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Abstract: Under traditional defined benefit (DB) plans, employees and employers make contributions of a given percentage of pay, but those contributions are an *average* of widely varying individual costs to fund the retirement benefit. Thus, unlike retirement account plans (defined contribution and cash balance), where the cost of the individual benefit is transparent to all, because it equals the contribution, under a DB plan, that contribution – common to all – masks individual costs that vary widely, by age of entry and exit. That is, there is an extensive pattern of cross-subsidization. This paper makes methodological and empirical contributions to previous literature on winners and losers under DB, compared to fiscally-neutral cash balance plans. Methodologically, we supplement previous analyses based on the metric of pension wealth with a more readily transparent metric – normal cost contribution rates; and we provide a comprehensive analysis of cross-subsidization across all entry and exit ages. We also clarify a confusion in the literature regarding the population (entrants or incumbents; numbers or lifetime earnings) that is pertinent for the system of gains and losses to add up. Empirically, we find widespread and substantial cross-subsidies under the California Teachers' Retirement System. About two-thirds of all entrants are losers, earning benefits with an employer cost rate that averages 0.8 percent, while one-third enjoy benefits with an average employer cost rate of 5.7 percent. These represent cross-subsidies of -2.7 percentage points from the losers and +2.2 points for the winners. In effect, this is a system of widely varying employer matches to the employee contribution, quite unlike the uniform match under typical retirement account plans. Under such plans, there would be no cross-subsidies.

Keywords: teacher pensions

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I. Introduction

In retirement account plans, typically the employee and employer contribute a given percentage of pay. Both defined contribution (DC) and cash balance (CB) retirement plans work this way: contributions accumulate in an account (personal or notional),[1] earn a return (risky or guaranteed), and, upon retirement, the cumulative sum can be annuitized or directly drawn upon. There is a direct connection between the percentage of pay contributed and the value of the retirement benefit, and *that connection is independent of the individual*. Under traditional defined benefit (DB) plans, employees and employers also contribute a given percentage of pay, but those contributions are an *average* of widely varying individual costs to fund their retirement benefits. Thus, unlike retirement account plans, where the cost of the individual benefit is transparent to all, because it equals the contribution, under a DB plan, that contribution – common to all – masks individual costs that vary widely, by age of entry and exit.

Specifically, in the actuarial calculation of the normal cost, each individual's rate is calculated separately, based on age of entry, but is not reported to the individual or the public – it is only the average that is reported and set as the common contribution. Each individual is led to believe that a common percentage contribution is made on his or her behalf by the employer (in addition to the employee's own contribution). However, those contributions are heavily redistributed, with some employees receiving no benefit from the employer contributions and others receiving benefits that cost far more than was contributed on their behalf. In fact, for

[1] In DC plans, the employee contribution may be wholly or partly voluntary and the employer contribution may include a match on top of a base percent.

many individuals, the employer portion of their normal cost is net negative. More generally, there is an extensive pattern of cross-subsidization of the employer contribution between employees of different entry and exit ages. It is that cross-subsidization that funds retirement benefits for individuals whose joint contributions would otherwise be insufficient. The purpose of this paper is to develop the methodology to render transparent the patterns of cross-subsidization and to illustrate with actual plan data from the California State Teachers' Retirement System (CalSTRS).

This paper is not addressed to the unfunded liabilities that plague so many systems – what might be termed intergenerational cross-subsidies. Rather, we take as given the actuarial assumptions to analyze the cross-subsidies within entry cohorts that are built into the system. These include cross-subsidies among those who enter at the same age, but exit at different ages (and thus varying years of service), and between those of different entry ages.

While it is well-established that teacher pension systems generate a substantial number of losers, as well as winners, relative to a fiscally-neutral cash balance system (Costrell and Podgursky, 2010a,b; Costrell and McGee, 2010; McGee and Winters, 2013), this view has been challenged in an analysis of CalSTRS that finds nearly all active teachers are winners under the current system (Rhee and Fornia, 2016). The main feature of this critique is a shift in the analysis from winners and losers among entrants to incumbent teachers, and, secondarily, an emphasis on the full distribution of entry ages, rather than selected ones (e.g. age 25). The methodological contributions of the present paper are: (i) to supplement previous analyses of winners and losers based on the metric of pension wealth with a more readily transparent metric – normal cost contribution rates; (ii) to provide a comprehensive analysis of cross-subsidization across all entry and exit ages; and (iii) to clarify that, for a cost-neutral comparison, the gains and losses of winners and losers must offset one another, and this requires a focus on entrants, rather than incumbents. Specifically, we show that the gains and losses measured in pension wealth must be weighted by shares of the entering cohort to add up, while gains and losses measured in normal cost rates, must be weighted by the entrants' shares of lifetime earnings, consistent with the well-established entry-age normal cost methodology.

Empirically, we offer new results for CalSTRS. There are features of the benefit formula (especially under the plan for new hires, since 2013, on which we focus) that tend to mute the cross-subsidies compared to other teacher pension systems. Even so, we find widespread cross-subsidies of substantial magnitude in the employer contribution rate for normal cost. Over all entry and exit ages, the losers (net negative cross-subsidy) comprise 66.4 percent of entrants, and they account for 44.7 percent of entrants' lifetime earnings. Their employer normal cost rate (i.e., over and above the employee contribution of 9.2 percent) averages 0.8 percent. The winners (33.6 percent of entrants, with 55.3 percent of lifetime earnings) enjoy benefits with an employer normal cost rate that averages 5.7 percent. This is a significant degree of cross-subsidization (-2.7 percentage points from the losers and +2.2 points for the winners). By analogy with account-based retirement systems (DC and CB), this is as if the employee contribution rate of 9.2 percent was supplemented by an employer match that averaged 0.8 percent for two-thirds of entrants and 5.7 percentage points for one-third. Of course, there are no such cross-subsidies under typical account-based retirement systems, such as cash balance plans with uniform employer contribution rates.

II. A Simple Example

We consider the individual normal cost rates for a model with two potential periods of work, two ages of entry, and two ages of separation. There are three distinct profiles of entry and separation ages: (e,s) = (0,0) for age-0 entrants who separate at the end of that year; (e,s) = (0,1) for age-0 entrants who separate at the end of the following year; and (e,s) = (1,1) for age-1 entrants who separate at the end of that year.[2] There are three individual normal cost rates corresponding to the three profiles of (e,s). In practice, a single normal cost rate is determined as a blend of the normal cost rates for e = 0 and e = 1, and the normal cost rate for e = 0 is itself a probabilistic blend of the rates that pertain to individuals who will separate at s = 0 and s = 1.

Under the entry-age normal (EAN) algorithm, the normal cost rate is the ratio of the present value of expected benefits to the present value of expected earnings, evaluated at (or back-dated to) entry. Thus, the general point is that individual normal cost rates will vary among the three profiles since the present value of benefits will typically vary in a greater or lesser proportion to the present value of earnings. If we denote B_{es} as the present value of benefits for an individual of profile (e,s), dated to entry, and similarly W_{es} as the present value of earnings, then the individual normal cost rate is $n_{es} = B_{es}/W_{es}$. This is the rate that, applied to that individual's annual earnings, would prefund his or her benefits. We know that $B_{01} > B_{11} \geq B_{00}$ and $W_{01} > W_{11} \geq W_{00}$ since both the present value of benefits and of earnings tend to increase with years of service and age at separation, but the question is the proportion.

In general, as previous literature has well established, for long-term employees, benefits are disproportionately high, relative to cumulative earnings (and, hence, relative to the cumulative value of contributions at a uniform rate), since benefit formulas freeze the final

[2] There are no individuals of type (e,s) = (1,0), since it is impossible to separate at a younger age than entry.

average salary of early separators and also generally delay their age of eligibility for first draw (Costrell and Podgursky, 2010a). Thus, $B_{01}/W_{01} > B_{00}/W_{00}$, so $n_{01} > n_{00}$. Moreover, it is generally the case that normal cost for older entrants is higher than for younger entrants with the same years of service, as they satisfy the age-eligibility conditions sooner. It seems likely that the normal cost rate for older entrants with short service lies between the individual normal costs of early and late separators among younger entrants (i.e., $B_{01}/W_{01} > B_{11}/W_{11} > B_{00}/W_{00}$, so $n_{01} > n_{11} > n_{00}$). This is, in fact, the pattern that we will observe in the CalSTRS data analyzed below.

Cross-Subsidization Within Entry-Age Cohorts: Weights and Adding Up

The uniform normal cost rate is calculated in two steps. First, the rate is determined for each entry age. Since the age of separation is not foreseeable for any individual, but only probabilistically for the cohort, there is but a single normal cost rate for each entry age. In this simple model, let p_{00} and p_{01} represent the probability that an individual of entry age 0 will separate at ages 0 and 1 respectively. Thus, the blended normal cost rate for e = 0 is:

(1) $$n_0 = (p_{00}B_{00} + p_{01}B_{01})/(p_{00}W_{00} + p_{01}W_{01})$$

$$= n_{00}(p_{00}W_{00})/(p_{00}W_{00} + p_{01}W_{01}) + n_{01}(p_{01}W_{01})/(p_{00}W_{00} + p_{01}W_{01}).$$

In other words, n_0 is the weighted average of n_{00} and n_{01}, for early and late separators, where the weights are their respective shares of the entry age-0 cohort's present value of earnings.

Let us suppose for the moment that n_0 is the uniform normal cost rate paid by or on behalf of all age-0 entrants. Thus, there is a cross-subsidy between early separators, whose individual normal cost rate is less than what is paid, and late separators, with the converse:

(2a) $$(n_{00} - n_0) = (n_{00} - n_{01})(p_{01}W_{01})/(p_{00}W_{00} + p_{01}W_{01}) < 0$$

(2b) $$(n_{01} - n_0) = (n_{01} - n_{00})(p_{00}W_{00})/(p_{00}W_{00} + p_{01}W_{01}) > 0.$$

The present values of the cross-subsidies, per early and late separator, are:

(3a) $(n_{00} - n_0)W_{00} = B_{00} - n_0W_{00} < 0$

(3b) $(n_{01} - n_0)W_{01} = B_{01} - n_0W_{01} > 0$.

These expressions represent the difference between the individual's present value of benefits and contributions.[3] The cohort's shares of early and late separators are p_{00} and p_{01}. Applying these weights to the present value of individual cross-subsidies, (3a)-(3b), and using (1), we find:

(4) $p_{00}(B_{00} - n_0W_{00}) + p_{01}(B_{01} - n_0W_{01}) = 0$.

The cross-subsidies sum to zero, by design: total contributions equal benefits for the cohort.

The zero-sum result holds in two forms: (1) for cross-subsidies in present value terms ((3a)-(3b)), applying weights for winners and losers equal to their shares of the entering cohort (p_{00} and p_{01}); or, equivalently, (2) for cross-subsidies in normal cost rates ((2a)-(2b)), applying weights equal to their shares of the entering cohort's lifetime earnings (proportional to $p_{00}W_{00}$ and $p_{01}W_{01}$). It is straightforward to show that the same result holds for cross-subsidies in the employer contribution rate (i.e., after netting out the uniform employee contribution rate).

The point of going through this exercise is to contrast it with the methodology recently presented in a widely publicized study of CalSTRS issued by the UC Berkeley Center for Labor Research and Education (Rhee and Fornia, 2016). This study also calculates the net gain or loss from the DB plan, compared to a CB plan. There are several differences, but the fundamental point of contrast is that the Berkeley study focuses on the distribution of gains and losses across the incumbent population, instead of across the entry cohort. Specifically, the study concludes that although "40% of new hires leave before vesting, these leavers represent just 6% of teaching

[3] One may also interpret these expressions as the net gain or loss of pension wealth compared to a fiscally neutral cash balance (CB) system. In the CB system, the contribution rate is the same, n_0, but the present value of benefits equals the present value of contributions, so the first term equals the second term on the RHS of (3a) and (3b), and there are no cross-subsidies.

positions" (p. 5), and, conversely, 79 percent of teaching positions are held by those who do better under the DB plan than a CB plan.

Our simple model illustrates the difference between the shares of losers and winners in the entry cohort, p_{00} and p_{01}, and the shares in the incumbent population. For example, if the workforce is constant, with annual entry cohort of 1, the total workforce is $1 + p_{01} = (p_{00} + p_{01}) + p_{01}$, of which p_{00} represents losers (current entrants who will leave), and $2p_{01}$ are winners (current entrants who will stay plus last year's entrants who stayed). That is, although the share of losers in the cohort is p_{00}, the share of losers among the incumbent workforce is lower, $p_{00}/(1 + p_{01})$.

The reason is that last year's leavers, p_{00}, are not part of the current workforce. The Berkeley study concludes that "focusing on new-hire attrition is misleading" (p. 5) since the losses of leavers are unimportant "from a public education policy perspective" (p. 6). But even leaving aside issues of equity, the focus on proportions of winners and losers among incumbents (instead of entrants) can leave a misleading (or at least incomplete) *financial* picture. If the vast majority of incumbents are winners, compared to a fiscally neutral plan, then how can the finances add up? Formally, if we replace p_{00} and p_{01} in (4) with the incumbent shares $p_{00}/(1 + p_{01})$ and $2p_{01}/(1 + p_{01})$, then the sum of the cross-subsidies is positive. The reason, of course, is that some of the gains of the incumbent stayers were financed by last year's leavers, who are no longer around. If we were to include them in our account, the losers' share of the total (incumbents plus prior leavers) would be $2p_{00}/(1 + p_{01} + p_{00}) = p_{00}$, the same as the share of entrants, and the cross-subsidies would sum to zero.

Cross-Subsidization Across Entry-Age Cohorts

The second step in determining the uniform normal cost rate applied to all employees, is to average the entry-age-specific normal costs, across all entry ages – in this simple case, the average of n_0 and n_1. There are various weights that can be used, but the ones we use here are, again, present value of earnings. As discussed in notes below, these are not the weights used in standard actuarial practice, but they are the weights that make the cross-subsidies add up to zero, so they are appropriate for this paper, which is focused on the pure cross-subsidies.[4] In this simple model, the blended rate is:

(5) $n^* = n_0(\alpha_0 W_0)/(\alpha_0 W_0 + \alpha_1 W_1) + n_1(\alpha_1 W_1)/(\alpha_0 W_0 + \alpha_1 W_1)$,

where α_0 and α_1 are the shares of the entering cohort of ages 0 and 1, and W_0 and W_1 are the present value of earnings for the average entrant of ages 0 and 1, across all exit ages. That is, in this simple case, $W_0 = p_{00}W_{00} + p_{01}W_{01}$ and $W_1 = W_{11}$.

We can now distinguish between two elements of cross-subsidy in the normal cost rates: The cross-subsidies within entry-age cohorts, as illustrated above by (2a)-(2b), and the cross-subsidies between age-cohorts, $(n_0 - n^*)$ and $(n_1 - n^*)$. We now turn to the general case.

III. The General Case

For the general set of entry ages e and separation ages s (i.e., not just 0 and 1), the individual normal cost rate, $n_{es} = B_{es}/W_{es}$, as given earlier, where, again B_{es} and W_{es} represent the present value at entry of the benefits and earnings of an individual of type (e,s). Note that n_{es} will remain unchanged "except for changes in provisions of the Plan or the actuarial assumptions

[4] We would also argue that these are the weights that are consistent with the EAN method for determining entry-age-specific normal costs and with its intended purpose: to generate contributions that will fund the benefits of the entry cohort, of all entry ages taken together, when all assumptions are met.

employed in projection of benefits and present value determinations" (Lamenzo, 2008, p. 35).[5] The normal cost rate for the entry age-cohort e generalizes readily from (1):

(6) $n_e = \sum_s p_{es}B_{es}/\sum_s p_{es}W_{es} = \sum_s n_{es}p_{es}W_{es}/\sum_s p_{es}W_{es} = \sum_s n_{es}(p_{es}W_{es}/\sum_s p_{es}W_{es})$.

Again, n_e is the weighted average of n_{es} where the weights are the shares of present value of earnings for each separation age among entrants of age e.

The uniform normal cost rate, using present value weights (generalizing (5)), is:

(7) $n^* = \sum_e n_e(\alpha_e W_e/\sum_e \alpha_e W_e)$,

where α_e is the share of each entry cohort of age e and $W_e = \sum_s p_{es}W_{es}$ is the present value of earnings for the average entrant of age e. Using (6) to take (7) a step further, we have:

(8) $n^* = \sum_e \sum_s n_{es}(\alpha_e p_{es}W_{es})\,/(\sum_e \sum_s \alpha_e p_{es}W_{es})$.

This naturally generalizes (6), as the weighted average of normal cost rates n_{es} across both entry ages e and separation ages s, where $\alpha_e p_{es}$ is the share of any entering cohort of type (e,s), and the weights on n_{es} are that type's share of the present value of earnings. Substituting $n_{es} = B_{es}/W_{es}$ into (8) shows that n* equals the ratio of the present value of benefits to that of earnings for the entering cohort as a whole.[6] It also follows from (8) that the cross-subsidy rates relative to n*, (n_{es} - n*) sum to zero when weighted by the shares of lifetime earnings:

(9) $\sum_e \sum_s (n_{es} - n^*)(\alpha_e p_{es}W_{es}) = 0$.

We can decompose the individual cross-subsidy rates into that within the entry-age cohort and that between entry ages: (n_{es} - n*) = (n_{es} - n_e) + (n_e - n*). Finally, we note that all these cross-subsidy rates (and their decomposition) hold not only for the total normal cost rate but also for the employer normal cost rate, since that is net of a uniform employee contribution rate.

[5] Specifically, n_{es} does not vary with deviations of the actual wage from that projected from the starting salary.
[6] This is not true for the standard weighting scheme used to blend entry-age-specific normal cost rates.

IV. Normal Cost Rates for CalSTRS

We consider the example of CalSTRS. To begin with, we estimate the matrix of individual normal cost rates, $n_{es} = B_{es}/W_{es}$, for e,s = 20, … , 75. Since B_{es} and W_{es} are proportional to the entry wage, n_{es} is independent of the entry wage, so we can normalize B_{es} and W_{es} per dollar of entry wage. Thus normalized, the equation for W_{es} is:

$$(10)\ \ W_{es} = \sum_{a=e}^{s} (1+r)^{(e-a)} \prod_{\alpha=e}^{a} \left(1 + g^{w}_{e,(\alpha-e)}\right).$$

Here $g^{w}_{e,(\alpha-e)}$ is the merit wage growth by entry age and service, plus inflation, as given by CalSTRS actuarial assumptions, and r is the CalSTRS discount rate of 7.5 percent.

Benefits can be in the form of an annuity or a refund,[7] so:

$$(11)\ \ B_{es} = (prob\ refund)_{e,s-e} PV(Refund_{es}) + \left[1 - (prob\ refund)_{e,s-e}\right] PV(Annuity_{es}).$$

CalSTRS actuarial assumptions include the probability of refund by entry age and service, as discussed further below. Refunds of employee contributions (at the current rate of 9.205 percent) include interest at approximately the two-year Treasury rate, currently 4.5 percent. Thus, $PV(Refund_{es})$, per dollar of entry wage, is a straightforward calculation.

The starting annuity for an individual of type (e,s) is calculated under the defined benefit program for new hires (since 2013), the “2% at 62” program. This is a final-average-salary (3 years) formula with age-specific multipliers ranging from 1.16 percent at age 55 to 2.4 percent at age 65 (with 2.0 percent at age 62), after 5-year vesting. Vested employees who withdraw before age 55 but do not cash out are assumed by CalSTRS to defer the pension to age 60. The annuity factors (including 2.0 percent simple COLA) are calculated using CalSTRS actuarial assumptions for female rates of mortality for active members, discounted back to entry.

[7] We leave aside disability and death benefits, which comprise about 5 percent of normal cost, less than 1 point.

The graduated multiplier structure mutes the cross-subsidies embedded in this system, compared to other systems with a uniform multiplier (e.g. 2.0 percent for all ages, once eligibility conditions have been met). Still, the cross-subsidies are substantial. Figure 1 depicts n_{es} for selected entry ages, 25, 30, 35, 40, and 45,[8] and for all exit ages. The graph illustrates a wide range of individual normal cost rates from 4.4 percent, for (e, s) = (25, 30), up to 20.4 percent, for (e, s) = (45, 65). The graph also includes the employee contribution rate, 9.205 percent, so we can also see the employer normal cost rate for each (e, s), by comparing with the employee contribution line. Thus, the employer normal cost rate varies from -4.8 percent, for (e, s) = (25, 30), up to 11.2 percent, for (e, s) = (45, 65).

Normal cost rates rise with age of entry (at least up to age 40) for any given exit age. We will examine this more closely below, but first consider the pattern within any entry-age cohort.

Variation in Normal Cost By Age of Exit, Within Entry-Age Cohorts

Figure 1 depicts four phases of normal cost by age of exit for any given entry age. In the first phase, prior to vesting, the benefit is the refund of employee contributions. The normal cost rate starts at the employee contribution of 9.205 percent and gently declines over the vesting period. Since the interest credit of 4.5 percent is below the fund's assumed return, 7.5 percent, the level contribution rate needed to cover the refund falls below the employee contribution rate over this phase, but not by much, since the vesting interval is only 5 years.

Then, at 5 years, the normal cost rate drops precipitously. The reason is that the individual is now eligible for a deferred pension with a very low normal cost, but CalSTRS

[8] These are representative of the vast majority of entrants. The proportions at or below ages 25, 30, 35, 40, and 45 are, respectively, 29%, 57%, 72%, 81%, and 88%. The full distribution, used here and below, is shown in Figure 3 of Rhee and Fornia (2016). The underlying data from CalSTRS was kindly provided to the authors by Fornia.

assumes a sizeable probability of eschewing the refund, which is worth a lot more. Figure 2 illustrates for age-25 entrants. The dotted curve represents the normal cost rate for refunds, gradually declining from the employee contribution rate, as the 7.5 percent discounting outweighs the 4.5 percent interest. The dashed curve is the normal cost rate for the pension, rising from a very low rate for separation upon immediate vesting, since the final average salary is frozen and the pension is deferred until age 60. The solid curve – the actual normal cost rate – is a weighted average of the dotted and dashed curves, with weights corresponding to the probability of taking the refund or not. Over the vesting period, the refund rate is 100 percent, so the solid curve coincides with the dotted curve, but immediately upon vesting CalSTRS assumes only 40 percent probability of refund (dropping gradually thereafter), even though upon strict present value calculation, the optimal choice is refund (leaving aside probability of re-entry). Indeed, we estimate that the normal cost rate for 25-year-old entrants is reduced by those who decline refunds up to age 47, and by those who continue to take refunds after age 47.[9]

In the third phase, from vesting up to age 65, the normal cost rate rises continuously, first as the deferral to age-60 becomes shorter and salaries continue to grow, and then as the age-specific multiplier grows from age 55 to 65.[10] Finally, in the fourth phase, after age 65, the multiplier stops growing, so the normal cost declines, as the negative impact of later exit on the number of years of pension draw becomes dominant.

[9] See Lueken (2014) for the first analysis of sub-optimal cash-out decisions, by Illinois teachers.

[10] Interestingly, there is no discontinuity at age 55, when the pension draw becomes immediate, instead of the 6-year deferral assumed for exits at age 54. That is because the age-specific multiplier is higher for age 60 than for 55, a feature that smoothes out the accrual pattern for CalSTRS, as noted previously by Costrell and Podgursky (2009).

Negative Employer Normal Cost

As explained above, the normal cost rate dips below the employee contribution rate throughout the vesting period, and for most entry ages, it drops further immediately upon vesting, before rising again. Consequently, for each entry age there is a range of exit ages over which the employer contribution rate is negative. These ranges can be read off Figure 1. For entry age 25, the employer contribution rate is negative up through exit age 53. The corresponding break-even points for entry ages 30, 35, 40, and 45 occur, respectively, after exit ages 51, 50, 50, and 50. For the few entrants at older ages, the employer contribution rate becomes positive immediately upon vesting (i.e., entry age plus five).

What proportion of entrants fall into these ranges of negative employer normal cost? Figure 3 shows that half or more of every entry cohort aged 38 or below will exit before the employer normal cost turns positive, and for older entrants, the proportion is generally 40 percent or more. Overall, we estimate 51 percent of all entrants receive benefits that cost less than the employee contribution. These entrants, however, are early leavers, so they account for a much smaller proportion of the cohort's lifetime earnings, as shown in the bottom curve of Figure 3.

V. Cross-Subsidies, Within Entry Age Cohort

Under the Entry-Age Normal method, an average normal cost rate is calculated for each entry age, before averaging across all entry ages for a uniform rate to be levied (jointly) upon employer and employee. We consider here the first step – the average normal cost rate within each entry age cohort, and how that compares with each individual's normal cost. As discussed above, the cohort's normal cost rate is a weighted average of the individual normal cost rates by exit age, where the weights are each exit age's share of the cohort's present value of earnings.

As a result, this cohort-specific normal cost rate would fund the cohort's benefits if all assumptions are met. Figure 4 presents our estimates for CalSTRS' normal cost rates by entry age. The solid blue curve at the top of the diagram is the joint normal cost rate (employer plus employee) and the dashed blue curve below is the employer normal cost rate. As is typically the case, these rates are higher for later entry ages, at least up through the most common entry ages.

Within each entry age cohort, those individuals with normal cost rates that are above the cohort's average may be said to enjoy a cross-subsidy from those below. Figure 5 illustrates for age-25 entrants, with the blue line representing the average rate of 11.3 percent for the cohort. Those who exit between the ages of 57 and 70, whose normal cost exceeds 11.3 percent, are beneficiaries in this sense from all others in their entry age cohort. One may also interpret this as comparing the benefits of this system with those of an ideal cash balance plan, where the (joint) contribution rate for age-25 entrants is a flat 11.3 percent and the interest credit is 7.5 percent.[11] Those below the blue line in Figure 5 are losers in that comparison and those above are winners.

Figure 6 represents the cross-subsidies within other age-entry cohorts. (This diagram simply shifts down Figure 1 by the corresponding cohort average from Figure 4.) Winners are those with positive normal cost rates relative to the cohort average and losers are those with negative figures. In examining this figure, it is helpful to bear in mind that each cohort's average normal cost rate is in the range of 10.4 – 16.7 percent, so these cross-subsidies, ranging from -8.7 to +4.7 percent can be quite substantial. Moreover, since all employees pay a uniform 9.205 percent, the figures depicted also represent the cross-subsidies in the employer normal cost rate.

[11] In practice, cash balance plans differ in a few ways: (i) they typically do not offer entry-age-specific contribution rates (although the rates can vary with years of service, as in Kansas' Tier 3 plan for teachers); and (ii) the guaranteed interest credit is typically below the actuarial discount rate.

These are all the more striking considering that each entry age cohort's average employer normal cost rate is in the range of 1.2 – 7.5 percent, as depicted in the bottom half of Figure 4.

How many winners and losers are there? Figure 7 shows the proportion of entrants who are losers by entry age. In most entry-age cohorts this is over 60 percent (62.3 percent overall average). However, since these losers are generally the earlier leavers, their proportion of the entry age cohort's lifetime earnings (in present value) is less, around 30-40 percent (32.5 percent overall average), also shown in Figure 7. These are the relevant shares for the purpose of adding up the cross-subsidies when measured in normal cost rates, as discussed earlier.

<u>A Potentially Misleading Measure of Winners and Losers</u>

The picture that emerges above, of large numbers of losers relative to comparable cash balance plans has been challenged by Rhee and Fornia (2016). While we find 62 percent of all entrants are losers, Rhee and Fornia (p. 31) find only 21 percent of "active teachers" are better off with a CB plan than the CalSTRS pension. Although there are some differences in how the CB plan is defined, the main difference is their focus on "active teachers," as opposed to entrants. Most of the entrants who are losers exit early, so they are under-represented among "active teachers," but the cross-subsidy they provided has remained behind.

For the cross-subsidies to add up to zero, the proper weights have to be assigned to the measures of gain and loss. If the measure of gain and loss is the annual normal cost rate, then the proper weights are the proportions of the cohort's lifetime earnings, as discussed above. Thus, in Figure 5, the large area below the blue line and above the black line (exit ages below 57 and above 70) is inhabited by entrants who earn only 31 percent of the cohort's lifetime earnings, so, properly weighted, it offsets the smaller area (exit ages 57 – 70) above the blue line and below the black line, weighted by their inhabitants' 69 percent share.[12]

For Rhee-Fornia, the measure of gain and loss is not an annual figure, but a figure related to pension wealth. Thus, the appropriate weights to make the gains and losses add up are not the winners' and losers' shares of lifetime earnings, but the shares of the relevant population. The problem is that Rhee-Fornia's figures of 21 percent losers and 79 percent winners do not pertain to the relevant population for this purpose: they are the shares of "active teachers" instead of entrants. As a result, the gains and losses do not add up. This can be seen in Figure 8 (reproducing their Figure 9), for age-25 entrants.[13,14] One can easily eyeball that if the area of losses (below the dotted line and above the solid line) is weighted by the 21 percent figure for losers, it cannot possibly offset the area of gains (above the dotted line and below the solid line), weighted by the 79 percent figure for winners. The cross-subsidies simply do not add up, for the simple reason that the cross-subsidies left behind by entrants who have exited are not counted.

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[12] In comparing the areas on the diagrams (here and below), weighted by the proportions that fall in those areas, we are speaking loosely, but close enough to the actual calculation, which is the sum of the products, year-by-year, for the negative and positive terms in $\Sigma_s (n_{es} - n_e) (p_{es} W_{es} / \Sigma_s p_{es} W_{es}) = 0$.

[13] Their estimate of 79 percent winners and 21 percent losers is based on "age 25 cutoffs for when the DB value exceeds the value of alternative plans." Their estimate appears to refer to all entry ages, not just age 25, but this is not entirely clear. If so, their result is even more at odds with fiscal neutrality than indicated in the text, since their diagrams for other entry ages are more lopsided on the areas of gains vs. losses.

[14] The exit ages for losers and winners relative to CB closely match those in our calculations, depicted in Figure 5.

VI. Cross-Subsidies Between Entry Age Cohorts

We calculate the weighted average normal cost rate across entry age cohorts, n*, as given in (7). As discussed above, we use present value of earnings for each entry age cohort as weights, in the same fashion that the Entry Age Normal method weights normal cost rates within entry age cohorts. As a result, this normal cost rate will fund the benefits of the entire cohort (across all entry ages) if all assumptions are met, in the same fashion that each EAN rate will fund the benefits of that entry age cohort.[15] We calculate the overall normal cost rate to be 12.8 percent, or 3.5 percent for employer normal cost.[16] Figure 4 illustrates how this weighted average compares with the normal cost rates by entry age. As can be seen, entry cohorts of age 30 or less cross-subsidize older entrants. These losing cohorts comprise approximately 57 percent of entrants and 65 percent of the entering cohort's lifetime earnings.

VII. Cross-Subsidies Within and Between Entry Age Cohorts

Finally, we consider the cross-subsidies both within and between entry age cohorts. Figure 5 illustrates for age-25 entrants. The red line is the overall normal cost rate, n*. The gap between the black curve for individual normal cost rates and the red line, instead of the blue line, shows that the cross-subsidy provided by age-25 entrants is exacerbated by the cross-subsidy provided to older entrants. All entrants of that age who exit prior to age 61 or after 67 provide a net cross-subsidy within and/or across entry ages. These net losers comprise 85 percent of the entry age cohort and account for 71 percent of the cohort's lifetime earnings – substantially more

[15] As stated earlier, these are ***not*** the weights used across entry ages under standard actuarial practice to determine the overall uniform normal cost rate. Those weights are, effectively, current payroll weights by entry age, rather than present value of career earnings. The difference may be substantial, as will be explored in other research.

[16] This is about two percentage points lower than CalSTRS' estimate of the normal cost rate for new entrants (netting out death and disability). This may be related, in part, to the weighting scheme issue in the previous note. It may also be related, in part, to our assumption that all entrants earn the same starting wage, regardless of age.

losers than for the within-entry-age-cohort calculations. Conversely, for entry ages 31 to 73, there are fewer losers, since the overall normal cost rate is less than the entry-age-specific rate.

Figure 9 depicts the proportion of losers for all entry ages (by number of entrants and by their lifetime earnings), analogous to Figure 7. Comparing the two figures, the point discussed above is readily apparent: for entry ages 30 or below, there are more losers within and across entry-age cohorts than only within, and for entry ages 31 to 73 the converse holds. Again, this follows directly from the gap between the overall normal cost rate, n*, and the entry-age-specific rates, n_e, depicted in Figure 4. Averaging across all entry and exit ages, the losers depicted in Figure 9 (net negative cross-subsidy, within and/or across entry age cohorts) comprise 66.4 percent of entrants, and they account for 44.7 percent of lifetime earnings. These are higher proportions than for the losers within-entry-age-cohorts only (62.3 percent and 32.5 percent).

The magnitude of the individual cross-subsidies in normal cost rates is depicted in Figure 10 for selected entry ages. Analogous to Figure 6, we see the net cross-subsidy – positive or negative – within and across entry ages, by age of exit.[17] Comparing Figure 10 with Figure 6, we see that the cross-subsidies across entry ages impart a tilt to the diagram, shifting down the curves for entry ages 30 or below and shifting up the curves for entry ages 31 to 73.

The average cross-subsidies for winners and losers in each entry-age cohort are depicted in Figure 11, as the solid curves above and below the 0-percent line. For example, the cross-subsidy depicted for losers among age-25 entrants, -2.3 percent, is the weighted average of Figure 10's individual cross-subsidies for age-25 entrants below that figure's 0-percent line, and similarly for the average cross-subsidy of +0.6 percent received by that entry-age's winners.[18]

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[17] While Figure 6 shifted Figure 1 down by the entry-age-specific normal cost rate, n_e, Figure 10 shifts it down by the uniform overall normal cost rate, n*.

[18] Taking winners and losers together, the cohort's net cross-subsidy is simply the -1.5 percent depicted in Figure 4 as the gap between the curves for age-25 entrants.

Figure 11 also provides the decomposition of the winners' and losers' cross-subsidies into those within and between entry-age cohorts, as described below equation (9). The dotted curves depict the cross-subsidies within entry-age cohorts, and the gap between the dotted and solid curves represent the cross-subsidies between entry-age cohorts. Thus, for entry-age-25, the losers would provide a cross-subsidy of -0.8 percent to the rest of the cohort, but the additional -1.5 percent to other entry-age cohorts raises their total cross-subsidy, within and across entry-age cohorts to -2.3 percent. In general, consistent with Figure 4, the cross-subsidies across entry-age cohorts exacerbate the losses (and reduce the gains) for entrants age 30 or below, and ameliorate the losses (and enhance the gains) for older entrants.

Over all entry and exit ages, the losers (66.4 percent of entrants, with 44.7 percent of lifetime earnings) provide a net cross-subsidy of -2.7 percentage points and the winners (33.6 percent of entrants, with 55.3 percent of lifetime earnings) receive a net cross-subsidy of +2.2 percentage points. Put differently, the losers receive an average employer normal cost rate of 0.8 percent (2.7 percent below the overall employer normal cost rate of 3.5 percent), while the winners receive an average employer cost rate of 5.7 percent (2.2 percent above the overall rate). By analogy with account-based retirement systems (DC and CB), this is as if employers' match to the employees' contribution averaged 0.8 percentage points for two-thirds of entrants and 5.7 percentage points for one-third. Figure 12 breaks out the employer normal cost rates for winners and losers by entry age.[19] The gap is quite striking.

[19] Figure 12 simply raises the solid curves of Figure 11 by the overall employer normal cost rate of 3.5 percent.

Conclusion

The distinguishing characteristic of traditional Defined Benefit plans is that the benefit is defined by formula, rather than by contributions, unlike account-based retirement plans, such as Cash Balance and Defined Contribution. With benefits de-linked from contributions, some individuals will receive benefits that cost more than the contributions made on their behalf and some will receive less, effectively a system characterized by cross-subsidies. Previous work on teacher pensions has analyzed the redistribution of benefits with an emphasis on years of service (or exit age) for any given entry age, and with the metric of pension wealth. The present paper adds to previous literature in two ways: (i) expanding the analysis to cross-subsidies both within and across entry-age cohorts; and (ii) measuring the redistribution in normal cost rates – to facilitate direct comparison with annual contribution rates for account-based plans.

We have also clarified a potential confusion in the literature, regarding the number of winners and losers between a traditional DB plan and a fiscally neutral CB plan. Rhee and Fornia (2016) have argued that the educationally-relevant shares of winners and losers in a teacher pension plan (CalSTRS, specifically) are those of the incumbent teaching force, rather than the entry cohort. Thus, those entrants who leave service without earning benefits commensurate with the contributions made on their behalf are not counted, because they are no longer teaching. This approach concludes that the vast majority of active teachers are winners under the traditional DB plan, compared to a fiscally neutral CB plan.

The problem is that for a fiscally neutral comparison, the gains of winners must add up to the losses of losers and that will not hold if we leave aside the losses of those who are no longer in the plan. To understand how the system adds up, we must focus on entrants. The winning and losing proportions among entering cohorts can be measured by their numbers and/or by their lifetime earnings. If the measure of gains/losses is pension wealth, then the numbers of winners and losers will make the finances add up; if the measure is annual normal cost rates, then it is their shares of lifetime earnings that make the cross-subsidies add up.

We have illustrated the analysis with the CalSTRS data used by Rhee and Fornia, portraying the full pattern of cross-subsidies by age of entry and exit. Overall, we find that 66.4% of all entrants, accounting for 44.7% of all entrants' lifetime earnings, receive benefits with an average employer normal cost rate of only 0.8%, compared to 5.7% for the winners. These are average cross-subsidies of -2.7 percentage points from the losers and +2.2 points for the winners. None of these cross-subsidies would exist at all under an account-based retirement system, such as a cash balance plan with uniform employer contribution rates.

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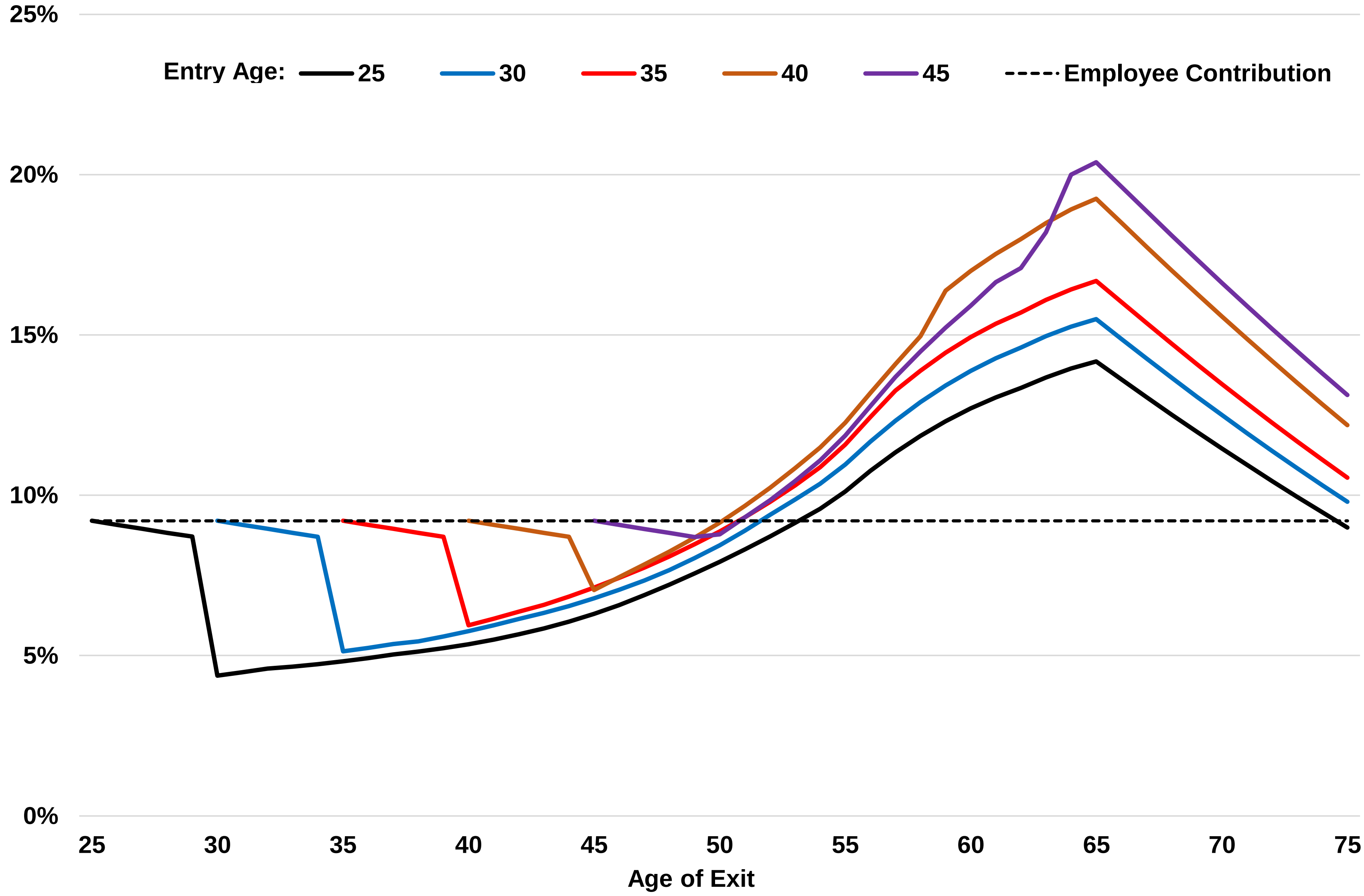
Figure 1. Normal Cost Rate, by Entry Age and Age of Exit, n_{es}

Estimated for CalSTRS New Entrants, using CalSTRS assumptions



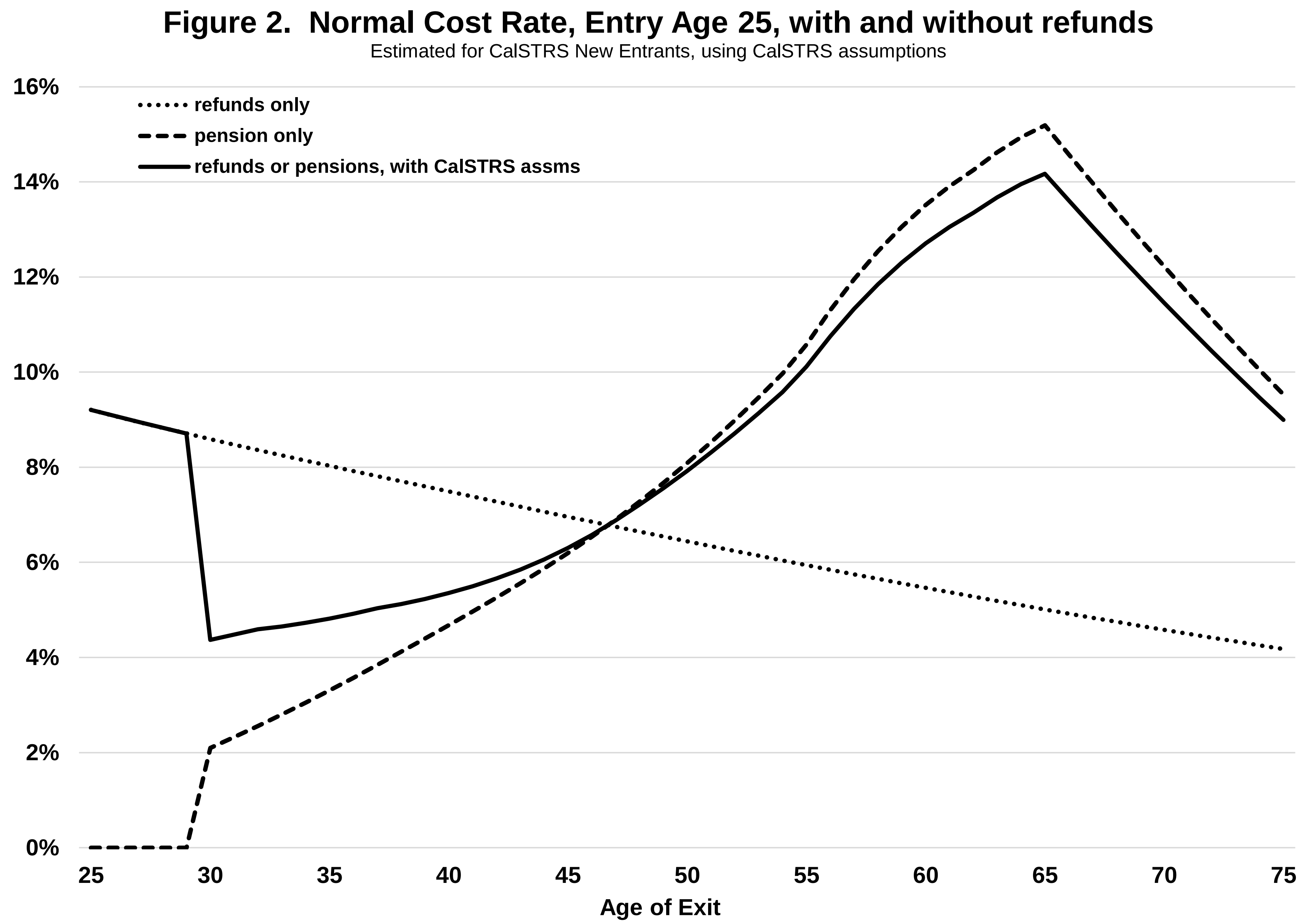


Figure 2. Normal Cost Rate, Entry Age 25, with and without refunds
Estimated for CalSTRS New Entrants, using CalSTRS assumptions
16%
14%
12%
10%
8%
6%
4%
2%
0%
refunds only
pension only
refunds or pensions, with CalSTRS assms
25
30
35
40
45
50
55
60
65
70
75
Age of Exit

Figure 3. Proportion with Negative Employer Normal Cost

n_{es} < employee contribution rate

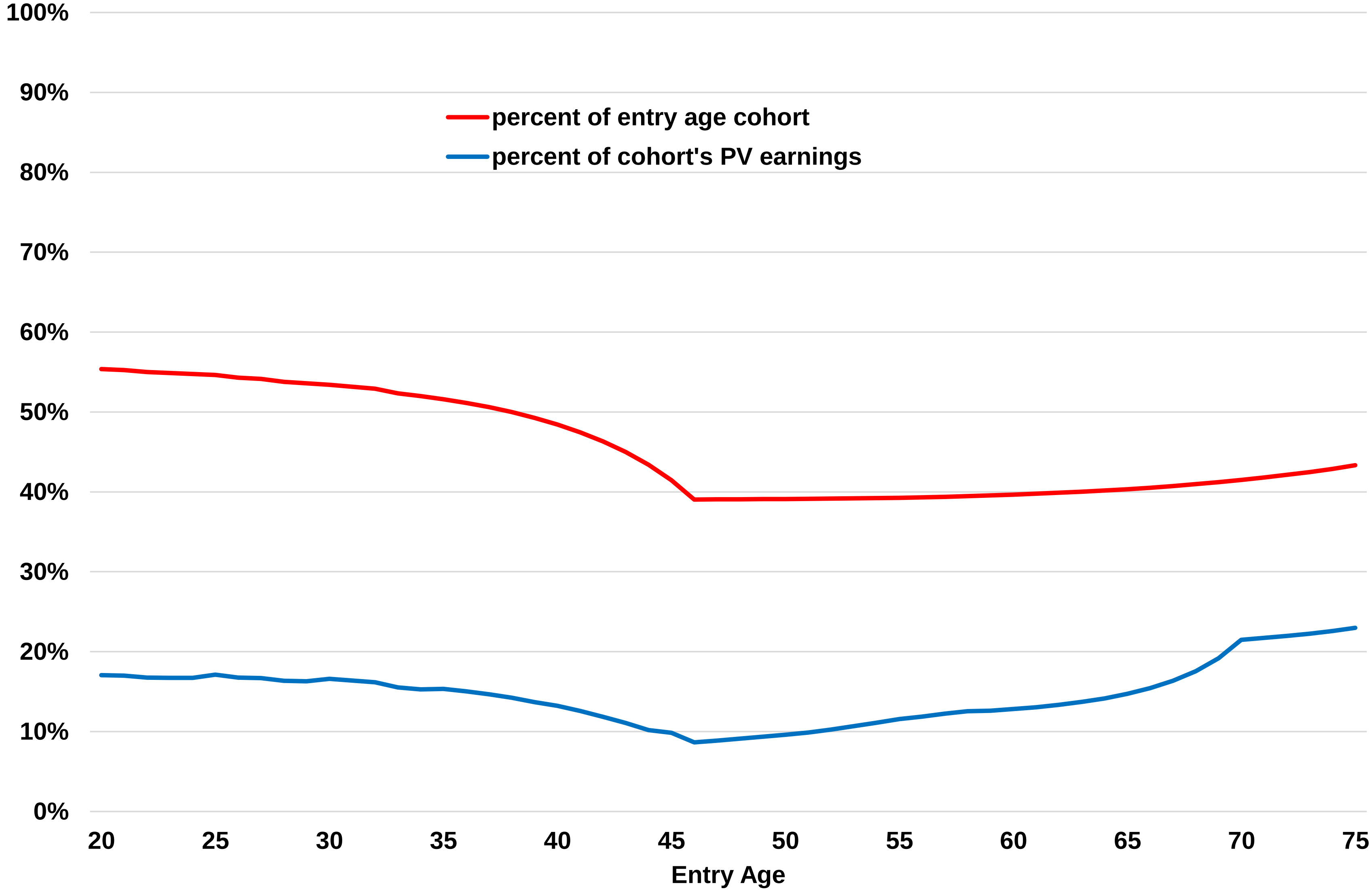
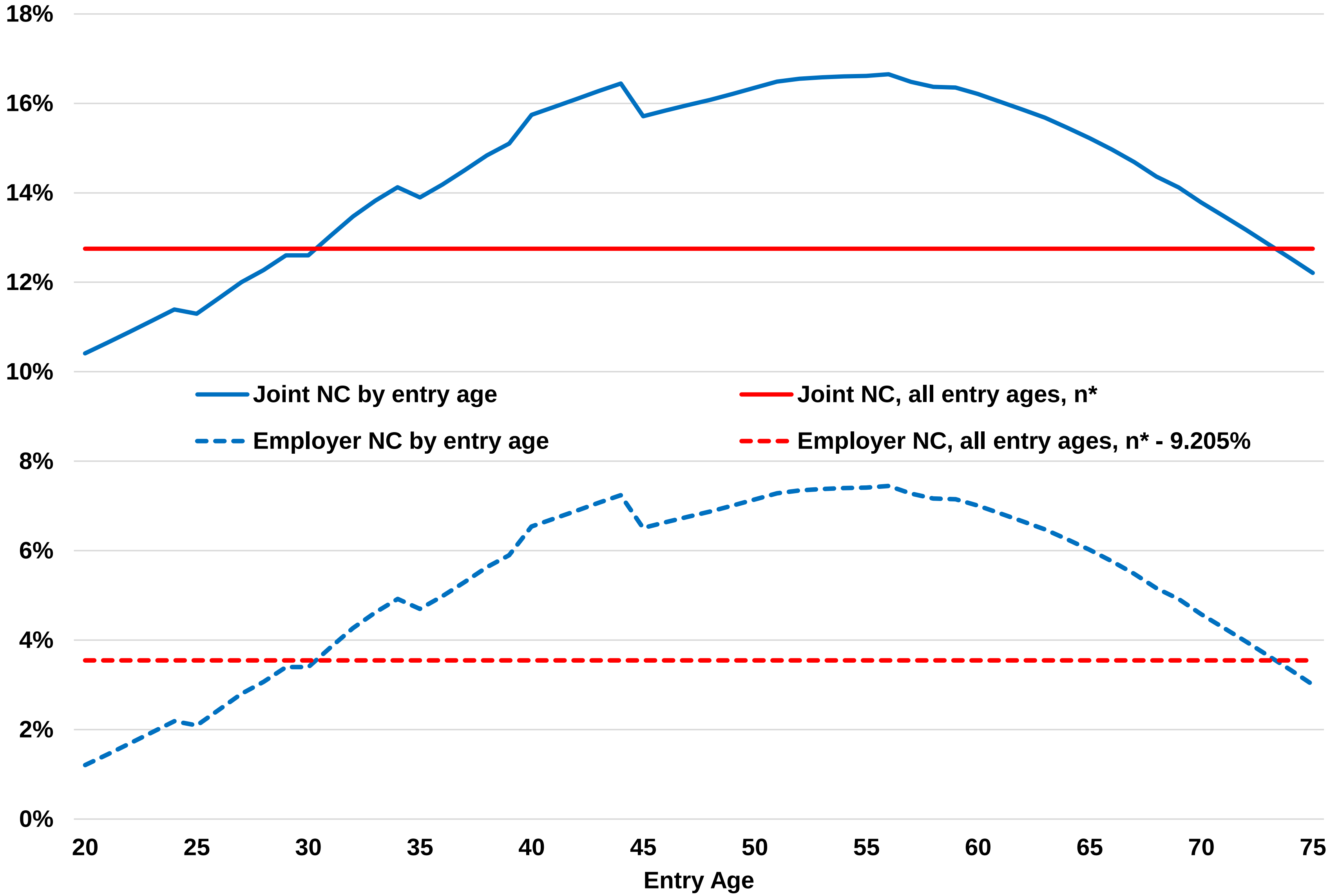


Figure 4. Estimated Normal Cost Rates by Entry Age Cohort, n_e



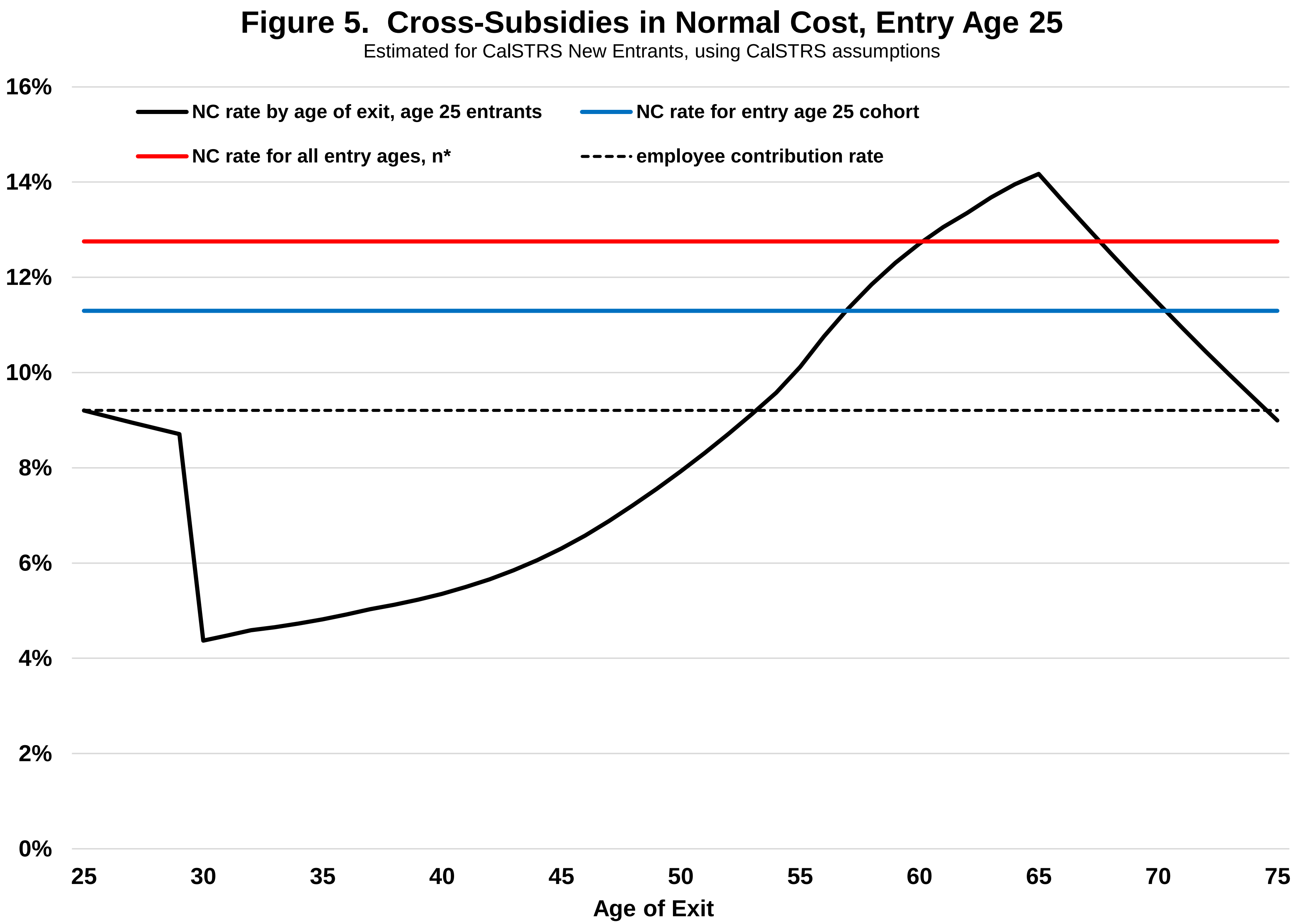


Figure 5. Cross-Subsidies in Normal Cost, Entry Age 25
Estimated for CalSTRS New Entrants, using CalSTRS assumptions
NC rate by age of exit, age 25 entrants
NC rate for entry age 25 cohort
NC rate for all entry ages, n*
employee contribution rate
16%
14%
12%
10%
8%
6%
4%
2%
0%
25
30
35
40
45
50
55
60
65
70
75
Age of Exit

Figure 6. Normal Cost Cross Subsidy Within Entry Age Cohort, n_{es} - n_e

Estimated for CalSTRS New Entrants, using CalSTRS assumptions

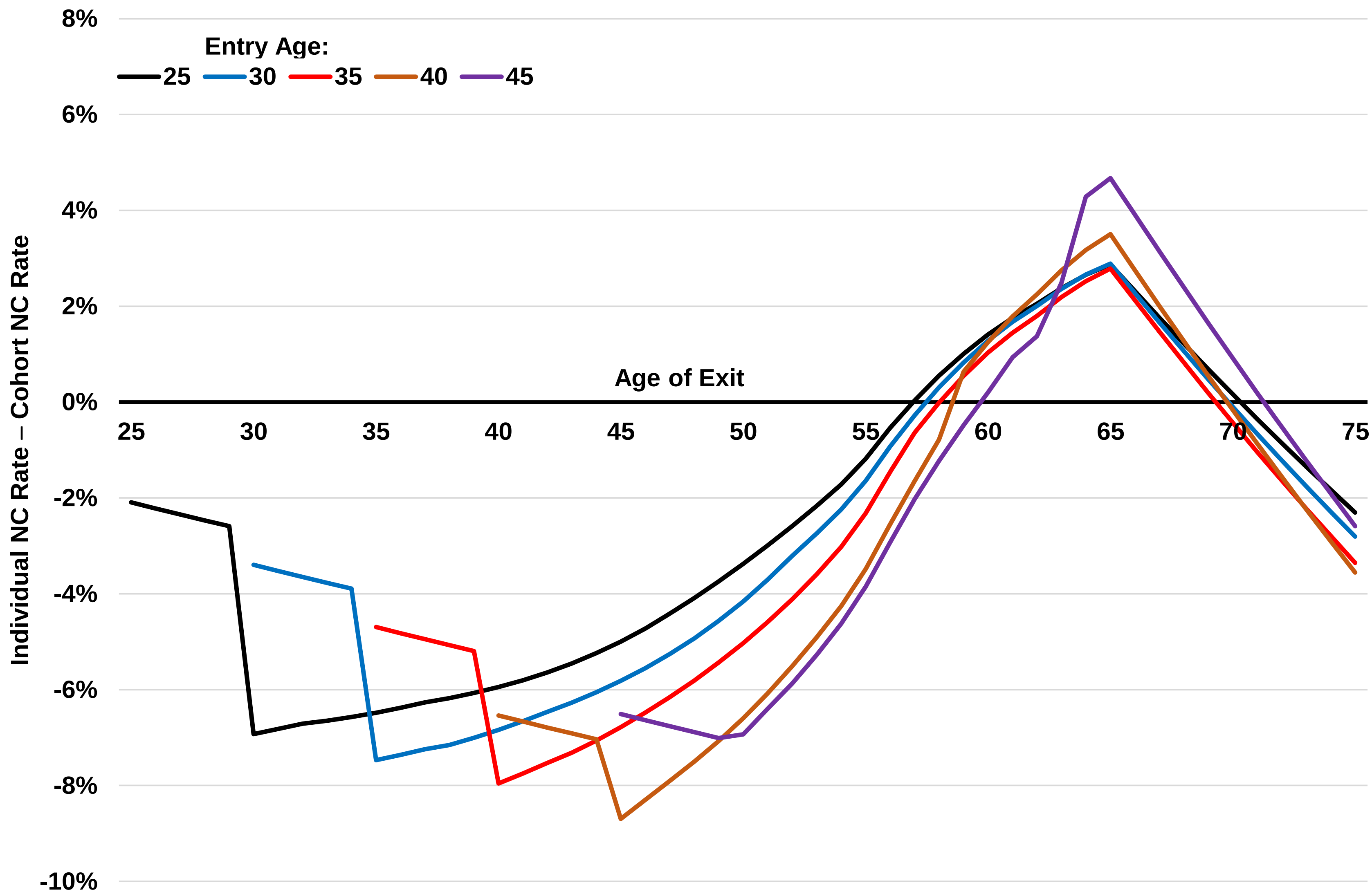
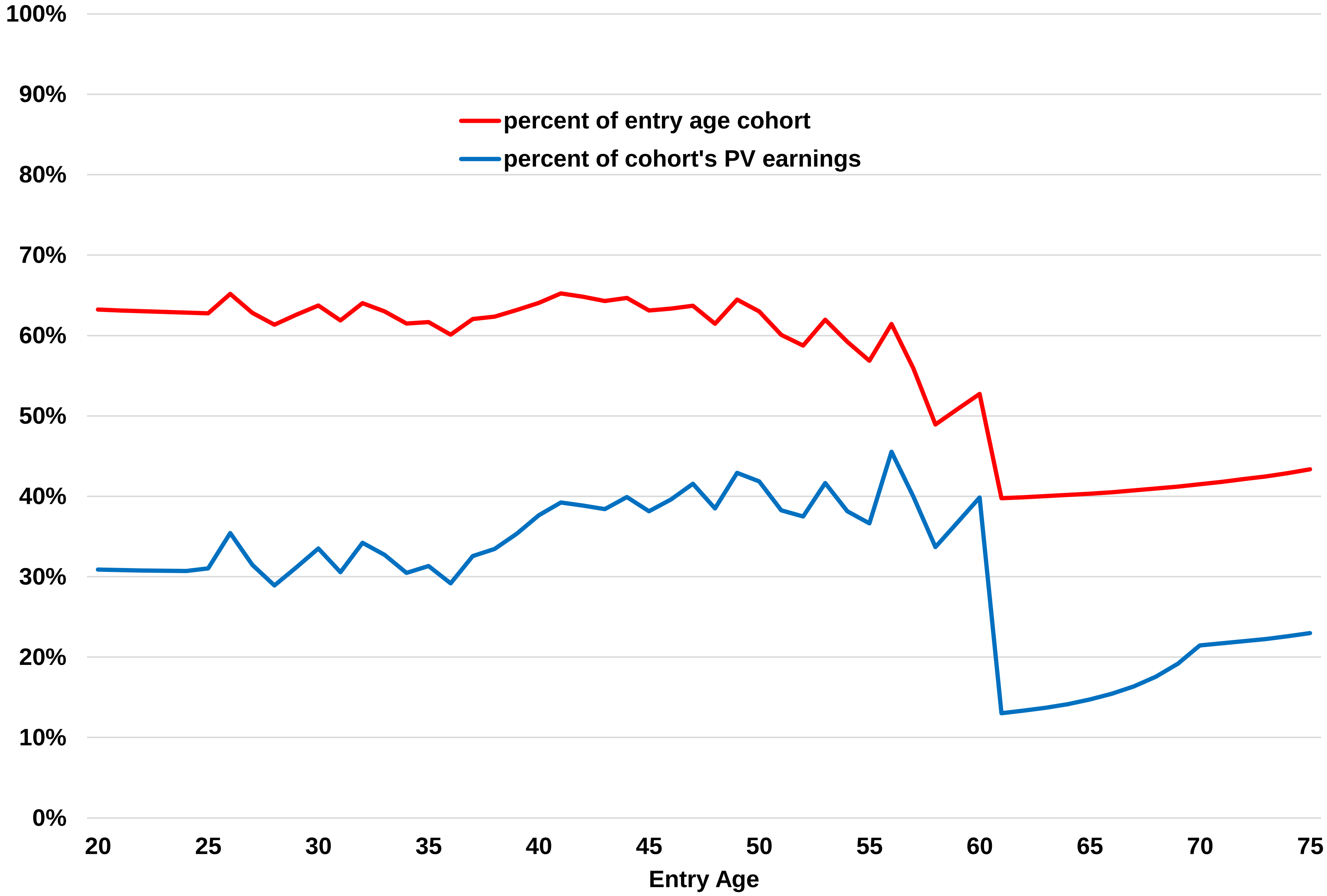


Figure 7. Proportion of Losers Within Entry Age Cohorts, $n_{es} < n_e$



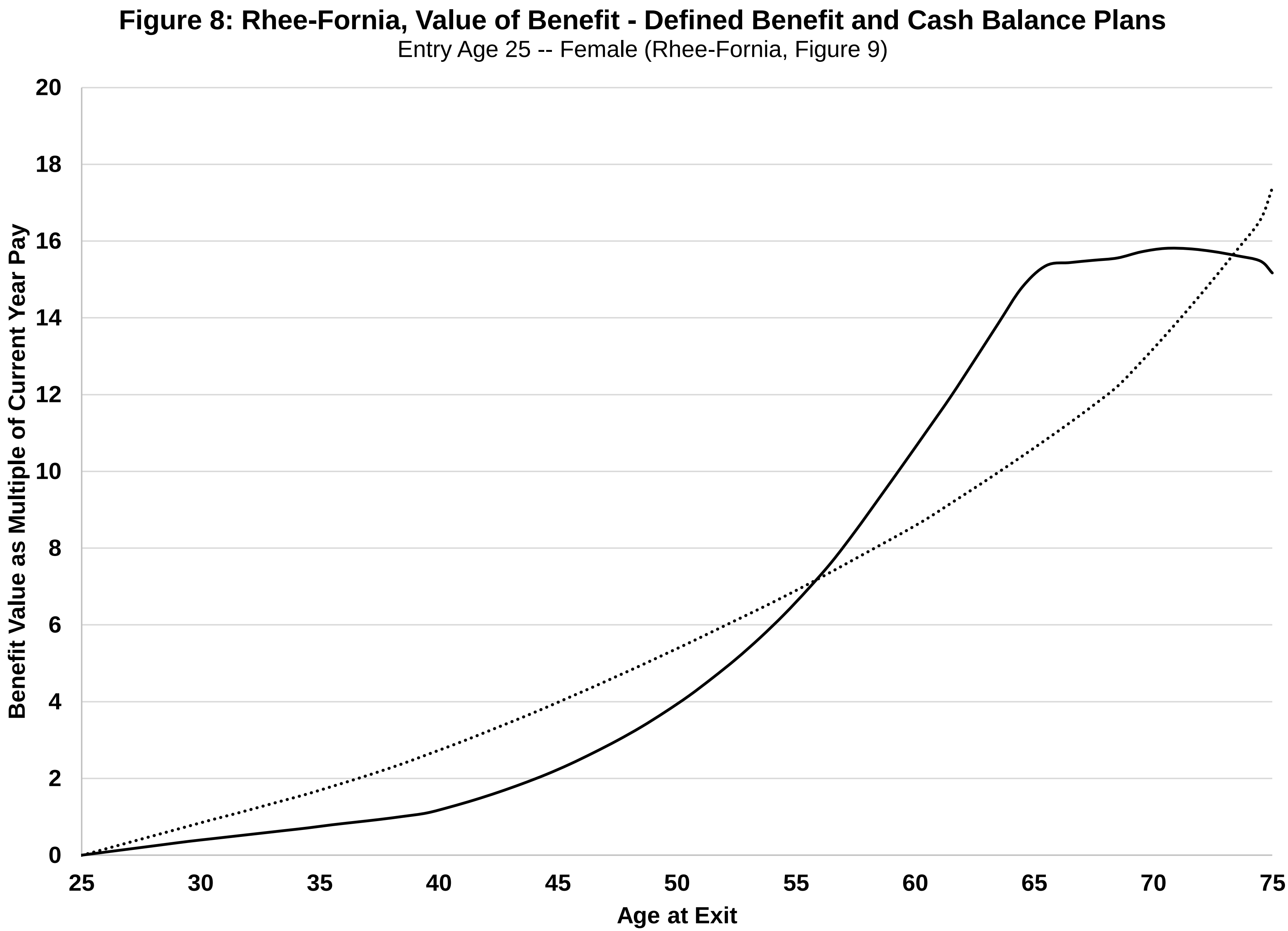


Figure 8: Rhee-Fornia, Value of Benefit - Defined Benefit and Cash Balance Plans
Entry Age 25 -- Female (Rhee-Fornia, Figure 9)
Benefit Value as Multiple of Current Year Pay
0
2
4
6
8
10
12
14
16
18
20
25
30
35
40
45
50
55
60
65
70
75
Age at Exit

Figure 9. Proportion of Losers Within & Across Entry Age Cohorts, $n_{es} < n^*$

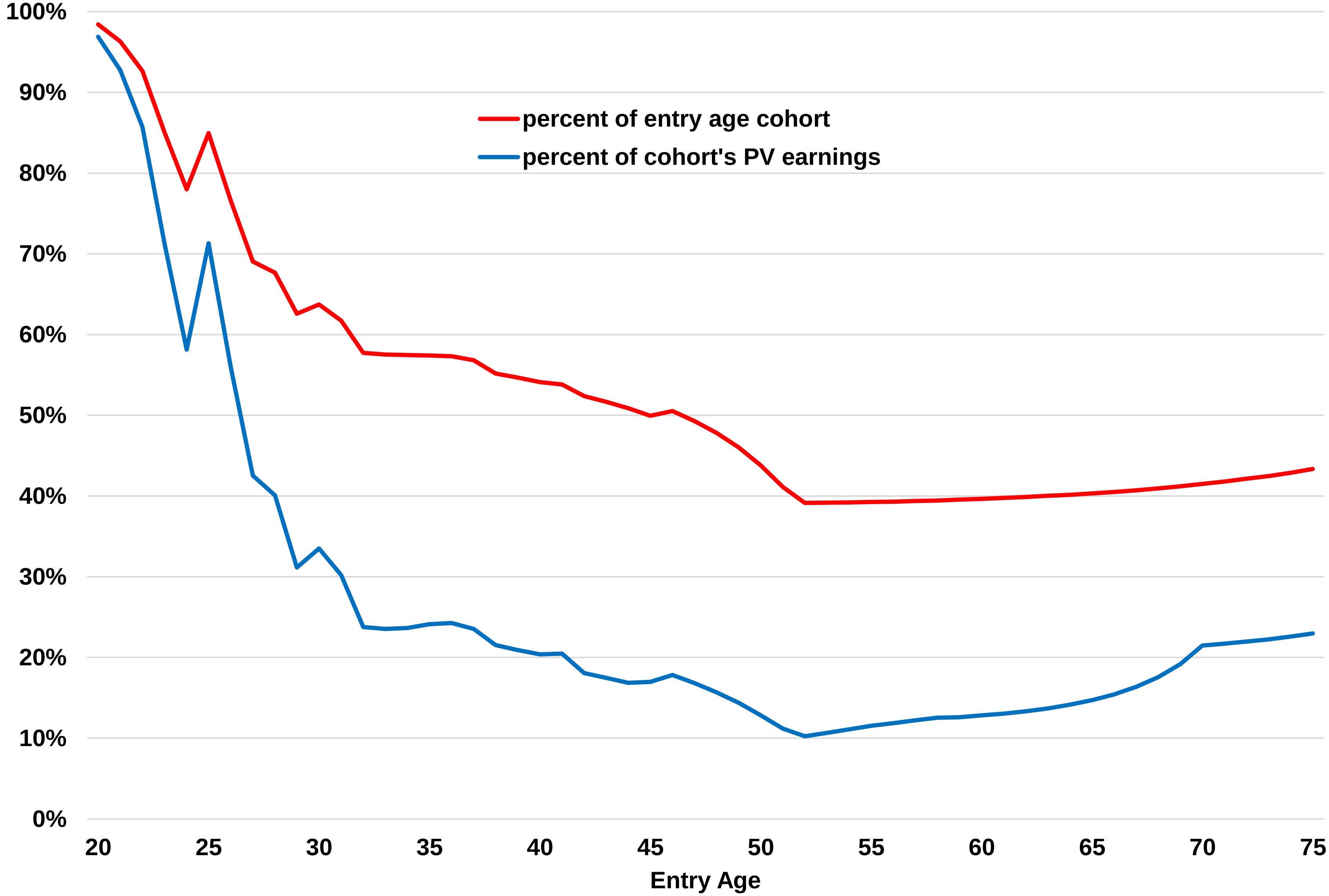


Figure 10. Normal Cost Cross Subsidy Within & Across Entry Ages, n_{es} - n*

Estimated for CalSTRS New Entrants, using CalSTRS assumptions

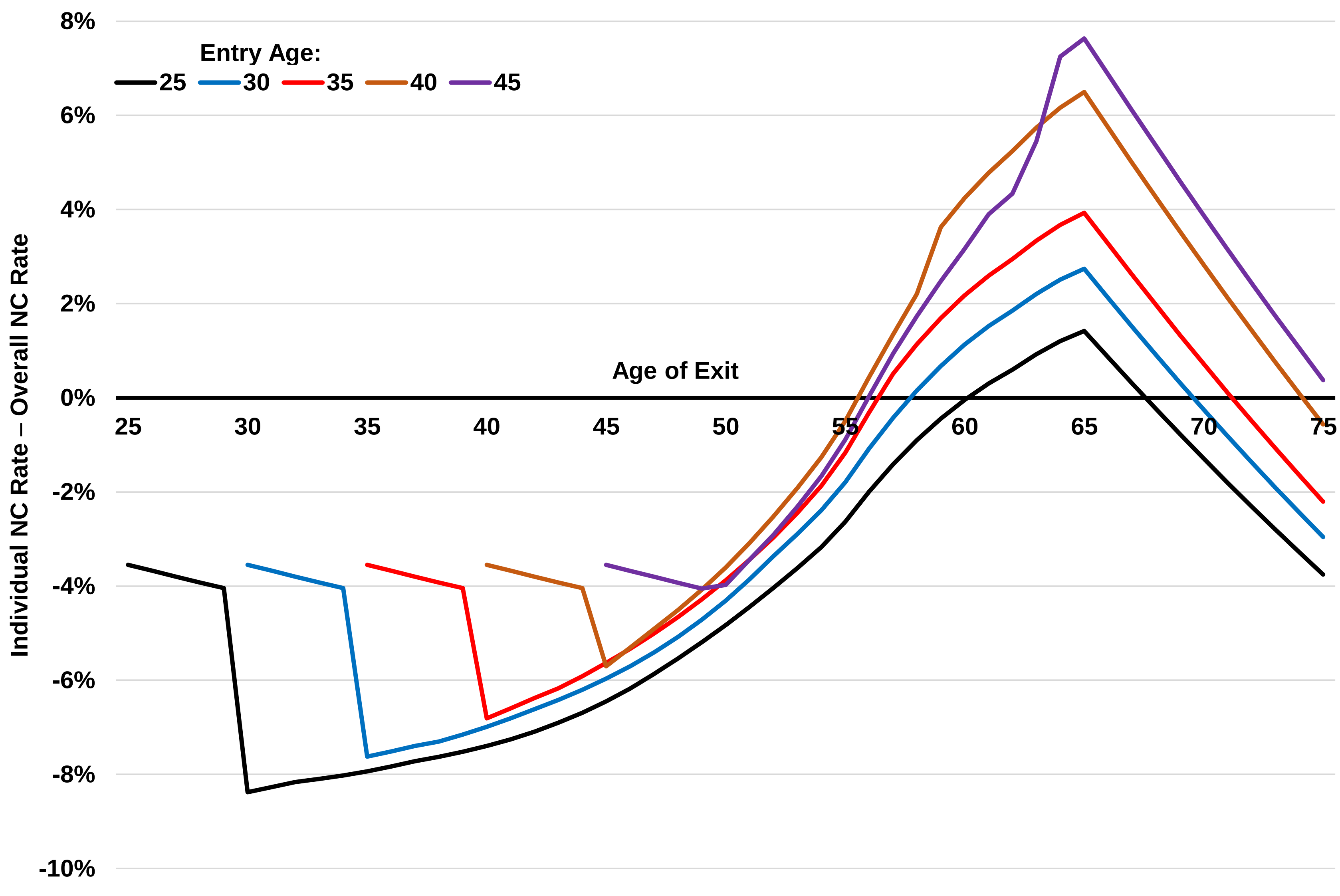


Figure 11. Average NC Rate Cross-Subsidies, Winners & Losers

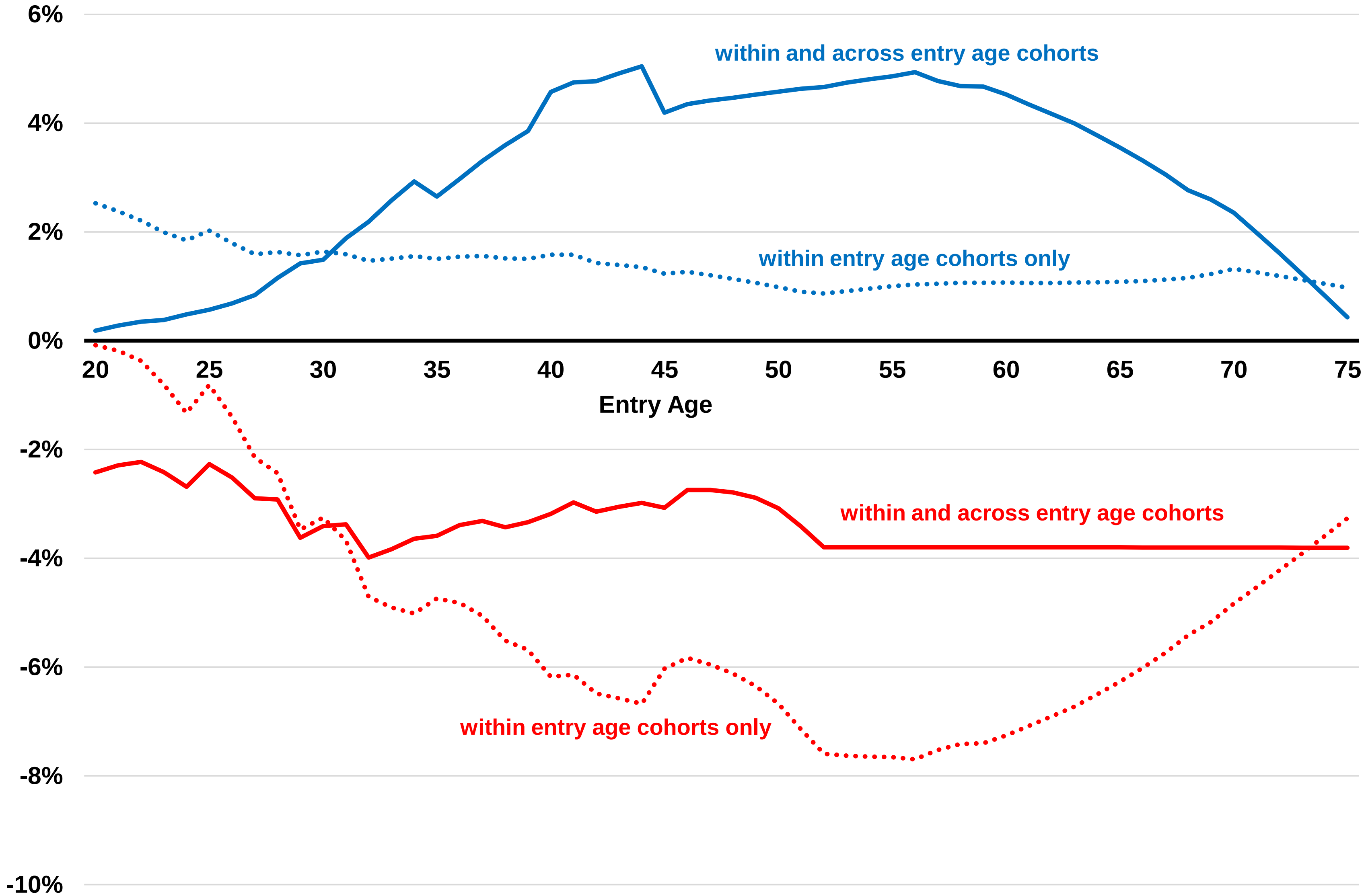


Figure 12. Average Employer NC Rate for Winners and Losers