Table 5: Ablation study results on Flickr(homo) dataset. Ours_w/o_CRL is our method without the causal representation module. Ours_w/o_ELBO&SM is our method setting the coefficient of $\mathcal{L}_{ELBO} + \mathcal{L}_{SM}$ to zero. Ours_w/o_IPM is our method setting the coefficient of $\mathcal{L}_{IPW}$ to zero. Ours (incorrect dim U) is our method setting all dimensions of U^i, U^c, U^n as 16 (ground truth is 3,4,3 respectively).

| | $\varepsilon_{average}$ | | | | | | $\varepsilon_{individual}$ | | | | | |
| | Within Sample | | | Out-of Sample | | | Within Sample | | | Out-of Sample | | |
Methods	AME	ASE	ATE	AME	ASE	ATE	IME	ISE	ITE	IME	ISE	ITE
Ours_w/o_CRL	$0.1937_{\pm 0.1692}$	$0.4576_{\pm 0.0485}$	$0.5531_{\pm 0.0711}$	$0.2083_{\pm 0.2122}$	$0.4577_{\pm 0.0498}$	$0.5198_{\pm 0.0908}$	$0.2135_{\pm 0.1999}$	$0.4632_{\pm 0.0535}$	$0.5721_{\pm 0.0585}$	$0.4279_{\pm 0.3143}$	$0.4910_{\pm 0.0929}$	$0.6700_{\pm 0.1424}$
Ours_w/o_ELBO&SM	$0.0316_{\pm 0.0172}$	$0.0191_{\pm 0.0126}$	$0.0257_{\pm 0.0190}$	$0.0316_{\pm 0.0172}$	$0.0191_{\pm 0.0126}$	$0.0258_{\pm 0.0189}$	$0.0316_{\pm 0.0172}$	$0.0191_{\pm 0.0126}$	$0.0257_{\pm 0.0190}$	$0.0316_{\pm 0.0172}$	$0.0191_{\pm 0.0126}$	$0.0258_{\pm 0.0189}$
Ours_w/o_IPM	$0.0359_{\pm 0.0262}$	$0.0133_{\pm 0.0050}$	$0.0598_{\pm 0.0366}$	$0.0394_{\pm 0.0262}$	$0.0123_{\pm 0.0060}$	$0.0602_{\pm 0.0355}$	$0.0410_{\pm 0.0228}$	$0.0155_{\pm 0.0033}$	$0.0643_{\pm 0.0337}$	$0.0424_{\pm 0.0242}$	$0.0142_{\pm 0.0044}$	$0.0632_{\pm 0.0334}$
Ours	$0.0238_{\pm 0.0096}$	$0.0092_{\pm 0.0080}$	$0.0312_{\pm 0.0191}$	$0.0235_{\pm 0.0096}$	$0.0091_{\pm 0.0081}$	$0.0314_{\pm 0.0190}$	$0.0241_{\pm 0.0094}$	$0.0094_{\pm 0.0080}$	$0.0315_{\pm 0.0193}$	$0.0249_{\pm 0.0100}$	$0.0108_{\pm 0.0070}$	$0.0329_{\pm 0.0195}$
Ours (incorrect dim U)	$0.0247_{\pm 0.0164}$	$0.0293_{\pm 0.0153}$	$0.0317_{\pm 0.0221}$	$0.0254_{\pm 0.0179}$	$0.0284_{\pm 0.0153}$	$0.0312_{\pm 0.0219}$	$0.0253_{\pm 0.0161}$	$0.0295_{\pm 0.0153}$	$0.0319_{\pm 0.0220}$	$0.0256_{\pm 0.0178}$	$0.0284_{\pm 0.0153}$	$0.0313_{\pm 0.0218}$

Table 6: High dimensional experiments on Flickr(homo) dataset.

| | $\varepsilon_{average}$ | | | | | | $\varepsilon_{individual}$ | | | | | |
| | Within Sample | | | Out-of Sample | | | Within Sample | | | Out-of Sample | | |
covariate dimensions	AME	ASE	ATE	AME	ASE	ATE	IME	ISE	ITE	IME	ISE	ITE
15	$0.0238_{\pm 0.0096}$	$0.0092_{\pm 0.0080}$	$0.0312_{\pm 0.0191}$	$0.0235_{\pm 0.0096}$	$0.0091_{\pm 0.0081}$	$0.0314_{\pm 0.0190}$	$0.0241_{\pm 0.0094}$	$0.0094_{\pm 0.0080}$	$0.0315_{\pm 0.0193}$	$0.0249_{\pm 0.0100}$	$0.0108_{\pm 0.0070}$	$0.0329_{\pm 0.0195}$
30	$0.0339_{\pm 0.0267}$	$0.0191_{\pm 0.0139}$	$0.0261_{\pm 0.0228}$	$0.0343_{\pm 0.0264}$	$0.0191_{\pm 0.0140}$	$0.0256_{\pm 0.0230}$	$0.0341_{\pm 0.0266}$	$0.0191_{\pm 0.0139}$	$0.0262_{\pm 0.0228}$	$0.0343_{\pm 0.0263}$	$0.0191_{\pm 0.0126}$	$0.0256_{\pm 0.0230}$
100	$0.0403_{\pm 0.0442}$	$0.0228_{\pm 0.0238}$	$0.0320_{\pm 0.0360}$	$0.0403_{\pm 0.0442}$	$0.0228_{\pm 0.0237}$	$0.0320_{\pm 0.0361}$	$0.0403_{\pm 0.0442}$	$0.0228_{\pm 0.0237}$	$0.0320_{\pm 0.0360}$	$0.0403_{\pm 0.0442}$	$0.0228_{\pm 0.0237}$	$0.0320_{\pm 0.0361}$
500	$0.0285_{\pm 0.0081}$	$0.0255_{\pm 0.0230}$	$0.0324_{\pm 0.0250}$	$0.0284_{\pm 0.0081}$	$0.0256_{\pm 0.0229}$	$0.0324_{\pm 0.0250}$	$0.0285_{\pm 0.0082}$	$0.0256_{\pm 0.0230}$	$0.0324_{\pm 0.0250}$	$0.0284_{\pm 0.0081}$	$0.0256_{\pm 0.0229}$	$0.0324_{\pm 0.0249}$
1000	$0.0289_{\pm 0.0228}$	$0.0260_{\pm 0.0214}$	$0.0241_{\pm 0.0158}$	$0.0289_{\pm 0.0227}$	$0.0259_{\pm 0.0214}$	$0.0239_{\pm 0.0157}$	$0.0289_{\pm 0.0227}$	$0.0260_{\pm 0.0214}$	$0.0241_{\pm 0.0158}$	$0.0289_{\pm 0.0226}$	$0.0259_{\pm 0.0214}$	$0.0240_{\pm 0.0157}$

Table 7: Experiments with different dimension ratio of $U^i : U^c : U^n$.

| | $\varepsilon_{average}$ | | | | | | $\varepsilon_{individual}$ | | | | | |
| | Within Sample | | | Out-of Sample | | | Within Sample | | | Out-of Sample | | |
dimensions of $U^i : U^c : U^n$	AME	ASE	ATE	AME	ASE	ATE	IME	ISE	ITE	IME	ISE	ITE
3:4:3	$0.0238_{\pm 0.0096}$	$0.0092_{\pm 0.0080}$	$0.0312_{\pm 0.0191}$	$0.0235_{\pm 0.0096}$	$0.0091_{\pm 0.0081}$	$0.0314_{\pm 0.0190}$	$0.0241_{\pm 0.0094}$	$0.0094_{\pm 0.0080}$	$0.0315_{\pm 0.0193}$	$0.0249_{\pm 0.0100}$	$0.0108_{\pm 0.0070}$	$0.0329_{\pm 0.0195}$
2:6:2	$0.0529_{\pm 0.0326}$	$0.0465_{\pm 0.0380}$	$0.0992_{\pm 0.0987}$	$0.0377_{\pm 0.0161}$	$0.0360_{\pm 0.0237}$	$0.0735_{\pm 0.0603}$	$0.0794_{\pm 0.0694}$	$0.0591_{\pm 0.0532}$	$0.1267_{\pm 0.1361}$	$0.0583_{\pm 0.0419}$	$0.0452_{\pm 0.0350}$	$0.0946_{\pm 0.0910}$
1:8:1	$0.0504_{\pm 0.0246}$	$0.0239_{\pm 0.0179}$	$0.0633_{\pm 0.0425}$	$0.0554_{\pm 0.0174}$	$0.0211_{\pm 0.0151}$	$0.0616_{\pm 0.0379}$	$0.0708_{\pm 0.0239}$	$0.0298_{\pm 0.0193}$	$0.0710_{\pm 0.0374}$	$0.0639_{\pm 0.0188}$	$0.0244_{\pm 0.0157}$	$0.0643_{\pm 0.0357}$
0:10:0	$0.0513_{\pm 0.0276}$	$0.0404_{\pm 0.0268}$	$0.0782_{\pm 0.0600}$	$0.0477_{\pm 0.0248}$	$0.0325_{\pm 0.0121}$	$0.0689_{\pm 0.0460}$	$0.0566_{\pm 0.0333}$	$0.0489_{\pm 0.0432}$	$0.0857_{\pm 0.0729}$	$0.0493_{\pm 0.0259}$	$0.0404_{\pm 0.0260}$	$0.0740_{\pm 0.0528}$

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