

Supplementary Materials

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Table S2. Sensitivity analysis of overall survival treating radiotherapy receipt as a time-varying exposure.

Figure S1. Covariate balance across treatment groups, measured by standardized mean differences before and after overlap weighting, for prespecified survival comparisons: (A) BCS+RT and Mx-RT, (B) RT and no RT among BCS patients, and (C) RT and no RT among PMRT-indicated mastectomy patients.

Figure S2. Distribution of estimated propensity scores before and after overlap weighting for prespecified survival comparisons: (A–B) BCS+RT versus Mx-RT, (C–D) RT and no RT among BCS patients, and (E–F) RT and no RT among PMRT-indicated mastectomy patients.

Figure S3. Unweighted Kaplan-Meier curves comparing overall survival between patients receiving BCS+RT and Mx-RT.

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Figure S6. Adjusted marginal probabilities of radiotherapy receipt by age group.

Table S1. Tumor, socioeconomic, and demographic characteristics by radiation receipt.

	RT use ¹ N = 988,164 no. of death = 134,492	No RT use ¹ N = 469,079 no. of death = 102,502	p-value ²
Age at diagnosis	60 (51, 68)	62 (50, 74)	<0.001
Median follow-up (years)	6.2 (3.6, 9.8)	5.8 (3.2, 9.4)	<0.001
Race/ethnicity			<0.001
NH White	761,731 (77.1%)	364,245 (77.7%)	
NH Black	110,414 (11.2%)	48,638 (10.4%)	
Hispanic	60,323 (6.1%)	28,642 (6.1%)	
NH Asian	37,750 (3.8%)	19,024 (4.1%)	
NH American Indian	3,028 (0.3%)	1,517 (0.3%)	
NH Pacific Islander	997 (0.1%)	507 (0.1%)	
Other/unknown	13,921 (1.4%)	6,506 (1.4%)	
Tumor size (cm)	1.60 (1.00, 2.60)	1.70 (1.10, 2.70)	<0.001
Positive lymph nodes			<0.001
0	649,949 (65.8%)	332,891 (71.0%)	
1-3	215,357 (21.8%)	76,067 (16.2%)	
4-9	63,087 (6.4%)	11,166 (2.4%)	
≥10	26,999 (2.7%)	5,566 (1.2%)	
Positive (unknown)	6,926 (0.7%)	1,729 (0.4%)	
Unknown	25,846 (2.6%)	41,660 (8.9%)	
Histology			<0.001
Ductal	784,153 (79.4%)	358,329 (76.4%)	
Lobular	161,109 (16.3%)	84,021 (17.9%)	
Other	42,902 (4.3%)	26,729 (5.7%)	
Tumor grade			<0.001
Well diff.	217,650 (22.0%)	101,119 (21.6%)	
Moderately diff.	408,203 (41.3%)	195,755 (41.7%)	
Poorly diff.	257,085 (26.0%)	128,588 (27.4%)	
Other/unknown	105,226 (10.6%)	43,617 (9.3%)	
Lymphovascular invasion			<0.001
Not Present	569,498 (57.6%)	280,012 (59.7%)	
Present/Identified	146,682 (14.8%)	52,335 (11.2%)	
N/A or Unknown	271,984 (27.5%)	136,732 (29.1%)	
Breast cancer subtype			<0.001
HR+/HER2-	616,802 (62.4%)	274,126 (58.4%)	
HR+/HER2+	78,756 (8.0%)	37,711 (8.0%)	
HR-/HER2+	28,603 (2.9%)	16,252 (3.5%)	
Triple Negative	93,898 (9.5%)	46,100 (9.8%)	
Unknown	170,105 (17.2%)	94,890 (20.2%)	
Charlson Comorbidity Index			<0.001
0	836,010 (84.6%)	379,903 (81.0%)	
1	117,253 (11.9%)	64,376 (13.7%)	
2	23,892 (2.4%)	16,014 (3.4%)	
≥3	11,009 (1.1%)	8,786 (1.9%)	
Year of diagnosis			<0.001
2004-2007	69,043 (7.0%)	37,222 (7.9%)	
2008-2011	190,312 (19.3%)	97,913 (20.9%)	
2012-2015	246,413 (24.9%)	121,223 (25.8%)	
2016-2021	482,396 (48.8%)	212,721 (45.3%)	
Urban rural status			<0.001
Metro	815,378 (82.5%)	382,372 (81.5%)	
Urban	122,607 (12.4%)	61,548 (13.1%)	
Rural	18,320 (1.9%)	9,333 (2.0%)	
Unknown	31,859 (3.2%)	15,826 (3.4%)	
Geographic region			<0.001
Northeast	201,827 (20.4%)	77,076 (16.4%)	
South	330,778 (33.5%)	180,393 (38.5%)	
Midwest	234,452 (23.7%)	104,494 (22.3%)	
West	170,346 (17.2%)	75,561 (16.1%)	
Unknown	50,761 (5.1%)	31,555 (6.7%)	
Treatment facility size			<0.001
100-499 cases/year	69,390 (7.0%)	33,103 (7.1%)	
≥500 cases/year	393,396 (39.8%)	184,061 (39.2%)	

Academic program ³	272,462 (27.6%)	124,402 (26.5%)	
Others	252,916 (25.6%)	127,513 (27.2%)	
Primary payer			<0.001
Private/Managed	553,324 (56.0%)	222,836 (47.5%)	
Medicaid	66,818 (6.8%)	29,124 (6.2%)	
Medicare	328,869 (33.3%)	198,781 (42.4%)	
Other/Unknown	39,153 (4.0%)	18,338 (3.9%)	
Income ⁴			<0.001
Low Income (<\$46K)	116,675 (11.8%)	62,811 (13.4%)	
Lower-Mid (\$46K-\$57K)	169,441 (17.1%)	85,231 (18.2%)	
Upper-Mid (\$57K-\$74K)	203,720 (20.6%)	97,987 (20.9%)	
High Income (\$74K+)	362,651 (36.7%)	161,955 (34.5%)	
Unknown	135,677 (13.7%)	61,095 (13.0%)	
Crowfly distance (miles) ⁵			<0.001
≤5	250,654 (25.4%)	114,862 (24.5%)	
5–10	211,606 (21.4%)	95,945 (20.5%)	
11–25	249,915 (25.3%)	117,086 (25.0%)	
26–50	91,873 (9.3%)	49,288 (10.5%)	
>50	58,210 (5.9%)	35,602 (7.6%)	
Unknown	125,906 (12.7%)	56,296 (12.0%)	
Chemotherapy use			<0.001
No/unknown	528,185 (53.5%)	301,805 (64.3%)	
Yes	459,979 (46.5%)	167,274 (35.7%)	
Hormone therapy use			<0.001
No/unknown	231,919 (23.5%)	175,309 (37.4%)	
Yes	756,245 (76.5%)	293,770 (62.6%)	
Immunotherapy use			<0.001
No/unknown	901,291 (91.2%)	433,439 (92.4%)	
Yes	86,873 (8.8%)	35,640 (7.6%)	

Abbreviations: NH, Non-Hispanic.

¹Median (Q1, Q3); n (%).

²Kruskal-Wallis rank sum test; Pearson's Chi-squared test.

³Academic/research programs treating ≥500 cases/year.

⁴Median household income for each patient's area of residence, estimated using 2020 American Community Survey data and adjusted for 2020 inflation.

⁵The great circle distance between the patient's residence and the case-reporting hospital.

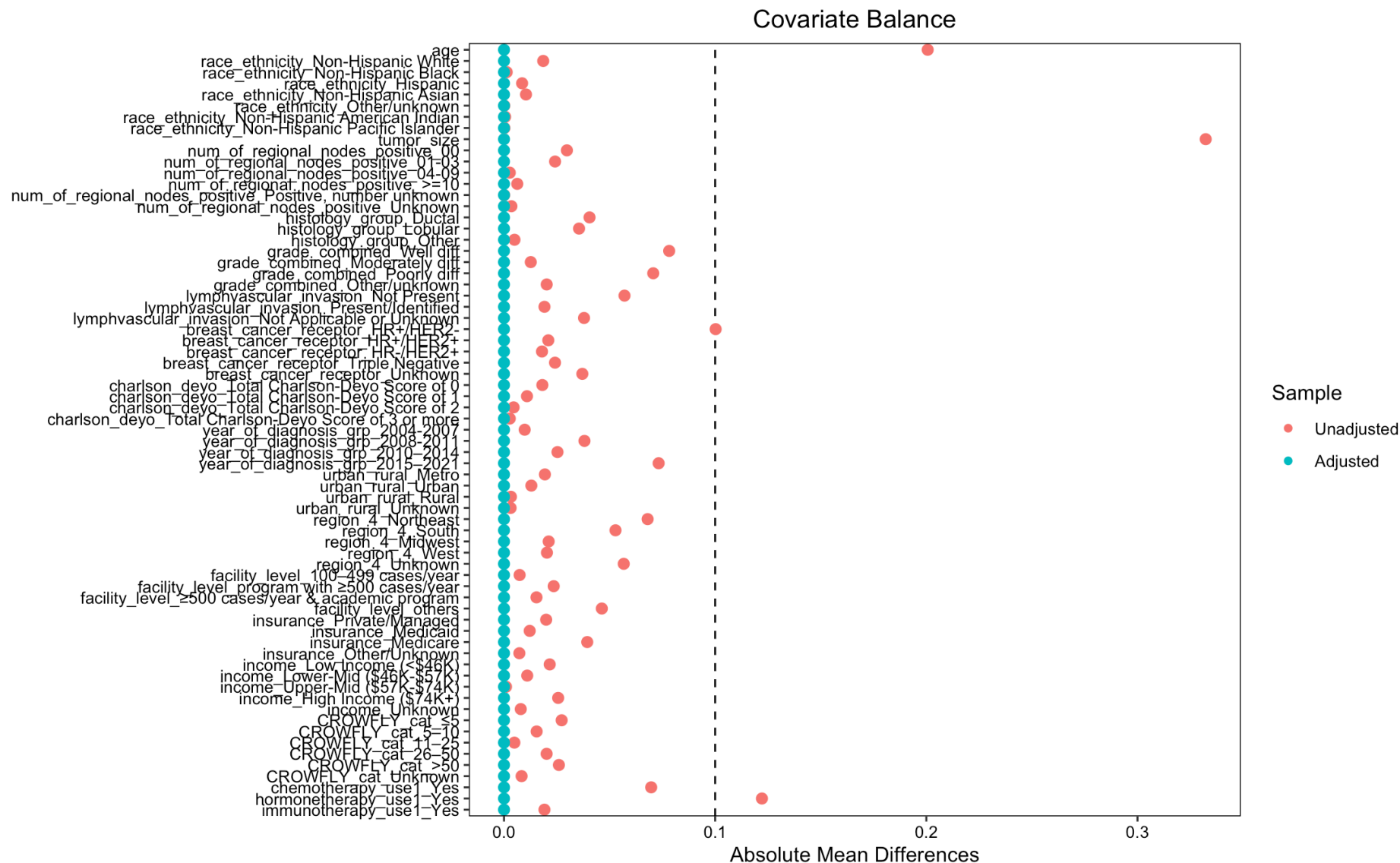
Table S2. Sensitivity analysis of overall survival treating radiotherapy receipt as a time-varying exposure.

Cohort	Time-varying Exposure	Adjusted HR (95% CI)
BCS patients	RT vs. no/not-yet RT	0.67 (0.66–0.68)
Mx patients indicated for PMRT	PMRT vs. no/not-yet PMRT	0.97 (0.95–0.98)

*Hazard ratios estimated using time-varying Cox proportional hazards models; adjusted for age, race/ethnicity, tumor size, number of positive lymph nodes, histology, tumor grade, lymphovascular invasion, breast cancer receptor, Charlson-Deyo score, year of diagnosis group, urban/rural status, region, facility level, insurance, income, distance from home to treatment facility, chemotherapy use, hormone therapy use, and immunotherapy use.

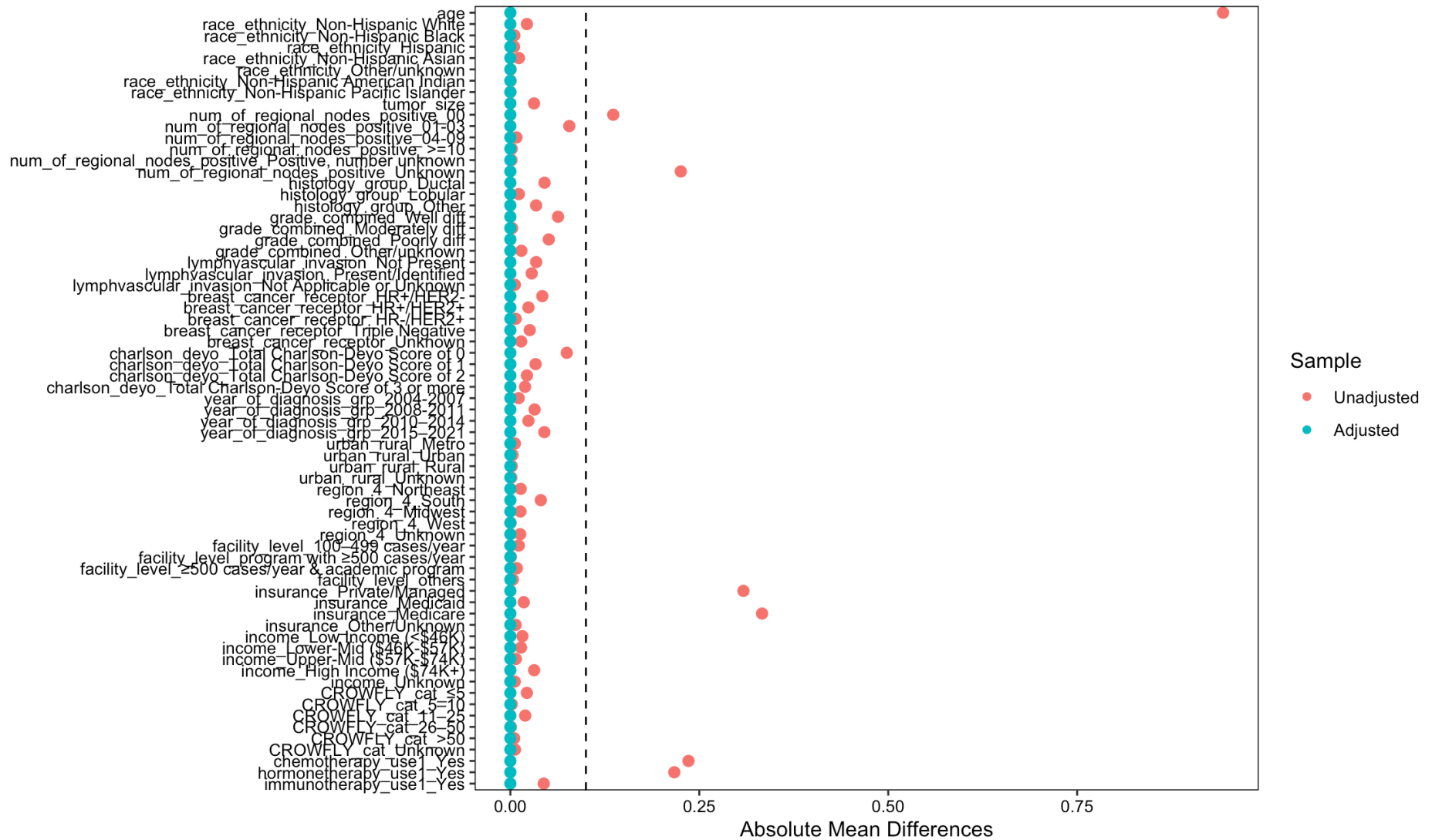
Figure S1. Covariate balance across treatment groups, measured by standardized mean differences before and after overlap weighting, for prespecified survival comparisons: (A) BCS+RT and Mx-RT, (B) RT and no RT among BCS patients, and (C) RT and no RT among PMRT-indicated mastectomy patients. *The standardized mean difference (SMD) is a measure of covariate imbalance between treatment groups; larger SMDs indicate greater differences in the covariate across treatment groups (worse balance). A SMD < 0.10 is commonly considered acceptable balance (the threshold is marked by the horizontal dashed line). Red points are SMDs before overlap weighting and blue points after.*

A



B

Covariate Balance

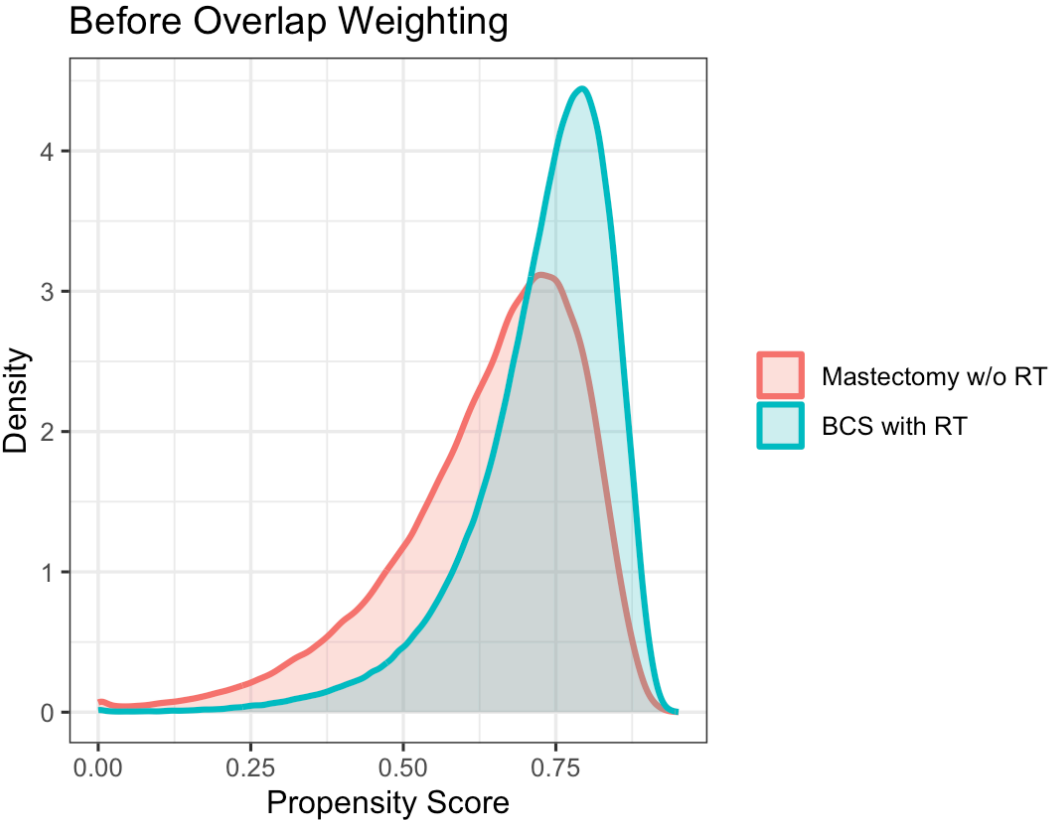


C

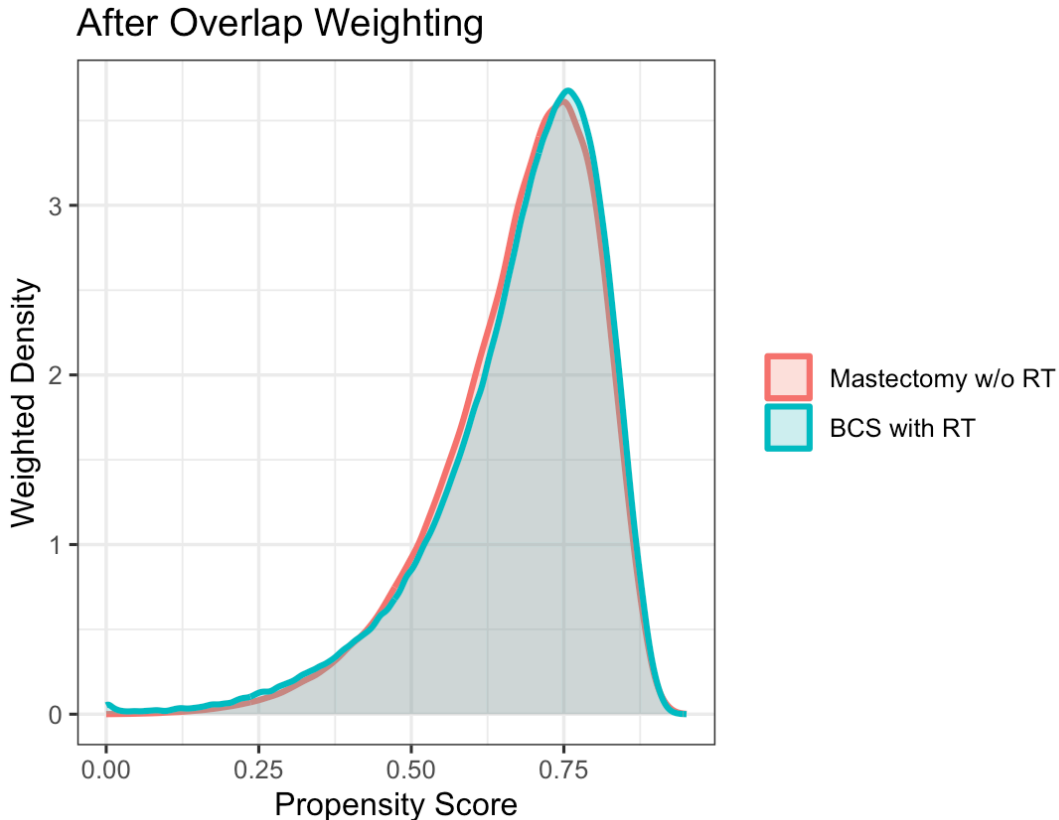


Figure S2. Distribution of estimated propensity scores before and after overlap weighting for prespecified survival comparisons: (A–B) BCS+RT versus Mx–RT, (C–D) RT and no RT among BCS patients, and (E–F) RT and no RT among PMRT-indicated mastectomy patients. *For each comparison, the left panel shows the propensity score distribution before overlap-weighting and the right panel shows the distribution after.*

A

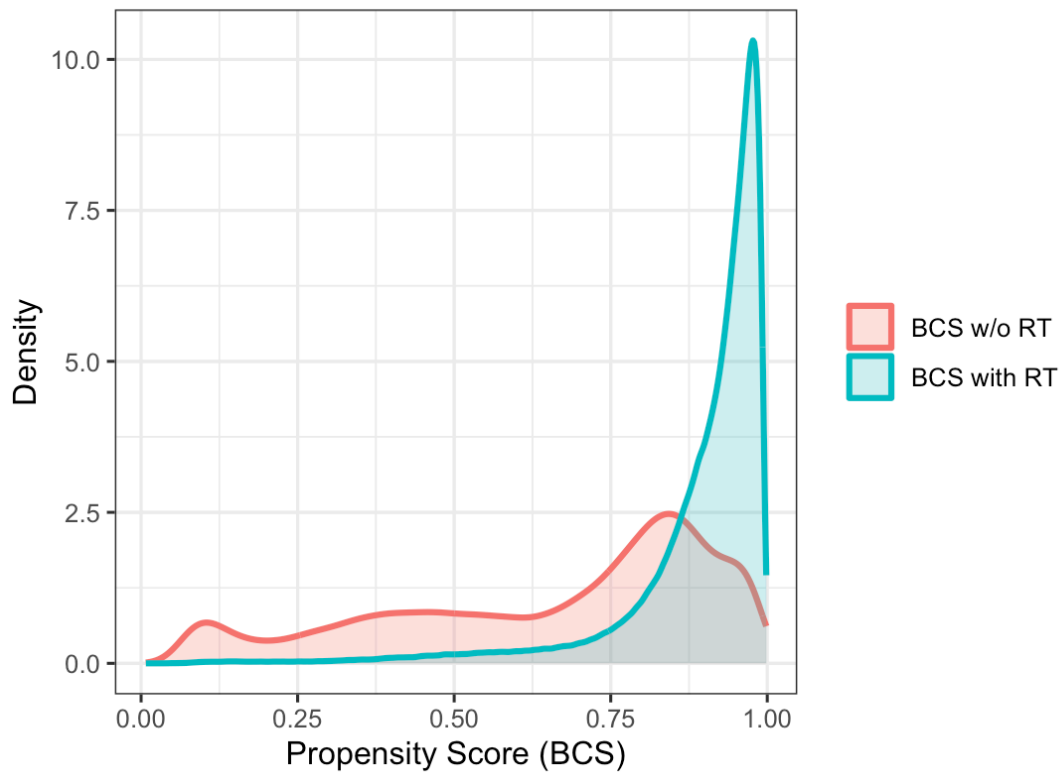


B



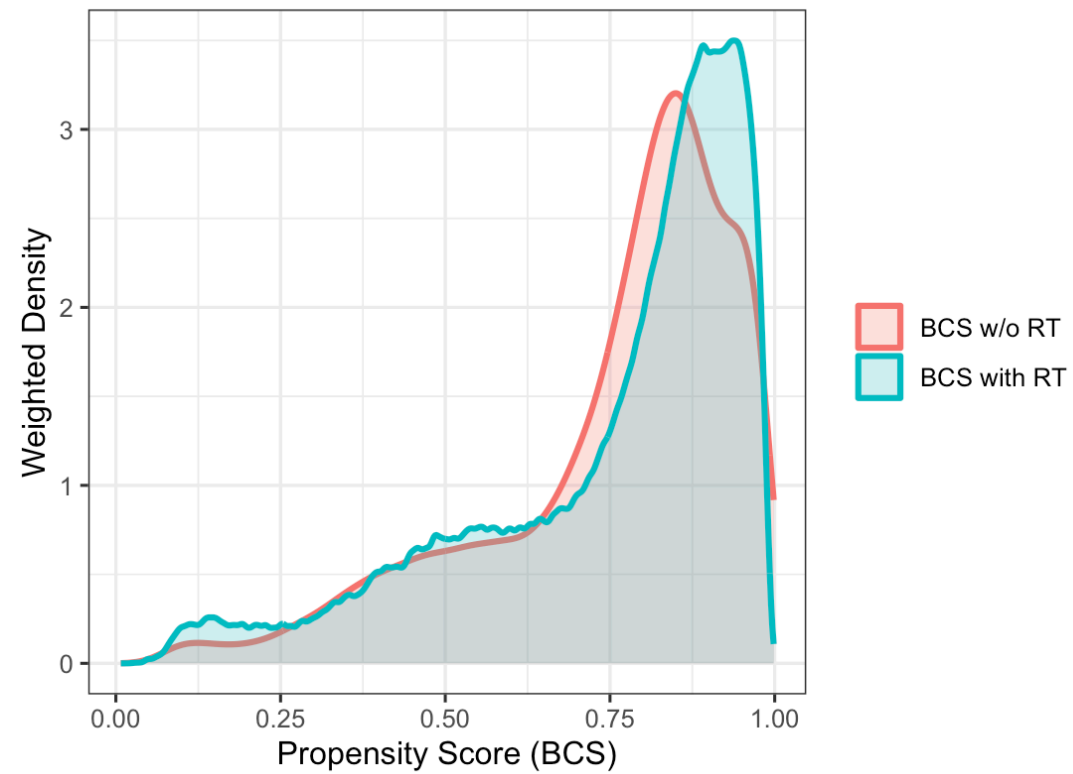
C

Before Overlap Weighting

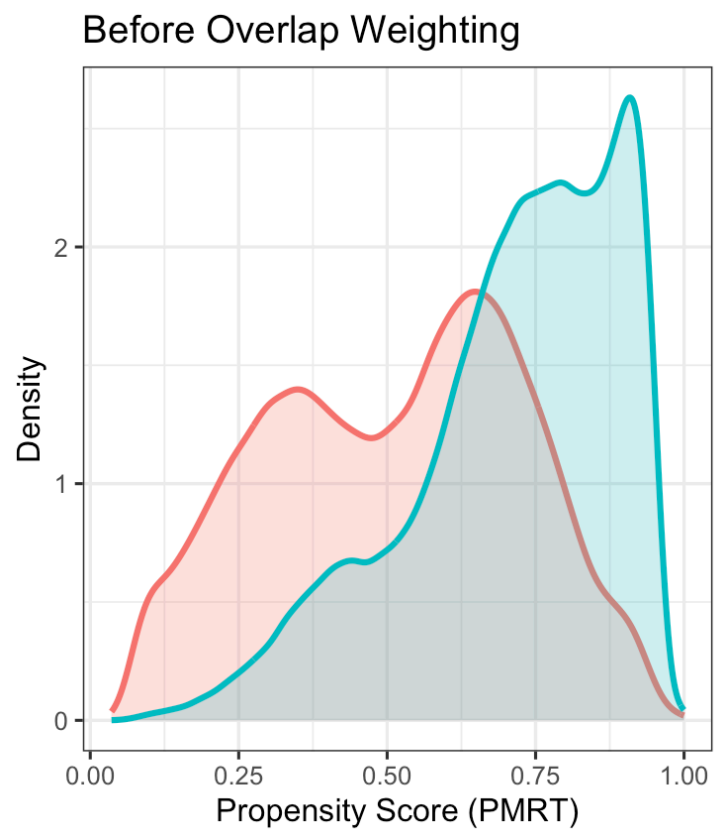


D

After Overlap Weighting



E



F

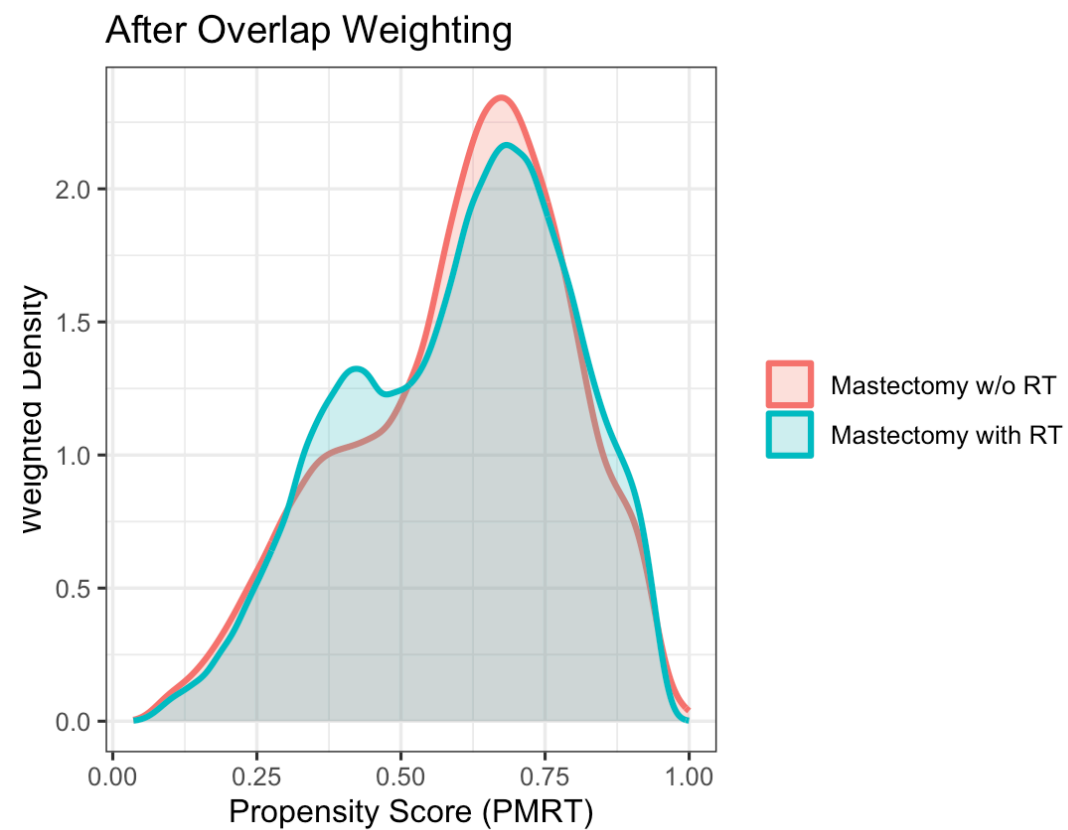


Figure S3. Unweighted Kaplan-Meier curves comparing overall survival between patients receiving BCS+RT and Mx-RT. *Numbers at risk* represent unweighted patient counts.

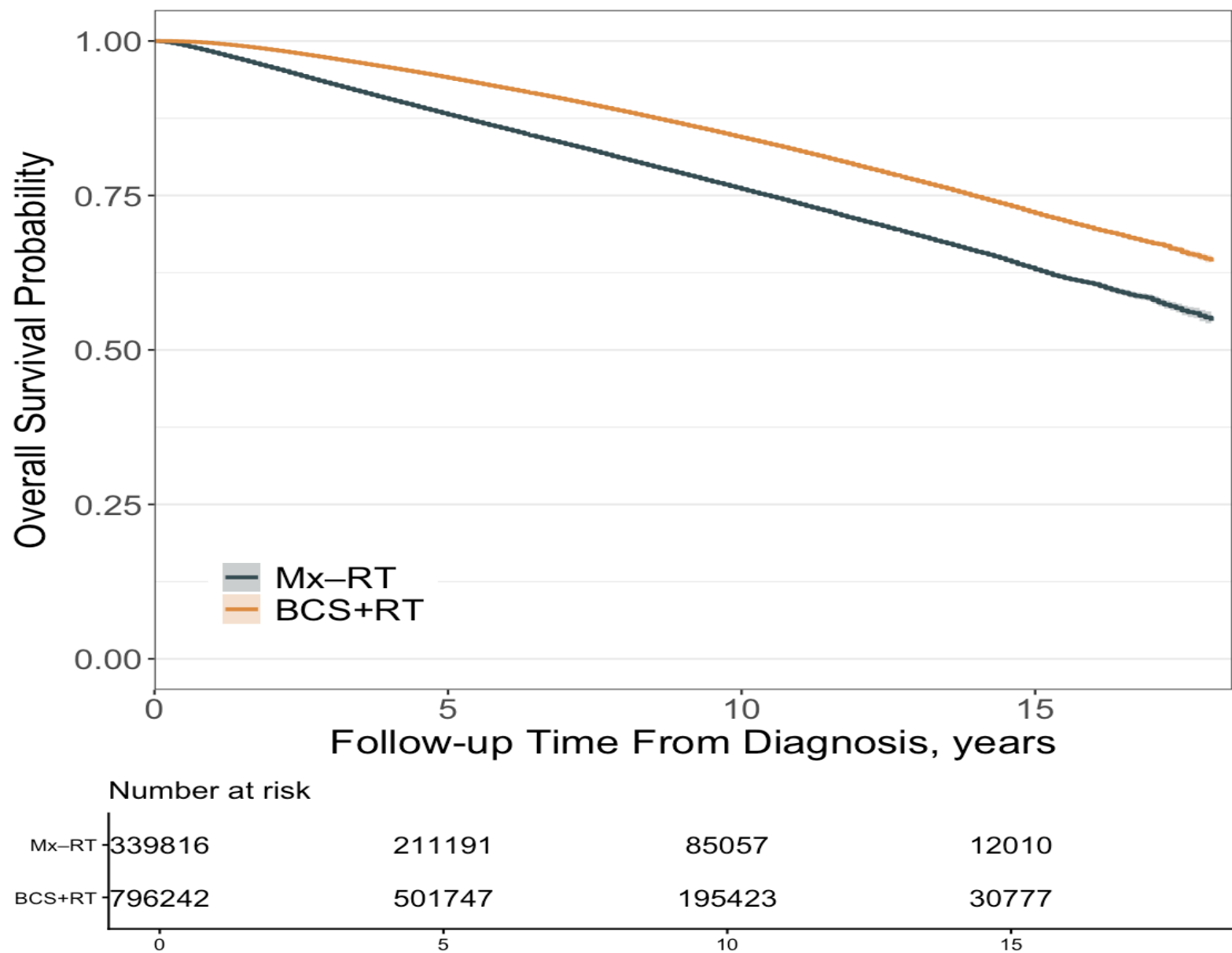


Figure S4. Unweighted Kaplan-Meier curves comparing overall survival and adjuvant RT among patients who received BCS. *Numbers at risk* represent unweighted patient counts.

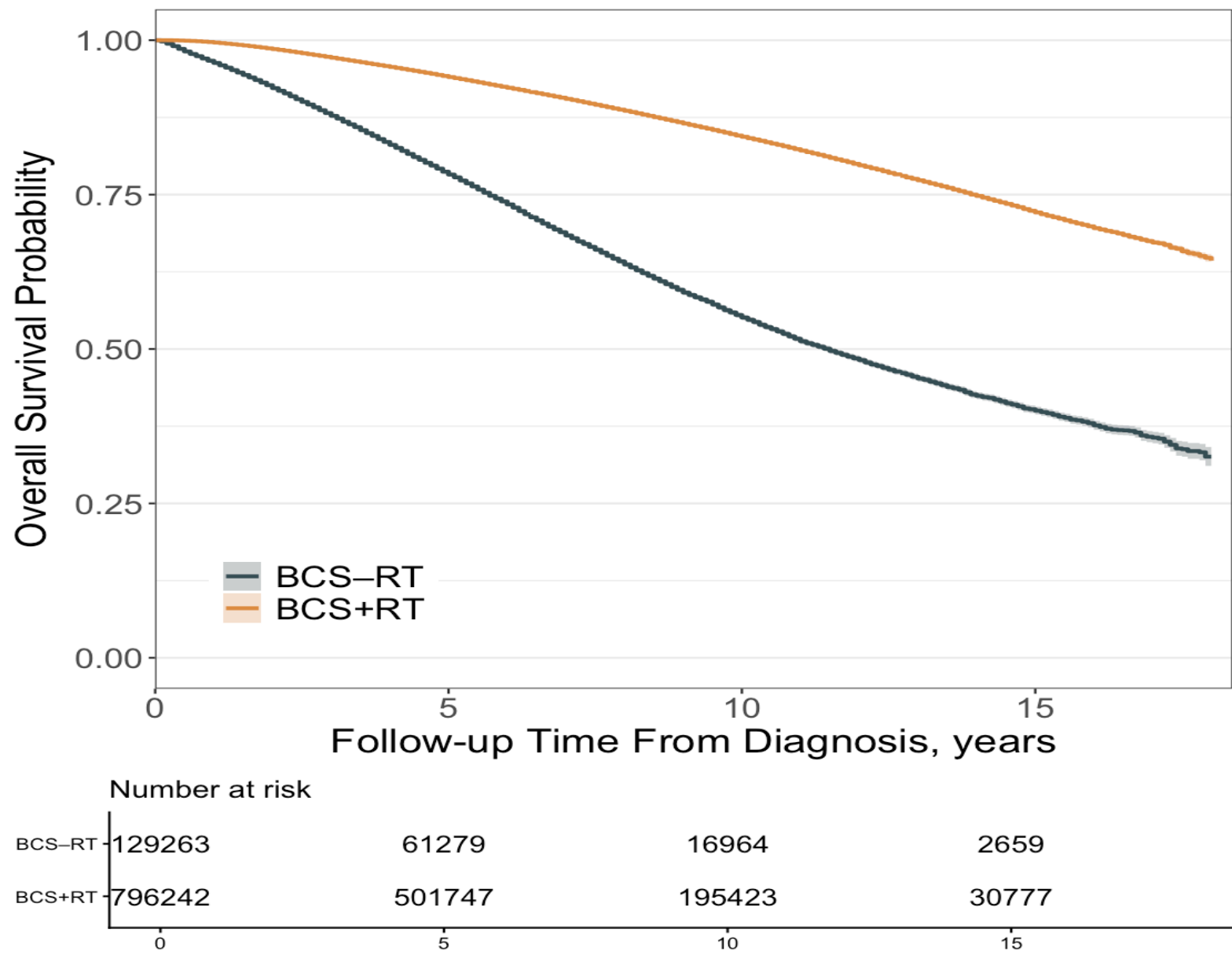


Figure S5. Unweighted Kaplan-Meier curves comparing overall survival and adjuvant RT among PMRT-indicated mastectomy patients. *Numbers at risk represent unweighted patient counts.*

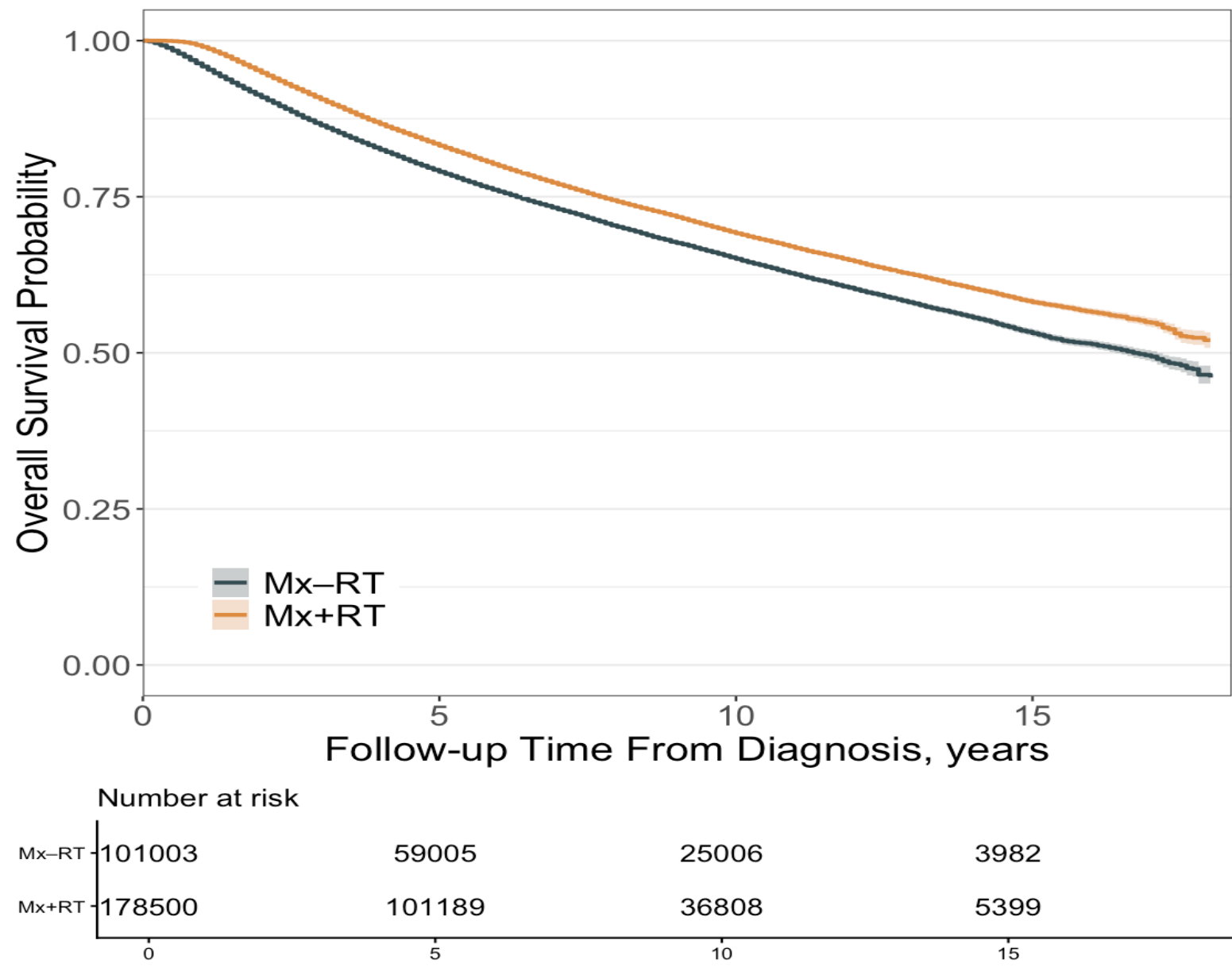


Figure S6. Covariate-adjusted marginal probabilities of radiotherapy receipt by age group. *Marginal probabilities were estimated using multivariable logistic regressions for the BCS and PMRT-indicated cohorts, standardized over each cohort's empirical cohort distribution. Models adjusted for race/ethnicity, tumor size, number of positive lymph nodes, histology, tumor grade, lymphovascular invasion, breast cancer receptor, Charlson-Deyo score, year of diagnosis group, urban/rural status, region, facility level, insurance, income, distance from home to treatment facility, chemotherapy use, hormone therapy use, and immunotherapy use. Error bars indicate 95% CI.*

