. Because only contributions *above* 12 percent were matched by the employer, 12 percent was likely to be a suboptimal contribution rate for employees. Employees who remained at the 12 percent default contribution rate had average income that was approximately one-third lower than would be predicted from the relationship between salaries and contribution rates among employees who were not at 12 percent. Defaults may influence low-income employees more strongly in part because these employees face higher psychological barriers to active decision making.

Keywords: automatic enrollment; default contribution rate; defined contribution plan

JEL codes: D14; D90; G51

Automatic enrollment in defined contribution retirement savings plans – where eligible individuals begin saving in the plan at a strictly positive default contribution rate with balances invested in a default asset allocation unless they opt out – has been growing rapidly in prevalence.[1] A comprehensive review of prior research (presented in Section 1) finds that relative to a regime where one must opt into saving, automatic enrollment increases plan participation rates by 26–91 percentage points at short time horizons (up to one year after employees are automatically enrolled). Employees frequently remain at the default contribution rate and asset allocation. At time horizons of up to five years, 22–72 percent of employees continue to contribute at the default contribution rate, and at time horizons of up to four years, 26–89 percent of plan participants continue to have their balances entirely invested in the default asset allocation.

This previous research examines modest default contribution rates in the range of 1–6 percent of income. What happens when the default is much higher?

In this paper, we provide initial evidence on employee responses to a very high default contribution rate by analyzing the defined contribution retirement savings plan of a firm in the United Kingdom with a 12 percent default contribution rate. This default was not only considerably higher than

[1]In 2005, only 5 percent of plans administered by Vanguard featured automatic enrollment; in 2021, this percentage was 56 percent among all Vanguard plans and 74 percent among Vanguard plans with more than 5,000 participants (Clark, 2022). Various state and local governments in the United States have enacted legislation requiring employers that do not offer their own retirement savings plan to automatically enroll their employees in a government-sponsored retirement savings plan. The SECURE 2.0 Act requires most 401(k) and 403(b) plans established after 2022 to implement automatic enrollment and automatic escalation starting in 2025. Automatic enrollment also plays a prominent role in the national retirement savings policies of Canada, Italy, Lithuania, New Zealand, Poland, Turkey, and the United Kingdom.

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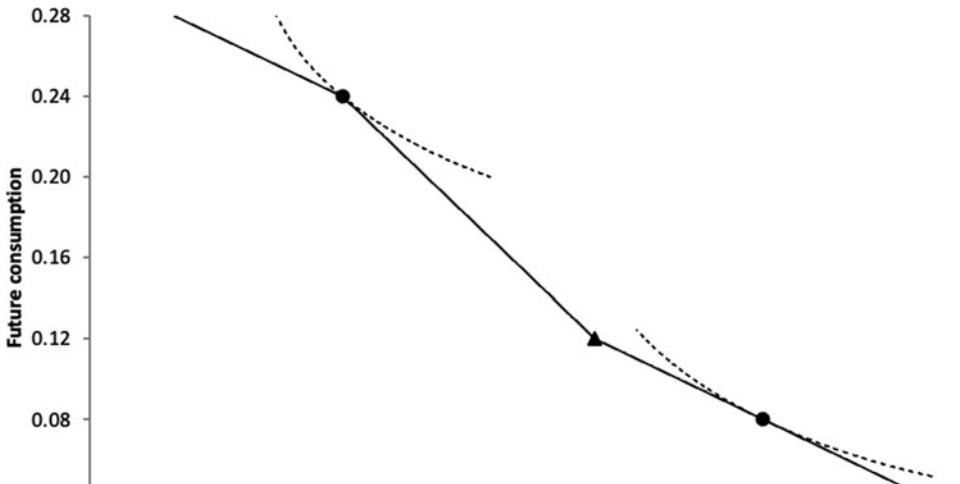


Figure 1. Two-period model of the employee's contribution rate decision. This figure illustrates the structure of employer matching contributions in the retirement savings plan that we study. In this stylized two-period model, income in the present period is one, and income in the future period is zero. Employee contributions and employer contributions are invested in an asset with a net rate of return of zero. There are no taxes. The solid lines depict the employee's budget set. In the bottom-right corner of the figure, the budget set begins at the point characterized by 0.96 in present consumption and 0.04 in future consumption because a 4% employee contribution rate is the minimum contribution rate allowed in the retirement savings plan that we study. From that point, the budget set travels up and to the left with a one-unit reduction in present consumption translating into a one-unit increase in future consumption until present consumption reaches 0.88, which is a contribution rate of 12%. Employee contributions between 12% and 18% earned employer matching contributions on a one-for-one basis, so the budget set then travels up and to the left with a one-unit reduction in present consumption translating into a two-unit increase in future consumption until present consumption reaches 0.82. At that point, employer matching contributions ceased, and the budget set resumes traveling up and to the left with a one-unit reduction in present consumption translating into a one-unit increase in future consumption. The dotted curves in the figure are two possible indifference curves, with their tangency points indicated by circles. The triangle marks the non-convex kink in the budget set at the contribution rate of 12%, which is also the default contribution rate. Note that no smooth indifference curve could be tangent to the budget set at this default.

previously studied defaults, but it was also likely to be a suboptimal contribution rate for employees. The firm did *not* make any matching contributions on the first 12 percent of pay contributed by the employee, but only matched the next 6 percent of pay contributed (at a 100% marginal match rate). In a stylized two-period model where the employee divides resources between present and future consumption, this match structure creates a non-convex employee budget set (see Figure 1 and its caption for details). A standard indifference curve cannot be tangent to the budget set at the point corresponding to a 12 percent contribution rate, where there is a non-convex kink. In addition, when it is possible to contribute in more than one year, a strategy that contributes 12 percent in both years t and t', which earns no matching dollars, is likely inferior to strategies that earn matching dollars by contributing less than 12 percent in t and more than 12 percent in t'.[2]

Using data on employees hired at a firm between July 2006 and June 2007, we analyze the extent to which employees opted out of this likely suboptimal default to either lower unmatched contribution rates or higher marginally matched contribution rates. By 12 months of tenure, only 25 percent of employees had not opted out of the 12 percent default contribution rate. This percentage is smaller

[2]In the real-life setting we study, the requirement to contribute an integer percentage might have made 12 percent the optimal contribution rate for some employees. The strategy of contributing less than 12 percent in one year and more than 12 percent in another year could be suboptimal because an employee who elected a contribution rate higher than 12 percent agreed to maintain that contribution rate until the next annual open enrollment period.

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than the comparable percentages reported in previous research, which studied plans with lower contribution defaults. Among the papers reviewed in Section 1 that reported the comparable percentage for a group of employees with tenure levels in a range that included 12 months, the percentages were 33 percent (5–16 months), 41 percent (7–12 months), 42 percent (12–35 months), 55 percent (12–17 months), 65 percent (3–15 months), and 71 percent (0–23 months). In all of these examples, the default contribution rate was 3 percent.

At the firm we study, opt-out behavior along the asset allocation dimension was strikingly different from opt-out behavior along the contribution rate dimension: 66 percent of employees remained at the default investment allocation for their first 12 months of tenure, even though 73 percent of those who remained at the default investment allocation had opted out of the default contribution rate. This pattern suggests that the high opt-out rate from the contribution default was not purely driven by characteristics of the employee population, such as a tendency to be intensely engaged in their financial affairs. The pattern is consistent with the hypothesis that employees had some sense of their optimal contribution rate but little expertise in the multi-dimensional asset allocation problem, making them more likely to rely on the default asset allocation for guidance. The evidence is also consistent with the complementary hypothesis that the default asset allocation was close to the optimum for many employees, creating little need to opt out.

The evidence on opt-out behavior suggests that contribution rate defaults can lose influence as they become higher. Still, at the firm we study, a meaningful fraction of employees were slow to opt out of the default. We explore which types of employees contributed at the 12 percent default rate at 12 months of tenure, and we find that female employees and employees with higher salaries were less likely to be at the default.

We then examine the relationship between contribution rate decisions and salary in more detail. Employees who contributed at the 12 percent default rate after 12 months of tenure had an average salary that was approximately one-third lower than the level predicted from a regression of salary on contribution rate among employees who chose non-default contribution rates. This result echoes previous work documenting that low-income individuals are slower to opt out of defaults than high-income individuals (e.g., Choi *et al.*, 2004). Two explanations can potentially account for this pattern. First, low-income employees might be slower to opt out because the default is close to their ideal contribution rates, which are the options that they would select if they were forced to actively choose a contribution rate. Second, low-income employees might be slower to opt out because they face higher barriers to active decision making, such as a tendency to procrastinate or a lack of expertise in financial decision making. The first explanation invokes the natural idea that the likelihood of opting out increases as the distance between the ideal contribution rate and the default increases (Carroll *et al.*, 2009). Our analysis, however, suggests that the first explanation does not fully account for the lower opt-out frequency of low-income employees.[3,4] We conclude that the second explanation – higher barriers to active decision making – at least partly accounts for the lower opt-out frequency of low-income employees.[5]

[3]Two findings support this claim. First, among employees who opted out of the default, the mean absolute distance between the chosen contribution rate and the default is greater for low-income employees than for high-income employees. This pattern suggests that low-income employees, relative to high-income employees, have ideal contribution rates that are farther from the default, implying that low-income employees should be *more* likely to opt out of the default. Second, we show formally that the distributions of contribution rates among low-income employees and among high-income employees are inconsistent with a model in which the likelihood of opting out is equal to an increasing function of the absolute distance between the ideal contribution rate and the default, with the same function applying to all employees. See Section 5 and the Appendix.

[4]Low-income employees might have ideal contribution rates that are low and hence far from the default contribution rate because (a) they have low permanent income and will therefore receive payments from a progressive public retirement benefit program that replaces a large fraction of their working-age income or (b) they have temporarily low income and wish to smooth their consumption by saving at a low rate (Modigliani and Brumberg, 1954).

[5]The empirical patterns contrasting female employees and male employees are similar to but weaker than the patterns contrasting high-income employees and low-income employees. We do not conclude that male employees faced higher barriers to active decision making than female employees.

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It is important to note the key limitations of our analysis. We rely on data from a single company, so we must be cautious when extrapolating our results to other companies and contexts. Furthermore, we do not have data from a time period when the company's employees were not automatically enrolled in the retirement savings plan. Employees hired during such a time period could have served as a control group, and because we do not have this control group, we cannot draw sharp conclusions regarding the causal effects of automatic enrollment with a 12 percent default contribution rate relative to an opt-in retirement plan.[6] Nonetheless, our results provide practical insights for designing retirement savings plans. In particular, policy makers and managers should keep in mind that although employees may become less likely to remain at the automatic enrollment default contribution rate as it increases, low-income employees may face higher barriers to active decision making and thus be more likely than high-income employees to remain at the default.

In Section 1, we present a systematic review of the research literature on the causal effects of automatic enrollment in field settings. Section 2 provides background on the company we study and its savings plan design. Section 3 describes the data we use. Section 4 analyzes the frequency of opting out of the default, and Section 5 studies correlates of the likelihood of opting out. Section 6 concludes.

1. Previous research on automatic enrollment in defined contribution plans

We conducted a systematic search for previous research estimating the causal effect of automatic enrollment in defined contribution plans. We began with four early papers that studied this topic (Madrian and Shea, 2001; Choi *et al.*, 2002, 2004; Beshears *et al.*, 2008). The reference lists of these four papers revealed no additional research on our key question. We used Elsevier's Scopus database to identify the 1,607 articles published as of December 2022 that cited at least one of those four papers. We narrowed this set of articles to those that included at least one word from each of the following two lists in their title, abstract, or keywords:

(1) Words related to retirement savings: retire, pension, defined contribution, DC, 401(k), and their linguistic derivatives.
(2) Words related to automatic enrollment: automatic enrollment, auto-enrollment, auto enrollment, auto-IRA, auto IRA, default, opt-out, opt out, nudge, and their linguistic derivatives.

We manually examined the 606 articles identified by this process and found 15 that studied the effects of automatic enrollment or other default features in retirement savings plans.[7] We combined these 15 articles with the four that were the starting point for the search. From these 19 articles, we collected estimates of the effects of automatic enrollment or other default features on plan participation, contribution rates, and asset allocations. When an article reported results at multiple time horizons, we focused on the shortest horizon, the longest horizon, and the horizon closest to one year.

Table 1 summarizes the relevant empirical results from the 13 articles that studied automatic enrollment in a field setting. Table 2 summarizes the results from the six articles that studied other default features or studied automatic enrollment in a laboratory setting.

The evidence on the effects of automatic enrollment comes from employers of all sizes, ranging from the US Army, which automatically enrolled tens of thousands of new civilian employees per year (Beshears *et al.*, 2022), to the small firms (2–29 employees) analyzed by Cribb and Emmerson (2021). The employers represent a variety of industries, including manufacturing, food products, health care, and telecommunications. The employers are also in several countries: the United States, the United Kingdom, and Afghanistan.

[6]When we report results from the company that we study, we use previous results from the literature as reference points that provide context, but we do not use previous results from the literature to construct a control group.

[7]We excluded one article because it estimated the effect of introducing automatic enrollment and employer matching contributions simultaneously (Pereira and Afonso, 2020). We excluded a second article because its full text was not available (Utkus and Young, 2004).

Table 1. Previous research on automatic enrollment in defined contribution plans

Article	Data source	Policy and causal inference method	Participation results	Contribution results	Portfolio results
Beshears *et al.* (2008)	Administrative data from Hewitt on employees of a US chemical company	New policy automatically enrolled new hires at 3% default contribution rate with money market fund as default investment. Employees hired under new policy were compared with those hired earlier under opt-in policy. Both groups offered dollar-for-dollar employer match up to 6% of pay.	Percent of employees who had ever participated in the plan increased from 59% to 94% at 3 months of tenure, from 70% to 96% at 12 months, and from 75% to 97% at 24 months.	–	–
		New automatic enrollment policy increased default contribution rate from 3% to 6%. Employees hired under new policy were compared with those hired earlier under lower default. Both groups offered dollar-for-dollar employer match up to 6% of pay. Default investment was a money market fund for both groups.	Percent of employees who had ever participated in the plan increased from 94% to 97% at 3 months of tenure, from 96% to 97% at 12 months, and from 98% to 100% at 27 months.	At 15–24 months of tenure, percent of employees at 3% contribution rate dropped from 28% to 4%; percent at 6% increased from 24% to 49%; percent above 6% dropped from 41% to 30%.	At 15–24 months of tenure, percent of participants with balances completely invested in default fund increased from 26% to 40%.
		New policy automatically enrolled non-participating employees at 3% default contribution rate with money market fund as default investment. Non-participating employees were compared with those already participating and thus not subject to automatic enrollment. Both groups offered dollar-for-dollar employer match up to 6% of pay.	–	At 25–48 months of tenure, percent of employees at 3% contribution rate was 60% in automatically enrolled group and 3% in comparison group. Percent at or above 6% was 25% in former group and 89% in latter group.	At 25–48 months of tenure, percent of participants with balances completely invested in default fund was 61% in automatically enrolled group and 1% in comparison group.
Beshears *et al.* (2022)	Administrative data from the US Army on its civilian employees	New policy automatically enrolled new hires at 3% default contribution rate with a US Treasury fund as default investment. Employees hired	Percent of employees making positive contributions increased from 45% to 91% at 1–6 months of tenure, from	Mean cumulative employee contributions increased by 0.1% of first-year salary at 1–6 months of tenure, 0.3% at 7–12 months, 1.6% at 49–	–

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		under new policy were compared with those hired earlier under opt-in policy. Both groups offered dollar-for-dollar employer match on first 3% of pay contributed and 50% match rate on next 2% of pay contributed.	62% to 96% at 7–12 months, from 76% to 94% at 49–53 months.	53 months. Employees contributing 3% increased from 5% to 41% at 7–12 months, from 5% to 27% at 43–48 months.	
Blumenstock *et al.* (2018)	Administrative data from an Afghan mobile phone operator on its employees	Employees randomly assigned to (1) automatic enrollment treatment policy with 5% default contribution rate into digital wallet earning 0% interest or (2) control policy with 0% default contribution rate. Employees cross-randomized to employer match rates of 0%, 25%, or 50%. Employees in automatic enrollment group were compared to employees in the control group.	Averaging across match rates, percent of employees making positive contributions 2 months after randomization was 68% under treatment policy versus 28% under control policy.	Averaging across match rates, mean contribution rate 2 months after randomization was 4.5% under treatment policy versus 2.7% under control policy. Two months after randomization, percent of employees at 5% contribution rate was 36% under treatment policy with no match.	–
Butrica and Karamcheva (2019)	Survey data from the Health and Retirement Study on representative older US employees	Employees whose employers had adopted automatic enrollment were compared with those whose employers offered a DC plan but had not adopted automatic enrollment. Defaults and match rates were chosen by employers.	Percent of employees with positive employee or employer contributions increased from 66% to 86% at four years or less of tenure, from 87% to 93% at more than four years of tenure.	Mean employee contribution rate of plan participants decreased from 7.1% to 5.0% at four years or less of tenure, from 7.8% to 4.9% at more than four years of tenure.	–
Choi *et al.* (2002)	Administrative data from Hewitt on employees of an office equipment company	New policy automatically enrolled new hires at 2% default contribution rate with stable value fund as default investment. Employees hired under new policy were compared with those hired earlier under opt-in policy. Both groups offered 67% employer match rate on first 6% of pay contributed.	Percent of employees who had ever participated in the plan increased from 26% to 93% at 6 months of tenure, from 38% to 96% at 12 months, from 65% to 99% at 36 months.	At 24–35 months of tenure, percent of plan participants at 2% contribution rate increased from 20% to 64%, percent at or above match threshold of 6% dropped from 63% to 27%.	At 24–35 months of tenure, percent of balances invested in money market or stable value funds increased from 17% to 48%.

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Table 1. (*Continued.*)

Article	Data source	Policy and causal inference method	Participation results	Contribution results	Portfolio results
	Administrative data from Hewitt on employees of a health services company	New policy automatically enrolled new hires at 3% default contribution rate with money market fund as default investment. Employees hired under new policy were compared with those hired earlier under opt-in policy. Both groups offered 50% employer match rate on first 6% of pay contributed after they reached one year of tenure.	Percent of employees participating in the plan increased from 36% to 86% at 6 months of tenure, from 40% to 85% at 12 months, from 50% to 86% at 24 months.	At 0–23 months of tenure, percent of plan participants at 3% contribution rate increased from 11% to 71%, percent at or above match threshold of 6% dropped from 74% to 26%.	At 0–23 months of tenure, percent of balances invested in money market or stable value funds increased from 10% to 81%.
	Administrative data from Hewitt on employees of a food products company	New policy automatically enrolled new hires at 3% default contribution rate with stable value fund as default investment. Employees hired under new policy were compared with those hired earlier under opt-in policy. Both groups offered 50% employer match rate on first 6% of pay contributed.	Percent of employees who had ever participated in the plan increased from 43% to 96% at 6 months of tenure, from 50% to 97% at 12 months, from 69% to 100% at 36 months.	At 12–35 months of tenure, percent of plan participants at 3% contribution rate increased from 12% to 42%, percent at or above match threshold of 6% dropped from 79% to 49%.	At 12–35 months of tenure, percent of balances invested in money market or stable value funds increased from 18% to 56%.
Choi *et al.* (2004)1	Administrative data from Hewitt on employees of an office equipment company	New policy automatically enrolled new hires at 2% default contribution rate with stable value fund as default investment. Employees hired under new policy were compared with those hired earlier under opt-in policy. Both groups offered 67% employer match rate on first 6% of pay contributed.	Percent of employees who had ever participated in the plan increased from 20% to 89% at 4 months of tenure, 38% to 96% at 12 months, 71% to 99% at 48 months.	Mean contribution rate increased from 2.9% to 3.5% at 25 months of tenure, 3.8% to 4.2% at 47 months. Percent of employees at 2% increased from 12% to 53% at 24–29 months, from 11% to 46% at 42–47 months. Percent above 2% dropped from 39% to 36% at 24–29 months, from 53% to 44% at 42–47 months.	Percent of participants with balances completely invested in default fund increased from 17% to 58% at 24–29 months of tenure and from 10% to 52% at 42–47 months.
	Administrative data from Hewitt on employees of a health services company	New policy automatically enrolled new hires at 3% default contribution rate with money market fund as default investment. Employees hired	Percent of employees participating in the plan increased from 31% to 87% at 4 months of tenure, from 40% to 85%	Mean contribution rate increased from 1.5% to 3.3% at 1 month of tenure, 3.4% to 4.2% at 12 months, 4.4% to 4.9% at 26 months.	Percent of participants with balances completely invested in default fund increased from 2% to 89% at 3–5

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		under new policy were compared with those hired earlier under opt-in policy. Both groups offered 50% employer match rate on first 6% of pay contributed after they reached one year of tenure.	at 12 months, from 53% to 86% at 27 months.	Percent of employees at 3% increased from 4% to 72% at 3–5 months, from 3% to 55% at 12–17 months, from 5% to 41% at 24–26 months. Percent above 3% dropped from 25% to 14% at 3–5 months, increased from 30% to 31% at 12–17 months and from 44% to 45% at 24–26 months.	months of tenure, from 8% to 74% at 12–17 months, from 4% to 50% at 24–26 months.
Clark and Mitchell (2020)	Administrative data from a quasi-governmental agency on public employees	New automatic enrollment policy changed the default investment from a to-be-eliminated moderate risk asset allocation fund to a newly introduced age-appropriate target date fund. Employees' choices made 6 months after policy adoption were compared with the same individuals' choices made 15 months and immediately beforehand. Both groups subject to default contribution rate of 3%, default escalation of 1% of pay per year capped at 6%, with dollar-for-dollar employer match up to 6% of pay.	Percent of employees making positive contributions slightly decreased from 96% (both 15 months and immediately before policy adoption) to 95%.	Mean contribution rate among those who contributed a percent of pay (excluding those who contributed a flat dollar amount) was 8.8% (15 months before), 9.0% (immediately before), and 9.1% after policy adoption.	Percent of contributions invested in equity rose from 62% (15 months before) and 65% (immediately before) to 74%.
Clark and Pelletier (2022)	Administrative data from South Dakota Retirement System on public employees	New policy allowed agencies to automatically enroll new hires at $25 per month default contribution (about 1% of average pay) with age-appropriate target date fund as the default investment after a 90-day window. Employees hired by agencies that had adopted automatic enrollment were compared to employees in the same year whose agencies had not adopted automatic enrollment. Neither group offered an employer match.	Percent of employees who had ever participated in the plan increased from 3%–7% to 83%–94% at one year of tenure.	Median contribution rate of plan participants was between 0.9% and 1.0% for those who were automatically enrolled and between 0.6% and 1.5% for those who were not automatically enrolled.	–

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Table 1. (*Continued.*)

Article	Data source	Policy and causal inference method	Participation results	Contribution results	Portfolio results
		New policy allowed agencies to automatically enroll new hires at $25 per month default contribution (about 1% of average pay) with age-appropriate target date fund as the default investment after a 90-day window. Employees hired after policy adoption were compared to employees hired before policy adoption. Neither group offered an employer match.	Percent of employees who had ever participated in the plan increased from 1%–3% to 38%–45% at one year of tenure.	Median contribution rate of plan participants decreased from between 2.0% and 3.8% of pay to between 0.9% and 1.0% of pay.	–
Cribb and Emmerson (2020)	Annual Survey of Hours and Earnings for UK employees provided by the UK Office for National Statistics	New national policy required employers to automatically enroll employees. Defaults and match rates chosen by employers, with minimum default employer contribution of 1% of pay and minimum default employee plus employer contribution of 2% of pay. Policy rollout date staggered by employer size. Employees whose employers were already required to adopt policy were compared with those whose employers were not yet required to do so.	1–30 months after policy adoption, percent of employees with positive contributions increased by 36 percentage points. Pre-automatic enrollment participation rate was 49%.	1–30 months after policy adoption, mean employee contribution rate rose by 0.5% of income. Pre-automatic enrollment mean was 2.1% of income.	–
Cribb and Emmerson (2021)	Annual Survey of Hours and Earnings for UK employees provided by the UK Office for National Statistics	New national policy required employers to automatically enroll employees. Defaults and match rates chosen by employers, with minimum default employer contribution of 1% of pay and minimum default employee plus employer contribution of 2% of pay. Small employers (2–29 employees) pseudo-randomly	2–10 months after policy adoption, percent of employees with positive contributions was 70%, versus 23% in the control group.	2–10 months after policy adoption, mean employee plus employer contribution rate was 3.8%, versus 2.0% in the control group.	–

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		assigned to adopt the policy at different times. Employees whose employers were already required to adopt policy were compared with those whose employers were not yet required to do so.			
Falk and Karamcheva (2023)	Administrative data from Enterprise Human Resources Integration and Federal Thrift Retirement Investment Board on federal civilian workers	New policy automatically enrolled new hires at 3% default contribution rate with the Government Securities Investment as the default investment. Employees hired under new policy were compared with those hired earlier under opt-in policy. Both groups offered dollar-for-dollar employer match on first 3% of pay contributed and 50% match rate on next 2% of pay contributed.	Percent of employees making positive contributions increased from 60% to 97% at 0–4 months of tenure, from 76% to 98% at 5–16 months of tenure, from 84% to 96% at 41–52 months of tenure.	Mean contribution rate rose from 2.9% to 4.4% at 0–4 months of tenure, from 4.5% to 5.1% at 5–16 months, from 5.8% to 6.1% at 41–52 months. Percent of employees at 3% increased from 8% to 40% at 0–4 months, from 7% to 33% at 5–16 months, from 6% to 22% at 41–52 months.	At 0–4 months of tenure, percent of participants with balances completely invested in default fund increased from 80% to 81%.
Goda *et al*. (2020)	Administrative data on Federal Thrift Savings Plan accounts	New policy automatically enrolled new hires at 3% default contribution rate. Employees hired under new policy were compared with those hired earlier under opt-in policy. Both groups offered dollar-for-dollar employer match on first 3% of pay contributed and 50% match rate on next 2% of pay contributed.	Seven years after policy adoption, percent of employees making positive contributions increased from 91% to 95%.	Seven years after policy adoption, mean annual contribution decreased from $8,699 to $5,160.	–
Madrian and Shea (2001)	Administrative data from Hewitt on employees of a	New policy automatically enrolled new hires at 3% default contribution rate with money	At 3–15 months of tenure, percent of employees making positive	At 3–15 months of tenure, mean contribution rate rose from 2.7% to 3.8%, percent	Percent of participants with balances completely invested in

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Table 1. (*Continued.*)

Article	Data source	Policy and causal inference method	Participation results	Contribution results	Portfolio results
	health care and insurance company	market fund as the default investment. Employees hired under new policy were compared with those hired earlier under opt-in policy. Both groups offered 50% employer match rate on first 6% of pay contributed after they reached one year of tenure.	contributions increased from 37% to 86%.	of employees at 3% contribution rate increased from 4% to 65%, percent at match threshold of 6% dropped from 11% to 7%.	default fund was 6% among opt-in cohort at 16–28 months of tenure, 75% among auto-enrolled cohort at 3–15 months of tenure.

*Results for the third company studied by Choi *et al.* (2004) are summarized by Choi *et al.* (2002) and appear in the Choi *et al.* (2002) entry in this table.

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Table 2. Previous research on other default features and automatic enrollment in the laboratory

Article	Data source	Description of policy and causal inference method	Results
Benartzi *et al*. (2013)	Administrative data from Vanguard on employees of 13 companies	New policy automatically enrolled new hires at 3% default contribution rate, with automatic 1 percentage point annual increase in contribution rate. Default investment varied across companies. Plan participants hired under new policy were compared with those hired earlier under policy with no default annual contribution rate increase. Within each company, both groups offered the same employer match structure, but structure varied across companies.	Percent of plan participants enrolled in contribution rate escalation program increased from 25% to 84%.
Camilleri *et al*. (2019)	Online survey with incentivized questions simulating lifecycle choices	Respondents randomly assigned to either 'smart' or 'dumb' default. Former treatment adjusted default retirement savings portfolio automatically over the course of respondent's simulated working life so that it matched the optimal choice from a lifecycle model. Latter always kept a medium-risk portfolio as the default. Both groups subject to compulsory 10% contribution rate, with no employer match.	Likelihood of choosing default investment was 60% for respondents assigned to 'smart' default portfolio and 42% for those assigned to 'dumb' default portfolio.
Foltice *et al*. (2018)	Survey with hypothetical questions	Students at a US university randomly assigned to either 3% or 15% default contribution rate. Default investment was not specified. Both groups offered a dollar-for-dollar employer match up to 3% of pay.	Mean contribution rate was 9.2% for students assigned to 15% default contribution rate, 7.3% for those assigned to 3% default.
Mahasuweerachai and Mahariwirasami (2019)	Administrative data on non-commissioned officers from saving cooperative of an infantry regiment of the Thai Army	Officers in a randomly selected treatment battalion were automatically enrolled in contribution escalator program and randomly assigned to have 10%, 15%, or 20% of salary increases contributed by default. Officers in two randomly selected control battalions were not automatically enrolled in or aware of the escalator program. Employer match structure was not specified.	Over a two-year horizon, mean change in savings rate out of total income was 0.4 percentage points for treatment officers assigned to 10% default, 0.7 percentage points for those assigned to 15% default, 1.2 percentage points for those assigned to 20% default. Corresponding mean changes for two control battalions were −0.3 and −0.4 percentage points.
Rubaltelli and Lotto (2021)	Administrative data on freelance psychologists from Italy's National Agency for Pension and Assistance for Psychologists	New policy increased default contribution rate from 10% to 20% and used additional nudges. Individuals' choices made under new policy were compared with the same individuals' choices made before new policy was implemented. Both before and after new policy was implemented, individuals subject to required minimum contribution rate of 10%, with no employer match.	Mean contribution rate increased from 10.2% one year before new policy was implemented to 11.7% immediately after new policy was implemented. Percent of individuals at 10% contribution rate dropped from 97% to 78%, percent of individuals at 20% contribution rate increased from 1% to 14%.

(*Continued*)

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Table 2. (*Continued.*)

Article	Data source	Description of policy and causal inference method	Results
Thaler and Benartzi (2004)	Data from investment consultant Brian Tarbox on employees of a US manufacturing company	Employees who met with an investment consultant were given a suggested contribution rate to be adopted immediately. Those who rejected the suggestion were offered plan that involved automatic 3 percentage point annual increases in contribution rate, with no cap, starting at time of next pay raise and repeating at subsequent pay raises. Employees who accepted offer were compared with those who accepted the suggested immediate contribution rate change and to those who rejected both. All employees offered 50% employer match rate on first 6% of pay contributed.	Four years after meeting with investment consultant, mean contribution rate was 13.6% for employees enrolled in auto-escalation, 8.8% for those who accepted suggested immediate contribution rate change, 5.9% for those who rejected both.
	Data from investment consultant Brian Tarbox on employees of Ispat Inland, a US steel company	Letter offered employees automatic 2 percentage point annual increases in their contribution rate, with an 18% cap, starting at time of the next pay raise and repeating at subsequent pay raises. Employees who accepted the offer were compared with those who did not.	Over horizon of 4–5 months, mean change in contribution rate was 1.8 percentage points for previous plan participants who accepted the offer and −0.1 percentage points for those who did not. Mean change in contribution rate was 2.3 percentage points for previous plan non-participants who accepted the offer and 0.3 percentage points for those who did not.
	Data from investment consultant Brian Tarbox on employees of Philips Electronics	Some employees offered auto-escalation at a financial education seminar or at a one-on-one meeting with financial planner. Could choose automatic 1, 2, or 3 percentage point annual increases in contribution rate, with 10% cap. Annual increases not necessarily linked to pay raises. Employees who accepted offer were compared with those who did not and to those who did not have access to seminar or one-on-one meeting (because they worked in other divisions of the company).	Over three months after seminar and one-on-one meetings, mean change in contribution rate was 1.6 percentage points for previous plan participants who accepted the offer, 0.3 percentage points for those who refused, 0.1 percentage points for those who did not have access. Mean change in contribution rate was 5.0 percentage points for previous plan non-participants who accepted the offer, 1.6 percentage points for those who refused, 0.7 percentage points for those who did not have access.

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Across this wide spectrum of employers, automatic enrollment consistently leads to large increases in the fraction of employees who participate in the retirement plan. The smallest reported effect size over a horizon of one year or less is 26 percentage points (Beshears *et al.*, 2008), and the largest is 91 percentage points (Clark and Pelletier, 2022). The effect size becomes smaller but is still substantial – in the range of 12 percentage points (Falk and Karamcheva, 2023) to 36 percentage points (Choi *et al.*, 2002) – at horizons of two to five years.

The large participation effects are primarily driven by employees' tendency to passively accept default contribution rates, which are as low as 1 percent and as high as 6 percent of pay in the articles included in Table 1. At horizons of less than one year, the fraction of employees who continue contributing at the default rate under automatic enrollment ranges from 36 percent (Blumenstock *et al.*, 2018) to 72 percent (Choi *et al.*, 2004). At horizons of two to five years, the fraction ranges from 22 percent (Falk and Karamcheva, 2023) to 64 percent (Choi *et al.*, 2002). In addition to increasing the contribution rates of some employees who would have contributed zero under opt-in enrollment, automatic enrollment sometimes decreases the contribution rates of some employees who would have contributed at a rate higher than the automatic enrollment default.

Automatic enrollment tends to have modest effects on mean contribution rates beyond a horizon of one year. Madrian and Shea (2001) estimate that at 3–15 months of tenure, automatic enrollment at a 3 percent default increased the average contribution rate by 1.1 percent of income, and Blumenstock *et al.* (2018) find that automatic enrollment at a 5 percent default increased the average contribution rate by 1.8 percent of income two months after implementation. But Choi *et al.* (2004) find that automatic enrollment at a 2 percent default contribution rate increased the average contribution rate by only 0.4 percent of income at 47 months of tenure, and automatic enrollment at the company studied by Madrian and Shea (2001) increased the average contribution rate by only 0.5 percent of income at 26 months of tenure. Similarly, Falk and Karamcheva (2023) record a mere 0.6 percent increase at 5–16 months of tenure, and a 0.3 percent increase at 41–52 months of tenure. At a horizon of 49–53 months, automatic enrollment at a 3 percent default contribution rate increased mean *cumulative* employee contributions by only 1.6 percent of pay among civilian employees of the US Army (Beshears *et al.*, 2022).

Table 1 also shows that employees often passively accept asset allocation defaults. At horizons of up to four years, the fraction of plan participants who remain at the automatic enrollment investment default ranges from 26 percent (Beshears *et al.*, 2008) to 89 percent (Choi *et al.*, 2004).[8] The articles in Table 1 that report these results all study a money market or stable value fund default investment option. Typical financial advice, as reflected in the design of target date retirement funds that are intended to be investment vehicles for retirement savings, recommends that retirement savings should be invested with substantial equity exposure (Choi, 2022). Money market and stable value funds hold no equities, so it is striking that employees nonetheless frequently passively accepted such funds when they were the default.

The articles summarized in Table 2 corroborate the overarching message from Table 1: defaults influence retirement savings outcomes. Camilleri *et al.* (2019) find that approximately half of the participants in their online experiment accept the default investment option in a simulated lifecycle portfolio choice problem. Foltice *et al.* (2018) demonstrate in a laboratory experiment that changing the default contribution rate from 3 percent to 15 percent increases participants' mean chosen contribution rate from 7.3 percent to 9.2 percent. We chose not to include these two articles in Table 1 because they involve subjects making hypothetical decisions and might therefore be less predictive of workers' behavior in defined contribution plans than field data.

Rubaltelli and Lotto (2021) introduced a new web interface for Italian freelance psychologists choosing retirement savings plan contributions. Relative to a version that featured a pre-selected

[8]Some of the articles summarized in Table 1 focus on the percentage of contributions or the percentage of balances invested in the default fund, instead of the percentage of employees with balances completely invested in the default fund. The results are similar across the different measures.

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contribution rate of 10 percent (the mandatory minimum), a web interface that had a pre-selected contribution rate of 20 percent increased the mean chosen contribution rate from 10.2 percent to 11.7 percent. Even though this study changed the default contribution rate in a field setting, we did not include it in Table 1 because the freelancers in the study had taken the active step of visiting the web interface, an experience that is different from that of an employee under automatic enrollment, which requires no action by the employee.

The other three articles summarized in Table 2 examine automatic contribution escalation programs. Employees who are enrolled in such a program experience automatic increases in their contribution rates at prespecified times (e.g., on an annual basis) unless they opt out. Employees frequently accept their scheduled contribution rate increases (Thaler and Benartzi, 2004; Mahasuweerachai and Mahariwirasami, 2019). Furthermore, when employees are automatically enrolled in an automatic escalation program, only 16 percent opt out (Benartzi *et al.*, 2013).

In summary, our literature review finds consistent evidence that individuals often accept retirement savings plan defaults. However, the estimated effects of automatic enrollment on mean contributions are modest. Automatic escalation programs lead to contribution rate increases, but these increases are implemented only slowly over time. A natural question is whether automatically enrolling employees upon hire at a contribution rate well above 6 percent would generate large, immediate contribution rate increases. On the one hand, employees might passively accept a high default contribution rate like they accept low defaults. On the other, employees might opt out of a high default because it is outside the range of contribution rates that they find acceptable. Our analysis of a retirement plan with a 12 percent default contribution rate provides initial evidence on this open question.

2. Company background and plan design

We study a global company that had its headquarters in the United Kingdom using data from July 2006 through June 2008. At this time, the UK pension system consisted of three tiers. The first tier, the Basic State Pension, was a mandatory government scheme to which individuals contributed while working in return for an annuity stream in retirement.[9] The second tier, the State Second Pension, was also a government scheme, but it was less progressive in the provision of benefits, as payouts in retirement were more closely linked to lifetime earnings.[10] The third tier was the system of private retirement savings plans. Contributions to these plans were tax-deductible for individuals up to a limit[11] and were generally tax-deductible for employers.[12] In 2006, slightly more than half of UK workers were enrolled in a private defined benefit or defined contribution retirement savings plan, and of these workers, approximately one-third had a defined contribution plan.[13]

The company had more than 50,000 employees engaged in a range of job functions, including manufacturing, marketing, research and development, and administration. It maintained legacy defined benefit plans for some of its employees, but all UK employees hired during 2006–2008 were eligible only for a defined contribution plan. We restrict our analysis to the company's primary defined contribution plan for UK employees. Less than one percent of UK employees hired during this period were not eligible for the primary plan but were instead eligible for a plan with a different

[9]In 2009, a complete contribution record entitled an individual to £95.25 per week from the Basic State Pension.

[10]Both the first tier and the second tier were 'pay-as-you-go' schemes. It was possible for workers to 'contract out' of the second tier by contributing to a private pension instead of the State Second Pension, and many employees adopted this approach. For example, in a sample of individuals born between 1951 and 1954, 82 percent had contracted out for at least one year as of 2011, and 66 percent had contracted out for more than 10 years (Crawford *et al.*, 2013).

[11]The 2009–2010 annual limit on tax-deductible contributions for individuals was the lesser of £245,000 and 100 percent of annual income. A lifetime limit also applied.

[12]This information on the three tiers of the UK pension system is from the Pensions Policy Institute (2010).

[13]These figures are derived from data from the Office for National Statistics (2008). Public sector workers, who almost always had defined benefit plans, are included in the sample. Their employer-sponsored plans are considered 'private' in this context to denote that the plans are distinct from the basic state pension and the state second pension.

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structure. These employees generally had low salaries, and we exclude them from our analysis because they faced distinct plan rules and are too few in number to be examined separately.

New UK employees of the firm we study (besides the small ineligible group described above) were automatically enrolled upon hire in the primary defined contribution plan at a 12 percent default contribution rate. Employees could opt out of the plan entirely, but in order to remain active plan participants, they ordinarily had to contribute at least 4 percent of every paycheck to the plan.[14] Subject to the 4 percent floor and some restrictions described below, employees could elect any contribution rate at any time.[15] The firm did not match the first 12 percent of income contributed by employees, but the next 6 percent of income contributed was matched at a 100 percent marginal rate, so that employees could receive a maximum of 6 percent of their income in matches. Matching contributions vested immediately. In order to receive the match, an employee was required to elect a contribution rate greater than 12 percent within their first three months of hire or within the three-week open enrollment period in late May and early June, and the employee was required to maintain this contribution rate until the next open enrollment period. Employees who chose contribution rates greater than 12 percent outside of the designated windows did not receive matching contributions.[16] All contributions to the plan were made on a before-tax basis, and loans from the plan were not permitted.

Plan balances were allocated according to the employee's wishes across 11 investment funds: one cash fund, two bond funds, and eight equity funds. During 2006–2008, the plan's investment menu did not include target date retirement funds (which slowly shift from equities to fixed-income investments over time) or employer stock. Employees who did not elect otherwise had their contributions invested in the default asset allocation, which was a mix of bonds and equities.

3. Data on plan outcomes

We have monthly administrative retirement plan records from three data extracts. The first extract covers March 2006 through October 2007; the second extract covers November 2007 through March 2008; and the third extract covers April 2008 through June 2008. Each extract includes all employees who were active participants in the plan as of the end of the extract period (October 31, 2007; March 31, 2008; or June 30, 2008). We restrict our attention to the 671 employees who began their tenure at the firm between July 1, 2006, and July 1, 2007,[17] and who have data records for their first twelve full months of employment.[18] Our analysis excludes employees who left the firm or plan before the end of their twelfth tenure month, as well as employees who left the firm or plan after the end of their twelfth tenure month but before the end of the extract period that would have included their twelfth tenure month. We do not have data to construct a control group of employees who were not automatically

[14]The firm occasionally allowed an employee to remain a plan participant while contributing less than 4 percent of pay, but this privilege was granted on a case-by-case basis.

[15]Some fraction of the first 12 percent of employee contributions was designated as employer contributions for the purposes of determining National Insurance contribution levels. We do not observe the magnitude of the fraction. The designation affected neither the amount of money that was credited to employee defined contribution accounts nor the corresponding deduction from employee pay, but the designation did reduce payments to the National Insurance system. Despite the relabeling of this portion of contributions, we follow Cribb and Emmerson (2020, 2021) and refer to the contributions as 'employee contributions' because this term most accurately reflects the relationship between pay deductions and cash flows into employee accounts.

[16]In some cases, the firm allowed an employee to (a) earn matching contributions by choosing a contribution rate greater than 12 percent outside the designated windows, (b) change a match-earning contribution rate before the next open enrollment period, or (c) earn matching contributions with a contribution rate less than or equal to 12 percent. Out of the 671 employees in the sample that we study, 7 were granted exception (a), 8 were granted exception (b), and 11 were granted exception (c) over their first 12 months of tenure at the company.

[17]We do not include employees hired between March and June of 2006 because the retirement plan rules were in flux during that period.

[18]If an individual began employment on the first working day of a month, that month is tenure month one. If an individual began employment on a later day in the month, the subsequent month is tenure month one.

enrolled in the retirement plan. This data limitation makes it difficult to draw strong conclusions regarding the causal effect of automatic enrollment at a 12 percent default contribution rate relative to a system under which employees must actively opt in to contribute to the retirement plan. Nonetheless, savings outcomes under an automatic enrollment policy with a 12 percent default contribution rate are interesting in their own right, and results from previous research examining automatic enrollment at lower default contribution rates serve as a useful reference point.

The data set includes the gender, marital status, age, and hire date of each employee. In addition, for each month, we observe employee compensation, the value of employee contributions to the plan, and the value of employer contributions to the plan. To calculate employee and employer contribution rates, we divide contributions by compensation. However, we make some adjustments to these calculations because administrative processes in the retirement savings plan often lagged those in the employee payroll system. For instance, when an employee received a pay raise, the compensation record reflected the pay increase immediately, but the plan contribution amount sometimes stayed at the contribution rate multiplied by the *previous* compensation level, generating a misleadingly low ratio of contributions to compensation. In this example, the subsequent month's contribution amounts often adjusted upward to reflect the new compensation level *and* to make up for the missed contributions in the previous month, generating a misleadingly high ratio of contributions to compensation. More complicated scenarios arose when an employee experienced multiple salary changes within a short timeframe. A similar issue affected plan contributions at the beginning of an employee's tenure: contributions in the first or second full tenure month sometimes represented contributions for that month *and* for previous month(s). In all of these cases, we reattribute contributions to the appropriate months before calculating contribution rates.

Another factor that affects the calculation of contribution rates is employee contributions out of bonus pay. Bonuses do not appear in our compensation data, but the plan contributions that we observe represent the sum of contributions out of regular pay and contributions out of bonuses. The contributions out of bonuses sometimes generate misleadingly large calculated contribution rates. Our analysis attempts to ignore contributions out of bonus compensation by adopting the following procedure. Because bonuses were often awarded in April, when we calculate an April employee contribution rate that exceeds the March contribution rate and the May contribution rate by more than six percentage points, we set the April contribution rate equal to the March contribution rate.

After making the above adjustments, some non-integer contribution rates still remain. We round these to the nearest integer.

Our data do not include a variable indicating which employees were participants in the firm's primary defined contribution plan. However, the difference in structure between the primary plan and the other plan (for which almost no employees were eligible) allows us to identify employees who were likely to be members of the other plan. The primary plan provided matching contributions only when the employee contribution rate exceeded 12 percent, whereas the other plan provided a match when the employee contribution rate exceeded 4 percent. An employee who received a marginal match on contributions above 4 percent of pay would therefore be identified as a participant in the other plan, although no such employees exist in our sample. To be conservative, our analysis sample excludes employees who are never observed with a contribution rate greater than 4 percent of pay (the default contribution rate in the other plan), even though some of these individuals might have been participants in the primary plan. This restriction eliminates five employees from the sample (0.7% of the sample), a fraction that is in line with the fact that less than one percent of employees were eligible for the other plan instead of the primary plan.

Finally, our data include information on employee asset allocations. On a monthly basis, we observe the value of shares bought or sold in each mutual fund in the investment menu, as well as variables indicating whether an employee had ever opted out of the default asset allocation for new contribution flows and whether an employee had ever reallocated existing balances across funds.[19]

[19]In some cases, the variable for whether an employee had ever reallocated existing balances indicates that an employee made such a change a few months before the change appears in the data on mutual fund flows. We rely on the mutual fund flow data when these discrepancies arise.

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Table 3. Sample characteristics

	Mean	Std. dev.	10th percentile	Median	90th percentile
Female	55.0%				
Married	47.7%				
Age (years)	35.0	9.4	24.4	33.1	48.5
Annual salary (£1,000s)	35.3	22.4	15.7	28.7	64.5
Employee contribution rate (percent of pay)	9.4	5.7	4.0	9.0	18.0
Employer contribution rate (percent of pay)	0.9	2.0	0.0	0.0	6.0

This table presents summary statistics for the 671 employees who are observed in the data for at least 12 months. The variables are measured as of tenure month 12 for each employee. For the employee contribution rate, contributions out of bonuses are disregarded.

Table 3 presents summary statistics for our sample. More than half of the employees were female, and slightly less than half were married. The mean age was 35 years. At £28,700, the median annual salary was higher than the median for full-time UK workers at the time, but there was considerable variation in pay across the firm's employees. The mean employee contribution rate at 12 months of tenure was 9.4 percent of pay, and the mean employer contribution rate was only 0.9 percent of pay, reflecting the fact that the firm did not match employee contributions (on the margin) unless the employee contribution exceeded 12 percent of pay (with marginal matching capping out above 18% of pay contributed).

4. Opt-out rates

In this section, we analyze the rate at which employees opted out of the savings plan defaults. We are particularly interested in opt-out behavior vis-à-vis the 12 percent default contribution rate, since this can give us insight into employee reactions to higher contribution rate defaults. Furthermore, the budget set non-convexity created by this plan's match structure makes the 12 percent default contribution rate unlikely to be an optimal choice for employees,[20] so opt-out behavior in this setting sheds light on how employees respond when the default option is likely contrary to their best interests.

Figure 2 shows employee contribution rates at the firm by tenure. The darker gray bar represents the fraction of employees in our sample who had never opted out of the 12 percent default contribution rate up to that point; the white bar represents the fraction at a contribution rate below 12 percent; the small black bar represents the fraction who had originally opted out of the default but are now again at the 12 percent contribution rate; and the lighter gray bar represents the fraction who are at a contribution rate above 12 percent. In these calculations, we disregard contributions out of bonus pay because they are infrequent occurrences that involve a separate decision-making process. The figure indicates that employees opted out of the default rapidly. By tenure month 3, only 35 percent of the employees had never opted out of the default, and this fraction steadily declined to 25 percent by tenure month 12. As a point of contrast, recall from the Introduction of this paper that previous research, which examined automatic enrollment with lower default contribution rates, found that 33–71 percent of employees remained at the default contribution rate at roughly comparable time horizons.[21]

Of the employees who opted out of the default contribution rate, 55.4/75.4 = 74 percent chose a rate lower than 12 percent in tenure month 12. Figure 3 shows a more detailed distribution of employee contribution rates at 12 months of tenure. Consistent with the findings of previous studies (see, e.g., Choi *et al.*, 2004), many employees contributed the minimum amount required to receive the

[20]There may have been some employees for whom 12 percent was the optimal contribution rate, but this group of employees was small or non-existent. See footnote 2.

[21]The data sets used in prior work on contribution rate defaults included employees who opted out of the savings plan entirely, whereas the sample studied in this paper excludes such employees. We do not have data on these employees and hence cannot precisely quantify their prevalence, but the data provider indicated that there were very few of these employees. Including these employees in our sample would slightly decrease our reported fraction of employees who had never opted out of the default.

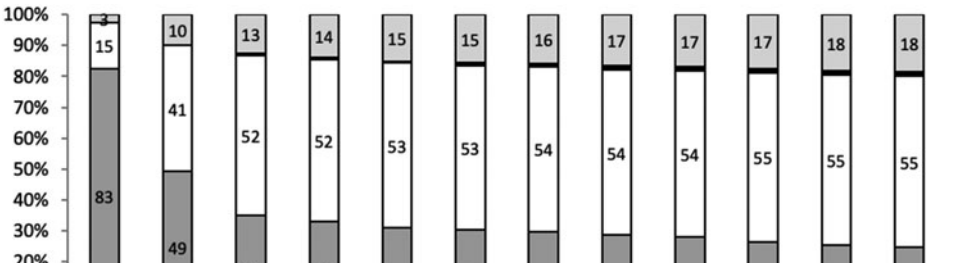


Figure 2. Opt-out from the 12% default contribution rate by tenure. For each level of tenure, this figure displays the fraction of employees who had never opted out of the 12% default contribution rate, opted out to a lower contribution rate, opted out of and subsequently returned to the 12% default contribution rate, and opted out to a higher contribution rate. The sample is the 671 employees who are observed in the data for at least 12 months.

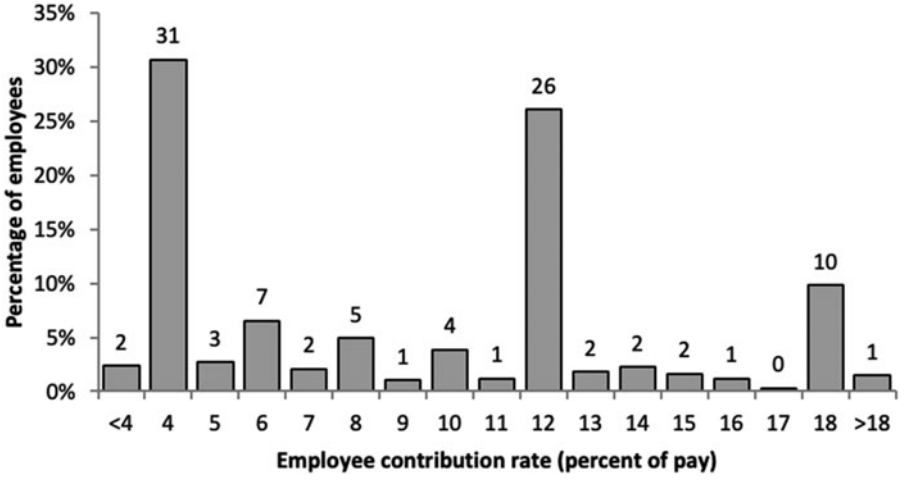


Figure 3. Distribution of employee contribution rates at tenure month 12. This figure shows the distribution of employee contribution rates at tenure month 12. Employee contributions out of bonuses are disregarded. The sample is the 671 employees who are observed in the data for at least 12 months.

maximum employer match – in this case, 10 percent of the sample had a contribution rate of 18 percent. However, 31 percent of the sample chose a contribution rate of 4 percent, which was the lowest officially permissible rate for employees who wished to remain active plan participants. A small number of employees received special permission to participate at a lower contribution rate. The distribution of contribution rates has little mass immediately to the left or right of 12 percent, so many employees who opted out of the default rejected the 12 percent contribution rate decisively (as predicted by optimization theory) instead of adjusting their contribution rates incrementally.

Opt-out patterns on the asset allocation dimension are quite different from those on the contribution rate dimension. Figure 4 shows that 66 percent of the sample had never opted out of the asset allocation default by tenure month 12. This outcome is close to the midpoint of outcomes in

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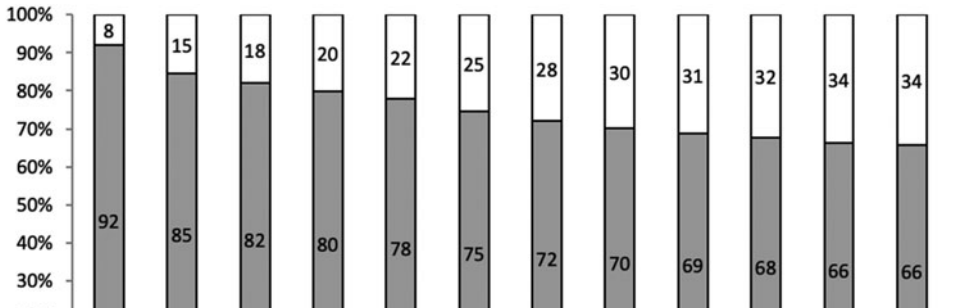


Figure 4. Opt-out from the default asset allocation by tenure. For each level of tenure, this figure displays the fraction of employees who had never opted out of the default asset allocation, which was a mix of bonds and equities. The sample is the 671 employees who are observed in the data for at least 12 months.

the plans studied in previous work, where 26–89 percent of participants had all of their balances invested in the default at roughly similar time horizons.

Figure 5 combines information on contribution rate opt-out behavior with information on asset allocation opt-out behavior. At 12 months of tenure, 18 percent of the sample had never opted out of the contribution rate default or the asset allocation default, whereas 27 percent had opted out of both. Interestingly, 48 percent had opted out of the contribution rate default but not the asset allocation default, and the reverse was true for only 7 percent of the sample. It is possible that the asset allocation default had a greater impact than the contribution rate default because individuals had more confidence in their ability to choose an appropriate savings rate than in their ability to choose an appropriate asset allocation. Such individuals might have opted out of the default contribution rate but maintained the default asset allocation, which they perceived as implicitly endorsed by their employer. It is also possible that many employees kept the default asset allocation because it was close to their optimal asset allocation.

5. Who remains at the default contribution rate?

In this section, we examine which employees were more likely to remain at the default contribution rate. We begin by studying correlations between contributing at the default rate and employee characteristics. Table 4 presents the results of ordinary least squares regressions in which the outcome variable is an indicator for being at the default contribution rate of 12 percent at tenure month 12. The sample is the 671 employees who remained in our data set for at least 12 months, and we calculate heteroskedasticity-robust standard errors.

In column 1 of Table 4, the sole predictor variable is an indicator for female employees, and we find that female employees are a statistically significant 11.6 percentage points less likely to be at the default contribution rate than male employees. In column 2, the sole predictor variable is an indicator for being married, and while the point estimate indicates that married employees are 4.5 percentage points less likely to be at the default contribution rate than non-married employees, the estimate is not statistically significantly different from zero. The sole predictor variable in column 3 is employee age, and the point estimate is close to zero and not statistically significant. In column 4, the sole predictor variable is the logarithm of annual salary, and we find that an increase in annual salary of 10 log points is

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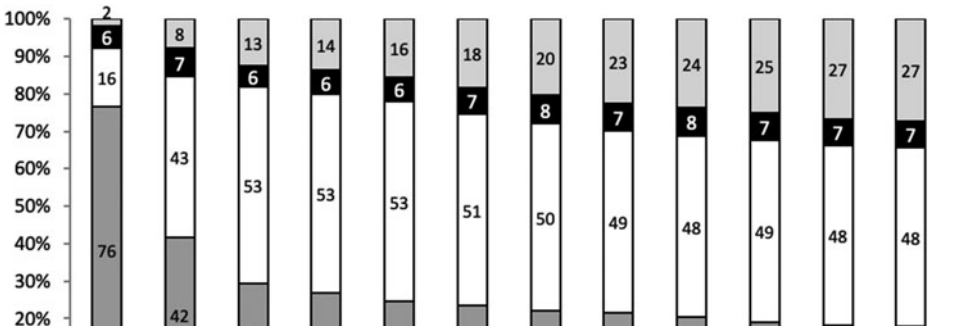


Figure 5. Opt-out from the default contribution rate and asset allocation by tenure. For each level of tenure, this figure displays the fraction of employees who had opted out of neither the 12% default contribution rate nor the default asset allocation, opted out of the default contribution rate but not the default asset allocation, opted out of the default asset allocation but not the default contribution rate, and opted out of both defaults. The sample is the 671 employees who are observed in the data for at least 12 months.

Table 4. Predictors of being at the default contribution rate

	(1)	(2)	(3)	(4)	(5)
Female	−0.116**				−0.142**
	(0.034)				(0.035)
Married		−0.045			−0.046
		(0.034)			(0.037)
Age (years)			0.001		0.004
			(0.002)		(0.002)
Log(annual salary)				−0.127**	−0.165**
				(0.032)	(0.034)
Month of hire indicators	No	No	No	No	Yes
R^2	0.017	0.003	0.000	0.024	0.098
Sample size	$N = 671$	$N = 671$	$N = 671$	$N = 671$	$N = 671$

This table presents the results of ordinary least squares regressions in which the outcome variable is an indicator for being at the default contribution rate of 12% at tenure month 12. The predictor variables, which are all measured as of tenure month 12, are as shown. The sample is the 671 employees who are observed in the data for at least 12 months. Heteroskedasticity-robust standard errors are in parentheses. * and ** indicate statistical significance at the 5% and 1% levels, respectively.

associated with a 1.27 percentage point decrease in the likelihood of contributing at the default rate. This estimate is statistically significant at the 1 percent level. The interquartile range for the logarithm of annual salary is 9.91–10.66, so a move from the 25th percentile to the 75th percentile of the distribution predicts a $0.127 \times (10.66 - 9.91) = 9.53$ percentage point decrease in the likelihood of being at the default contribution rate. In column 5, all four predictor variables are included in the same regression, along with a series of indicators for month of hire, and the results are similar. If anything, the coefficients on the female indicator and the logarithm of annual salary are larger in magnitude.[22]

[22]The results in all five columns of Table 4 are similar if we run logistic regressions instead of ordinary least squares regressions.

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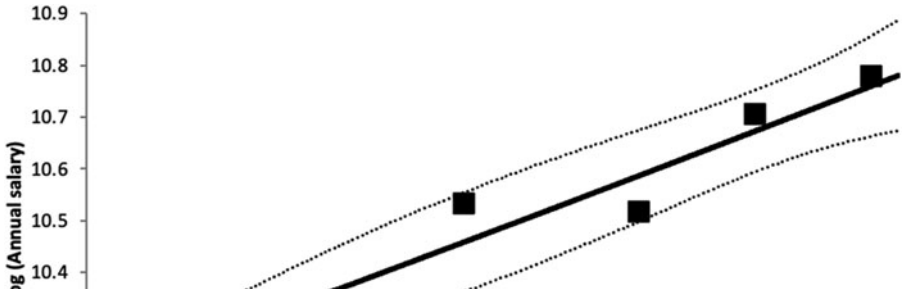


Figure 6. Employee salaries by contribution rate at tenure month 12. This figure divides employees into groups based on their employee contribution rate at tenure month 12. Employee contributions out of bonuses and employer contributions are disregarded. Employee contribution rates less than 4% are recoded to be equal to 4%, and employee contribution rates greater than 18% are recoded to be equal to 18%. The boxes indicate the mean of the logarithm of annual salary for employees in each group. We perform an ordinary least squares regression of the logarithm of annual salary on the employee contribution rate, the employee contribution rate squared, and an indicator variable for the employee contribution rate being 12%. The solid line shows the predicted values from this regression, restricting the contribution rate indicator variable to be zero at all contribution rates. The dotted lines delineate the 95% confidence interval. The sample is the 671 employees who are observed in the data for at least 12 months.

We proceed to conduct detailed analyses of the statistically significant relationships from the regressions, focusing first on the relationship between contribution rates and salaries. We will then show that the relationship between contribution rates and gender exhibits patterns that are similar but weaker.

In Figure 6, we group employees into eight categories based on their contribution rates at tenure month 12. Employees with a contribution rate of 12 percent form one group, but other groups are based on pairs of contribution rates. For example, employees with contribution rates of 13 percent and 14 percent are grouped together.[23] In this figure and in the regressions that accompany it (see Table 5), contribution rates less than 4 percent are recoded as being equal to 4 percent, and contribution rates greater than 18 percent are recoded as being equal to 18 percent, although the results are nearly identical if employees with contribution rates less than 4 percent or greater than 18 percent are dropped from the sample. The boxes in Figure 6 indicate the mean of the logarithm of annual salary for each group of employees. Annual salary is the sum of monthly compensation over the first 12 full months of tenure. It is clear from the figure that employees contributing at a 12 percent rate had lower salaries on average than employees who chose a slightly higher or lower contribution rate.

To formally show this difference in salaries, we run an ordinary least squares regression of the logarithm of annual salary on the employee contribution rate, the employee contribution rate squared, and an indicator variable for the employee contribution rate being equal to 12 percent (which keeps employees at the 12% default from affecting the estimation of the other contribution rate coefficients). The fitted values from this regression, restricting the indicator variable to be zero at all contribution rates, are shown by the solid line in Figure 6; the dotted lines delineate 95 percent confidence intervals. Employees at a 12 percent contribution rate had salaries that were 35 log points lower on average than

[23]We group contribution rates into pairs instead of analyzing them individually because some contribution rates attract very few employees (see Figure 3). Analyzing those contribution rates individually would add unhelpful noise to Figure 6 without adding valuable insights.

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Table 5. Regressions of log employee salary on contribution rate

	(1)	(2)	(3)	(4)
Indicator for contribution rate equal to 12%	−0.351**	−0.321**	−0.348**	−0.304**
	(0.051)	(0.048)	(0.065)	(0.063)
Contribution rate (percent of pay)	0.042**	0.030**	0.040	0.018
	(0.004)	(0.004)	(0.027)	(0.026)
Contribution rate squared/100			0.010	0.052
			0.124	(0.120)
Female		−0.199**		−0.198**
		(0.037)		(0.038)
Married		0.113**		0.115**
		(0.041)		(0.042)
Age (years)		0.013**		0.013**
		(0.003)		(0.003)
Month of hire indicators	No	Yes	No	Yes
R^2	0.150	0.287	0.150	0.287
Sample size	$N = 671$	$N = 671$	$N = 671$	$N = 671$

This table presents the results of ordinary least squares regressions in which the outcome variable is the logarithm of annual salary and the predictor variables are as shown. The contribution rate is the employee contribution rate, disregarding contributions out of bonuses and employer contributions. Employee contribution rates less than 4% are recoded to be equal to 4%, and employee contribution rates greater than 18% are recoded to be equal to 18%. All variables are measured as of tenure month 12 for each employee. The sample is the 671 employees who are observed in the data for at least 12 months. Heteroskedasticity-robust standard errors are in parentheses. * and ** indicate statistical significance at the 5% and 1% levels, respectively.

the level we would predict from the relationship between salaries and contribution rates among employees who are not at 12 percent, a highly statistically significant difference.

The regression results used to construct Figure 6 are reported in column 3 of Table 5. Column 1 of Table 5 reports the results when the squared term is dropped from the specification. Columns 2 and 4 add controls for gender, marital status, age, and month of hire to the regressions. All of the specifications give similar results: the coefficient on the indicator variable for having a contribution rate of 12 percent ranges from −0.304 to −0.351 and is always statistically significant at the 1 percent level, supporting the robustness of the claim that employees with 12 percent contribution rates had salaries that were approximately one-third lower on average than would be predicted by the characteristics of employees who chose non-default contribution rates. The composition of employees who contribute at the default rate is markedly different from the composition of employees who contribute at neighboring rates.

Previous studies have documented that low-income employees are slower to opt out of defaults than high-income employees (Choi *et al.*, 2004). The results from this savings plan are consistent with those prior results. Two broad sets of explanations could account for low-income employees' lower frequency of opting out of the default. First, the default might be closer to low-income employees' ideal contribution rates – what they would choose if they were compelled to make active decisions – than to high-income employees' ideal contribution rates.[24] Second, low-income employees might face higher barriers to active decision making, such as a tendency to procrastinate or a lack of financial expertise. We discuss next why the savings plan studied in this paper provides suggestive evidence that the latter explanation partly accounts for low-income employees' higher likelihood of remaining at the default.

Under the hypothesis that low-income employees are more likely to remain at the default only because the default is closer to their ideal contribution rates, low-income and high-income employees who have the same ideal contribution rate share the same probability of opting out of the default to that ideal contribution rate. Under the assumption that employees have a stronger desire to opt out of the default when the default is farther from their ideal contribution rate (e.g., due to a strictly

[24]Note that an employee's ideal contribution rate might be part of a dynamic contribution rate strategy. For example, an employee might wish to contribute at a rate lower than the 12 percent default and then, during the next open enrollment period, switch to a contribution rate higher than 12 percent to earn employer matching contributions.

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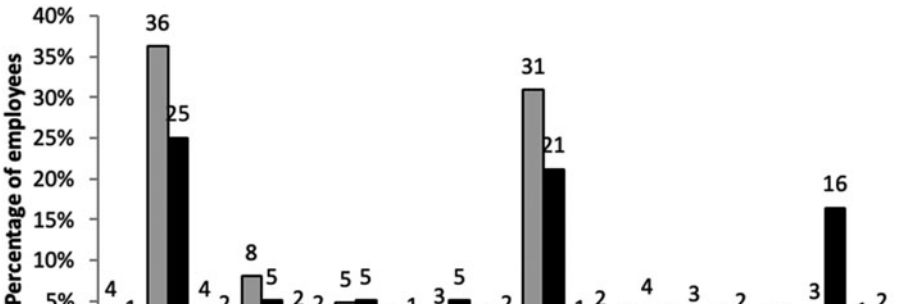


Figure 7. Distribution of employee contribution rates at tenure month 12 among employees with annual salaries above the median and among employees with annual salaries at or below the median. This figure shows the distribution of employee contribution rates at tenure month 12, separately for employees with annual salaries above the median and for employees with annual salaries at or below the median. The sample is the 671 employees who are observed in the data for at least 12 months. Employee contributions out of bonuses and employer contributions are disregarded.

monotonic loss function; see Carroll *et al*., 2009), this probability of opting out of the default increases with the distance between the default and the ideal contribution rate. If low-income employees' ideal contribution rates are closer to the default than high-income employees' ideal contribution rates, the percentage of low-income employees who remain at the default is higher than the percentage of high-income employees who remain at the default.

The savings plan studied in this paper seems not to fit this model of contribution rate decisions. Figures 7 and 8 suggest that low-income employees' ideal contribution rates are farther from the default than high-income employees' ideal contribution rates. Figure 7 shows the distribution of employee contribution rates at tenure month 12, separately for employees with annual salaries above the sample median and for employees with annual salaries at or below the sample median. When employees with salaries at or below the median opt out of the default contribution rate, they tend to opt out to contribution rates that are farther from the default than employees with salaries above the median. Indeed, conditional on opting out of the default, the mean absolute deviation between the selected contribution rate and the default of 12 percent was 6.9 percentage points for employees with salaries at or below the median and 6.0 percentage points for employees with salaries above the median, a difference that is statistically significant at the 1 percent level.[25] Of course, the chosen contribution rates of employees who opt out of the default are unlikely to be a perfect guide to the ideal contribution rates of employees who are still at the default, and the latter group of employees is relevant for judging whether low-income employees' ideal contribution rates are closer to the default than are high-income employees' ideal contribution rates. We therefore pursue a complementary analysis strategy, which we describe next.

Figure 8 shows the distribution of the absolute distance between the employee contribution rate and the default contribution rate, separately for employees with annual salaries above the sample median and for employees with annual salaries at or below the sample median. This figure reveals that the percentage of employees who opted out of the default to a contribution rate from 1 to X percentage

[25]If we set the 5.2 percent of absolute deviations that exceed 8 percentage points equal to 8 percentage points, the mean absolute deviation was 6.7 percentage points for employees with salaries at or below the median and 5.6 percentage points for employees with salaries above the median. This difference is also statistically significant at the 1 percent level.

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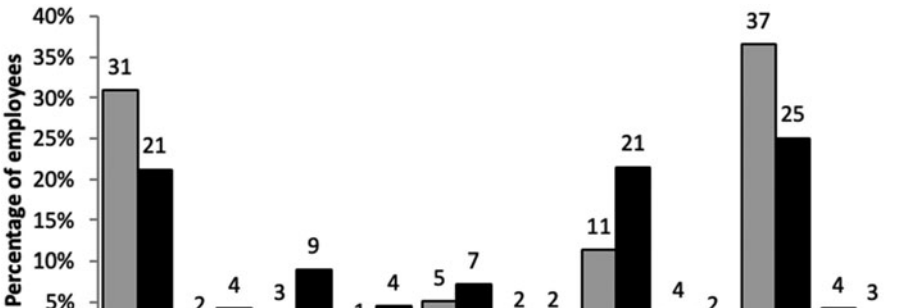


Figure 8. Distribution of absolute distance between employee contribution rate at tenure month 12 and default contribution rate among employees with annual salaries above the median and among employees with annual salaries at or below the median. This figure shows the distribution of the absolute distance between an employee's contribution rate at tenure month 12 and the default contribution rate of 12%, separately for employees with annual salaries above the median and for employees with annual salaries at or below the median. The sample is the 671 employees who are observed in the data for at least 12 months. Employee contributions out of bonuses and employer contributions are disregarded.

points away from the default is, for all positive values of X, greater for employees with salaries above the median than for employees with salaries at or below the median. In the Appendix, we show that this pattern is inconsistent with a model in which no employee has the default as their ideal contribution rate (see Figure 1) and in which the likelihood of opting out of the default is an increasing function of the absolute distance between the default and the ideal contribution rate, with the same function applying to all employees. Intuitively, interpreting the empirical pattern through the lens of the model implies that the percentage of employees with ideal contribution rates between 1 and X percentage points away from the default, for all feasible positive values of X, is greater for employees with salaries above the median than for employees with salaries at or below the median. But this is a contradiction because the percentage of employees with ideal contribution rates that are the maximum feasible distance from the default or less must be equal to 100 percent both for employees with salaries above the median and for employees with salaries at or below the median. We conclude that such a model of contribution rate decisions is incomplete.

A leading explanation for the observed patterns in the data is that if an employee with a salary at or below the median has the same ideal contribution rate as an employee with a salary above the median, the former employee is less likely to opt out of the default than the latter employee, perhaps due to barriers to active decision making, such as procrastination or a lack of expertise with respect to financial decisions. An important caveat, however, is that we cannot rule out some alternative interpretations. For example, the relationship between the likelihood of opting out and the signed difference between the ideal contribution rate and the default might not be symmetric around zero difference, as we assumed in our analysis. Perhaps employees with salaries at or below the median had weaker financial incentives to opt out of the 12 percent default because employees with salaries above the median had a greater capacity to increase their contribution rates above 12 percent and thereby obtain employer matching contributions. On the other hand, a countervailing argument is that if employees with salaries at or below the median are constrained in their ability to obtain employer matching contributions, they should have a strong motive to opt out of the default to lower contribution rates, which enables them to save outside the retirement plan and later choose higher contribution rates inside the plan to earn employer matching contributions. Overall, the evidence suggests that barriers to active

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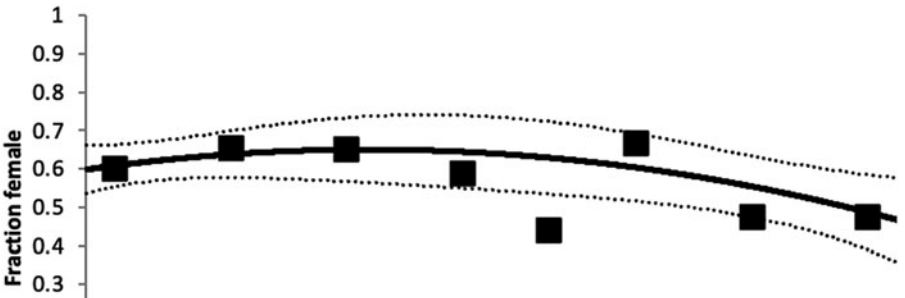


Figure 9. Fraction of employees who are female by contribution rate at tenure month 12. This figure divides employees into groups based on their employee contribution rate at tenure month 12. Employee contributions out of bonuses and employer contributions are disregarded. Employee contribution rates less than 4% are recoded to be equal to 4%, and employee contribution rates greater than 18% are recoded to be equal to 18%. Each box indicates the fraction of employees in a group who are female. We perform an ordinary least squares regression of an indicator for female employees on the employee contribution rate, the employee contribution rate squared, and an indicator variable for the employee contribution rate being 12%. The solid line shows the predicted values from this regression, restricting the contribution rate indicator variable to be zero at all contribution rates. The dotted lines delineate the 95% confidence interval. The sample is the 671 employees who are observed in the data for at least 12 months.

decision making partly explain why employees with salaries at or below the median have a lower likelihood of opting out of the default contribution rate than employees with salaries above the median.

The empirical contrast between female employees and male employees is directionally similar to but weaker than the contrast between employees with salaries above the median and employees with salaries at or below the median. Figure 9, which is analogous to Figure 6, shows that the percentage of employees at a 12 percent contribution rate who are female is 19 percentage points lower than would be predicted by the percentage of employees at neighboring contribution rates who are female. Table 6, which is analogous to Table 5, reveals that this qualitative conclusion is robust to different regression specifications, with the estimates indicating that the percentage of employees at a 12 percent contribution rate who are female is between 11.9 and 23.6 percentage points lower than would be predicted by the percentage of employees at non-default contribution rates who are female. Figure 10, which shows the distribution of employee contribution rates at tenure month 12 separately for female employees and for male employees, suggests that female employees who opt out of the default of 12 percent choose contribution rates that are closer to 12 percent than do male employees who opt out of the default. Figure 11, which shows the distribution of the absolute distance between the employee contribution rate and the default contribution rate separately for female employees and for male employees, indicates that the percentage of employees who opted out of the default to a contribution rate that is between 1 and X percentage points away from the default is, for all positive values of X, higher for female employees than for male employees. However, among employees who opted out of the default, the mean of the absolute distance between the chosen contribution rate and the default is 6.3 percentage points for female employees and 6.6 percentage points for male employees, a difference that is not statistically significant.[26]

[26]If we set the 5.2 percent of absolute deviations that exceed 8 percentage points equal to 8 percentage points, the mean absolute deviation was 6.1 percentage points for female employees and 6.2 percentage points for male employees. This difference is not statistically significant.

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Table 6. Regressions of female indicator on contribution rate

	(1)	(2)	(3)	(4)
Indicator for contribution rate equal to 12%	−0.119*	−0.175**	−0.189**	−0.236**
	(0.047)	(0.048)	(0.060)	(0.060)
Contribution rate (percent of pay)	−0.008	−0.001	0.039	0.040
	(0.004)	(0.005)	(0.027)	(0.026)
Contribution rate squared/100			−0.220	−0.194
			0.124	(0.123)
Married		−0.078		−0.085*
		(0.042)		(0.042)
Age (years)		0.002		0.002
		(0.002)		(0.002)
log(annual salary)		−0.211**		−0.209**
		(0.038)		(0.038)
Month of hire indicators	No	Yes	No	Yes
R^2	0.022	0.115	0.027	0.118
Sample size	$N = 671$	$N = 671$	$N = 671$	$N = 671$

This table presents the results of ordinary least squares regressions in which the outcome variable is an indicator for female employees and the predictor variables are as shown. The contribution rate is the employee contribution rate, disregarding contributions out of bonuses and employer contributions. Employee contribution rates less than 4% are recoded to be equal to 4%, and employee contribution rates greater than 18% are recoded to be equal to 18%. All variables are measured as of tenure month 12 for each employee. The sample is the 671 employees who are observed in the data for at least 12 months. Heteroskedasticity-robust standard errors are in parentheses. * and ** indicate statistical significance at the 5% and 1% levels, respectively.



Figure 10. Distribution of employee contribution rates at tenure month 12 among female employees and among male employees. This figure shows the distribution of employee contribution rates at tenure month 12, separately for female employees and for male employees. The sample is the 671 employees who are observed in the data for at least 12 months. Employee contributions out of bonuses and employer contributions are disregarded.

In summary, employees with salaries at or below the median likely faced greater barriers to active decision making than employees with salaries above the median, and those barriers can partly explain why employees with salaries at or below the median were less likely to opt out of the default contribution rate than employees with salaries above the median. It is not clear that male employees faced greater barriers to active decision making than female employees, although the evidence does not rule out this possibility.

6. Conclusion

Prior research has examined retirement savings plan automatic enrollment at default contribution rates in the range of 1–6 percent of income. This literature documents that 36–72 percent of employees

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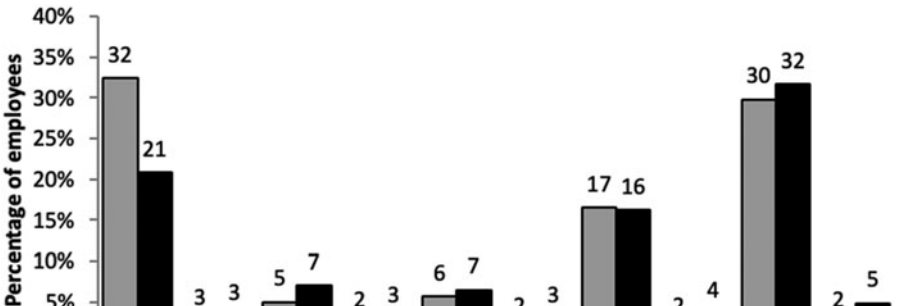


Figure 11. Distribution of absolute distance between employee contribution rate at tenure month 12 and default contribution rate among female employees and among male employees. This figure shows the distribution of the absolute distance between an employee's contribution rate at tenure month 12 and the default contribution rate of 12%, separately for female employees and for male employees. The sample is the 671 employees who are observed in the data for at least 12 months. Employee contributions out of bonuses and employer contributions are disregarded.

continue to contribute at the default rate at time horizons of less than one year. In this article, we study a unique plan that automatically enrolled new employees at a 12 percent default contribution rate. This default rate was likely suboptimal for employees because the employer only matched employee contributions that exceeded 12 percent of pay. By 12 months of tenure, 75 percent of the employees had opted out of this default, and many of these employees chose lower contribution rates. Thus, our results suggest that the default contribution rate loses some of its influence if it is not close to a rate the employees would actively choose for themselves.

Many employees opted out of the default contribution rate, but there were also some who did not. Employees who had a 12 percent contribution rate at 12 months of tenure had salaries that were approximately one-third lower than what would be predicted from the salaries of employees who had chosen non-default contribution rates. Our analysis suggests that barriers to active decision making, such as a tendency to procrastinate or a lack of domain relevant knowledge, played some role in low-income employees' higher likelihood of remaining at the default.

A limitation of our analysis is that we study data from a single retirement plan, and our results might not extrapolate to other plans. Another limitation is that we do not have data to construct a control group of employees at the same company who were not automatically enrolled in the retirement plan, making it difficult to draw strong conclusions regarding the causal impact of automatic enrollment at a 12 percent default contribution rate on savings outcomes. It would be valuable for future research to estimate the effects of high default contribution rates in settings that offer a control group.

It would also be valuable for future research to investigate the optimality of high default contribution rates from the social planner's perspective. We have emphasized that the structure of employer matching contributions at the company we study implies that the default contribution rate of 12 percent was unlikely to be the ideal contribution rate from the perspective of any individual employee. However, the default contribution rate of 12 percent might have been a wise policy for a social planner to adopt. It prompted many employees to opt out, and those employees might have had sufficient knowledge to select the contribution rates that were best suited to their individual circumstances. Carroll *et al.* (2009) derive theoretical conditions under which an unattractive default might be optimal for such a reason. At the same time, the employees who remained at the default saved at a rate that

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was higher than the rate of most other employees, suggesting that they were less likely to fall short of retirement savings goals. However, employees who accepted the default contribution rate at this particular employer received no matching dollars. Future work should analyze the consequences of high default contribution rates for consumption and retirement plan balances over the long run to better understand the implications for employee welfare.

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Author contributions. Conceptualized paper: J. B., D. L., B. C. M., J. C., wrote paper: J. B., J. C., edited paper: D. L., implemented empirical analysis: J. B., R. G., project leadership: J. B., J. C.

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Appendix. A model of the likelihood of opting out of the default contribution rate

Figures 7 and 8 contrast the contribution rate distribution at tenure month 12 for employees with annual salaries above the sample median with the contribution rate distribution at tenure month 12 for employees with annual salaries at or below the sample median. In this Appendix, we show that the empirical patterns in Figures 7 and 8 are inconsistent with a model in which an employee's likelihood of opting out of the default contribution rate and moving to their ideal contribution rate is an increasing function of the distance between the default and their ideal, with the same function applying to all employees.

Let π_d^h (π_d^l) denote the fraction of high-income employees (low-income employees) who have their ideal contribution rate an absolute distance of d percentage points away from the default contribution rate of 12 percent. We assume that $\pi_0^h = \pi_0^l = 0$ because in the retirement savings plan that we study, the default contribution rate of 12 percent corresponds to a non-convex kink in the budget set and is unlikely to be ideal for any employee (smooth indifference curves cannot be tangent to a budget set at a point where the budget set has a non-convex kink; see Figure 1). Given an ideal contribution rate of absolute distance d percentage points away from the default contribution rate, the function $f(d)$ maps the absolute distance d to the probability that the employee opts out of the default and moves to their ideal contribution rate. We assume that the function is identical for all employees in our model to capture the assumption that barriers to active decision making do not differ by salary. We further assume that $0 < f(d) \leqslant 1$ for $d > 0$ and that the function is non-decreasing in d: $f(d) \leqslant f(d')$ for $d < d'$. If an employee does not move to their ideal contribution rate, they remain at the default.

A high-income employee is observed at a contribution rate with an absolute distance of d percentage points away from the default if their ideal contribution rate is an absolute distance of d percentage points away from the default and they decide to opt out of the default. Thus, the fraction of high-income employees who are observed at a contribution rate with an absolute distance of d percentage points away from the default is $f(d)\pi_d^h$. The analogous fraction for low-income employees is $f(d)\pi_d^l$.

When we interpret Figure 8 through the lens of the model, it indicates that $\sum_{d=1}^{D} f(d)\pi_d^l < \sum_{d=1}^{D} f(d)\pi_d^h$ for $D = 1,\ 2,\ 3,\ \ldots,\ \bar{D}$, where $\bar{D}$ is the maximum possible value for d.[27] We will demonstrate that these conditions, which are implied by the combination of the model and the data, generate a contradiction.

We will show that $\sum_{d=1}^{D} \pi_d^l < \sum_{d=1}^{D} \pi_d^h$ for $D = 1,\ 2,\ 3,\ \ldots,\ \bar{D}$ by strong induction. First, note that $f(1)\pi_1^l < f(1)\pi_1^h$ implies that $\pi_1^l < \pi_1^h$, so the proposition holds for $D = 1$. We now describe the proof for $D > 3$, but straightforward shortened versions of the proof apply for $D = 2,\ 3$:

$$\sum_{d=1}^{D} f(d)\pi_d^l < \sum_{d=1}^{D} f(d)\pi_d^h$$

$$\Leftrightarrow 0 < \sum_{d=1}^{D} f(d)(\pi_d^h - \pi_d^l)$$

[27] For example, $\sum_{d=1}^{\bar{D}} f(d)\pi_d^l < \sum_{d=1}^{\bar{D}} f(d)\pi_d^h$ because 69 percent of low-income employees opted out of the default while 79 percent of high-income employees opted out of the default, a difference that is statistically significant at the 1 percent level.

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Because $\pi_1^h - \pi_1^l > 0$ and $f(d) \leq f(d')$ for $d < d'$:

$$0 < f(2)(\pi_1^h - \pi_1^l) + \sum_{d=2}^{D} f(d)(\pi_d^h - \pi_d^l)$$

$$\Leftrightarrow 0 < \sum_{d=1}^{2} f(2)(\pi_d^h - \pi_d^l) + \sum_{d=3}^{D} f(d)(\pi_d^h - \pi_d^l)$$

Because $\sum_{d=1}^{2} (\pi_d^h - \pi_d^l) > 0$ and $f(d) \leq f(d')$ for $d < d'$:

$$\Rightarrow 0 < \sum_{d=1}^{2} f(3)(\pi_d^h - \pi_d^l) + \sum_{d=3}^{D} f(d)(\pi_d^h - \pi_d^l)$$

$$\vdots$$

$$\Rightarrow 0 < \sum_{d=1}^{D-1} f(D-1)(\pi_d^h - \pi_d^l) + f(D)(\pi_D^h - \pi_D^l)$$

$$\Rightarrow 0 < \sum_{d=1}^{D-1} f(D)(\pi_d^h - \pi_d^l) + f(D)(\pi_D^h - \pi_D^l)$$

$$\Rightarrow 0 < \sum_{d=1}^{D} (\pi_d^h - \pi_d^l)$$

Thus, $\sum_{d=1}^{D} \pi_d^l < \sum_{d=1}^{D} \pi_d^h$ holds for all D. In particular, $\sum_{d=1}^{\bar{D}} \pi_d^l < \sum_{d=1}^{\bar{D}} \pi_d^h$. However, because $\{\pi_d^l\}$ and $\{\pi_d^h\}$ represent probability distributions and we assume that $\pi_0^h = \pi_0^l = 0$, we have $\sum_{d=1}^{\bar{D}} \pi_d^l = \sum_{d=1}^{\bar{D}} \pi_d^h = 1$, and we have reached the contradiction $1 < 1$. We conclude that the model and the data are inconsistent with each other.

Intuitively, Figure 8 shows that the fraction of high-income employees who choose contribution rates 1 percentage point away from the default is greater than the fraction of low-income employees who do the same. The model assumes that conditional on having the same ideal contribution rate, a high-income employee and a low-income employee have the same likelihood of opting out of the default to their ideal rate – that is, the same function f applies to all employees. When we interpret Figure 8 through this lens, we infer that a greater fraction of high-income employees than low-income employees have an ideal contribution rate that is 1 percentage point away from the default. Figure 8 further shows that the fraction of high-income employees who opt out to contribution rates that are $d > 1$ percentage points or less away from the default is greater than the fraction of low-income employees who do the same, regardless of the distance d that we consider. This fact, combined with the assumption that f is non-decreasing in d, implies that according to the model, a greater fraction of high-income employees than low-income employees have an ideal contribution rate that is 1 to d percentage points away from the default, regardless of the distance d that we consider. However, if we consider the maximum possible value for d – that is, $\bar{D}$ – we reach a contradiction because both the fraction of high-income employees and the fraction of low-income employees who have their ideal contribution rate 1 to $\bar{D}$ percentage points away from the default must be equal to one, since we assume that no employee's ideal contribution rate equals the default.

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