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Portfolio Analysis Using Machine Learning and Merton Models

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In this analysis, we calculate cumulative total returns for our Machine Learning Model (**MLM**) and Merton Model (**MM**) independently, based on out of sample testing against benchmark portfolios that did not include these model filters.

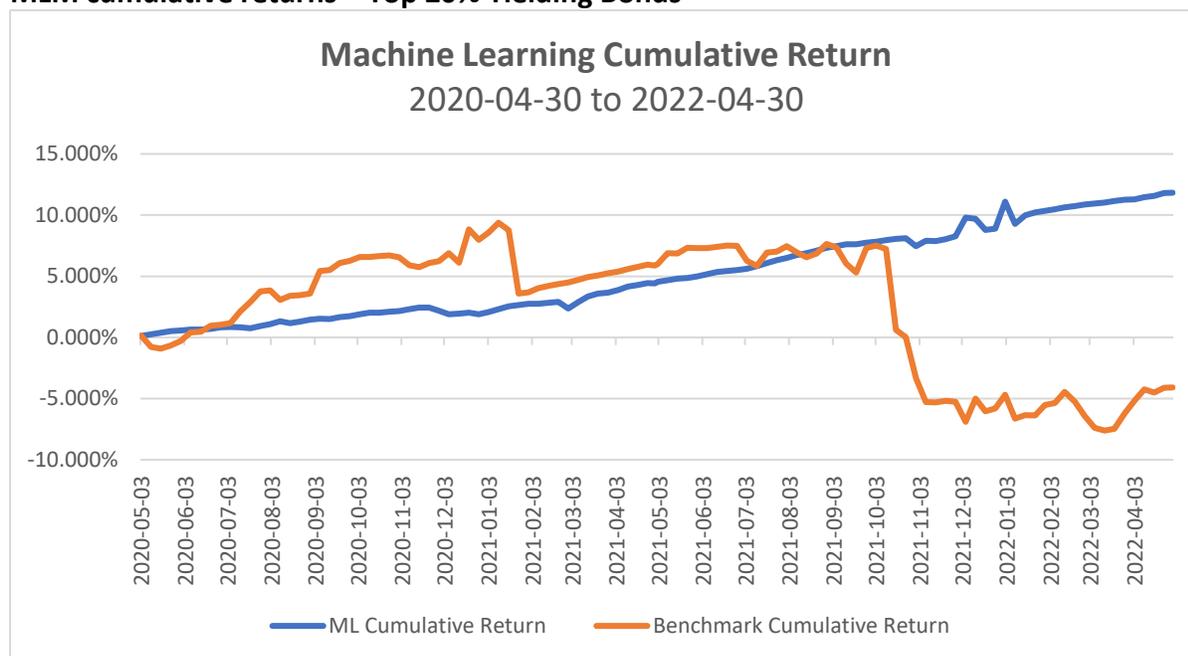
Machine Learning Model

The MLM portfolio is constructed as a buy and hold strategy for a 1-year period with two separate portfolios commencing on 4/30/20 and 4/30/21. We picked these start dates because mainland Chinese issuers are required to file their audited annual reports by those dates. The MLM is primarily derived from financial scores and makes a one-year prediction, based on actual release date of annual report for non-financial corporates.

Based on MLM scores, we removed the 3 riskiest buckets out of ten buckets in the overall market; the seven remaining buckets comprised our MLM portfolio (with 100% yield bracket) . No MLM filter was applied to the Benchmark portfolio. Liquidity is limited in the Chinese corporate bond market since most investors typically purchase the bonds at issuance and hold until maturity. Accordingly, the “# of target bonds” only includes bonds that traded in the 3 months prior to April 30. The “# bonds actually traded” only includes those target bonds that traded in the subsequent year. Total return is based on the portfolio of “# bonds traded”. We also divided the target bond portfolio into yield brackets to create high yield indices. The charts below are based on weekly data points. Further details on methodologies are explained at the end of this article.



MLM cumulative returns – Top 20% Yielding Bonds



Total Return Tables for other yield buckets for both MLM vs. Benchmark MLM: 2020/4/30 to 2022/4/30.

start_date	end_date	Yield in (top)	avg_yield	avg_maturity	# of target bonds	# bonds Actually Traded	Total return
2020-04-30	2021-04-30	100%	4.60%	2.30	63	53	2.23%
2020-04-30	2021-04-30	50%	5.59%	1.62	32	27	3.10%
2020-04-30	2021-04-30	40%	5.88%	1.67	25	21	3.31%
2020-04-30	2021-04-30	30%	6.23%	1.68	19	15	3.86%
2020-04-30	2021-04-30	25%	6.47%	1.60	16	13	4.21%
2020-04-30	2021-04-30	20%	6.76%	1.60	13	10	4.42%
start_date	end_date	Yield in (top)	avg_yield	avg_maturity	# of target bonds	# bonds Actually Traded	Total return
2021-04-30	2022-4-30	100%	4.11%	2.55	65	41	2.94%
2021-04-30	2022-4-30	50%	4.95%	2.79	33	23	2.41%
2021-04-30	2022-4-30	40%	5.20%	2.64	26	18	1.95%
2021-04-30	2022-4-30	30%	5.46%	2.64	20	14	5.95%
2021-04-30	2022-4-30	25%	5.61%	2.14	17	11	6.04%
2021-04-30	2022-4-30	20%	5.86%	1.84	13	8	7.09%



MLM 2-year summary:

start_date	end_date	Yield in (top)	avg_yield	avg_maturity	Total return
2020-04-30	2022-4-30	100%	4.36%	2.43	5.24%
2020-04-30	2022-4-30	50%	5.27%	2.21	5.59%
2020-04-30	2022-4-30	40%	5.54%	2.15	5.32%
2020-04-30	2022-4-30	30%	5.85%	2.16	10.04%
2020-04-30	2022-4-30	25%	6.04%	1.87	10.50%
2020-04-30	2022-4-30	20%	6.31%	1.72	11.83%

1. Benchmark: 2020/4/30 to 2022/4/30

start_date	end_date	Yield in (top)	avg_yield	avg_maturity	# of target bonds	# bonds Actually Traded	Total return
2020-04-30	2021-04-30	100%	5.35%	2.25	196	156	1.73%
2020-04-30	2021-04-30	50%	7.04%	1.92	98	70	2.66%
2020-04-30	2021-04-30	40%	7.57%	1.90	79	54	2.80%
2020-04-30	2021-04-30	30%	8.33%	1.87	59	36	2.87%
2020-04-30	2021-04-30	25%	8.83%	1.77	49	28	5.33%
2020-04-30	2021-04-30	20%	9.38%	1.82	40	21	5.87%
start_date	end_date	Yield in (top)	avg_yield	avg_maturity	# of target bonds	# bonds Actually Traded	Total return
2021-04-30	2022-4-30	100%	5.00%	2.40	192	112	0.10%
2021-04-30	2022-4-30	50%	6.74%	2.62	96	62	-2.81%
2021-04-30	2022-4-30	40%	7.42%	2.52	77	53	-4.01%
2021-04-30	2022-4-30	30%	8.38%	2.45	58	39	-5.47%
2021-04-30	2022-4-30	25%	9.07%	2.47	48	37	-6.10%
2021-04-30	2022-4-30	20%	9.90%	2.65	39	29	-9.41%

Benchmark 2-year summary:

start_date	end_date	Yield in (top)	avg_yield	avg_maturity	Total return
2020-04-30	2022-4-30	100%	5.17%	2.32	1.84%
2020-04-30	2022-4-30	50%	6.89%	2.27	-0.23%
2020-04-30	2022-4-30	40%	7.50%	2.21	-1.32%
2020-04-30	2022-4-30	30%	8.35%	2.16	-2.76%
2020-04-30	2022-4-30	25%	8.95%	2.12	-1.09%
2020-04-30	2022-4-30	20%	9.64%	2.23	-4.09%



MLM Table Explanation:

For the period 4/30/20 to 4/30/21, there were 196 bonds in the benchmark (target bonds that had both MLM and MM scores) which also had transaction records in the 3-month interval prior to 4/30/20 (the starting point). However, only 156 bonds actually traded during the following year (the bonds that actually traded comprise our benchmark portfolio returns). We remove all bonds in 3 highest risk buckets from the overall market. There are 63 target bonds left (# traded in 3-months prior to 4/30/20). We then select the top 20% highest yielding bonds, which equals 13 target bonds, of which 10 traded in the following year.

In 2020, the Benchmark included 7 bonds with a high risk of default and whose price decreased by more than 10 points. Please note that the MLM screened out all these risky bonds (ml_pd rank ≥ 8).

<u>bond_code</u>	<u>start_price</u>	<u>end_price</u>	<u>ml_pdrank</u>	<u>price_change</u>	<u>coupon_rate</u>	<u>yield</u>	<u>Top_yield_percentile</u>
101780003. IB	100.5	25.2852	10	-75.2148	5.8	5.67%	23.08%
122071. SH	88.77	51	10	-37.77	6.2	6.76%	12.18%
112723. SZ	95.99	58.996	9	-36.994	4	4.15%	58.33%
143693. SH	100.24	79.99	10	-20.25	4.4	4.35%	55.13%
143551. SH	102.2	84.1	10	-18.1	6.8	6.62%	12.82%
122249. SH	101	87.07	8	-13.93	5.07	5.04%	34.62%
136244. SH	101.6	91	10	-10.6	7	6.81%	10.90%

In 2021, the Benchmark included 12 bonds with a high probability of default and whose price decreased by more than 10 points. The MLM filtered all these bonds out except # 101901406 (Shanghai Shimao Co.) since ml_pd rank was ≥ 8 for the rest

<u>bond_code</u>	<u>start_price</u>	<u>end_price</u>	<u>ml_pdrank</u>	<u>price_change</u>	<u>coupon_rate</u>	<u>yield</u>	<u>Top_yield_percentile</u>
101759017. IB	98.2374	16.6	8	-81.6374	7.4	7.40%	6.25%
102002022. IB	98.1922	17.6644	8	-80.5278	6.8	6.94%	12.50%
101759069. IB	96.0261	15.75	8	-80.2761	6.9	7.20%	8.93%
149103. SZ	99.5	23.116	8	-76.384	6.95	6.98%	11.61%
101901406. IB	99.3028	37	6	-62.3028	4.24	4.27%	45.54%
155061. SH	94	39.89	9	-54.11	6.58	7.00%	10.71%
155405. SH	95	49	9	-46	6.48	7.22%	8.04%
136360. SH	95.49	53	9	-42.49	6.7	7.40%	5.36%
101769001. IB	73.2	56.5	10	-16.7	5.7	8.18%	1.79%
101669034. IB	66.8	52.8	10	-14	4.23	6.06%	20.54%
143896. SH	99.5	85.55	9	-13.95	5.9	5.92%	23.21%
102001655. IB	100	87.45	9	-12.55	7.2	7.29%	7.14%

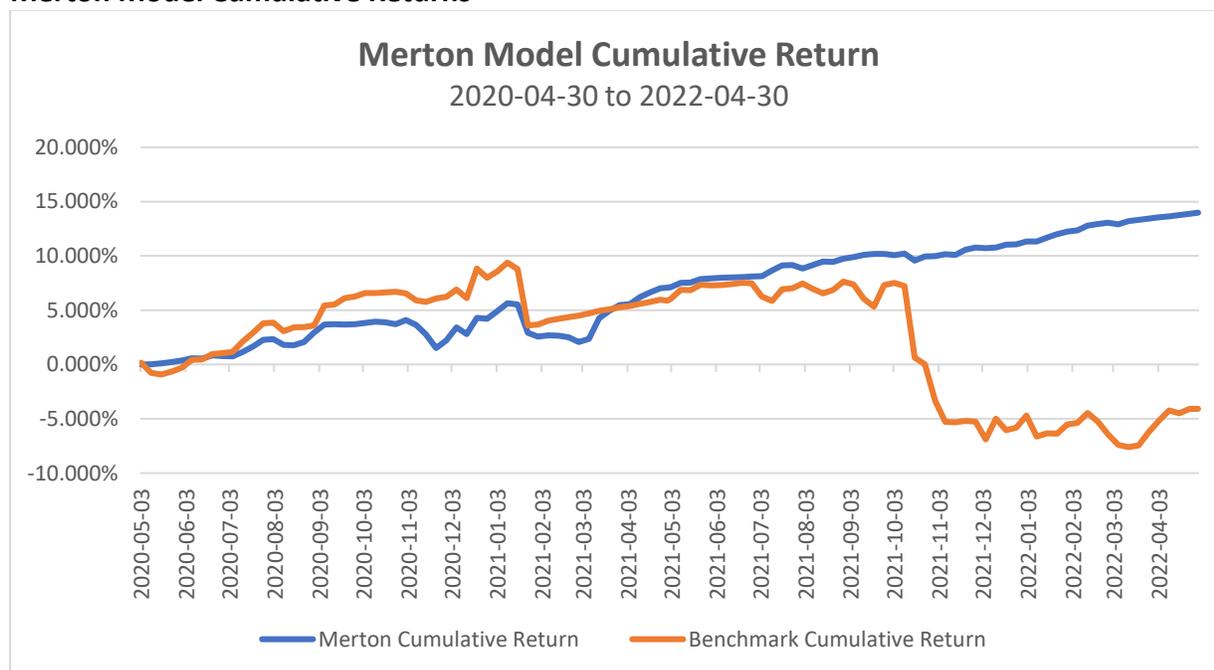


Merton Model (MM) Weekly Cumulative Returns.

From 2020-04-30 to 2022/4/30:

Since the MM is updated daily and can give more timely probability of default, we used a weekly update for our MM portfolio by removing all bonds in the 3 riskiest buckets out of 10 buckets total. Then we picked the top 20% yielding bonds from this filtered portfolio.

Merton Model Cumulative Returns





Details on Methodologies for construction of both MLM and MM

Machine Learning Model - Buy & Hold

- 1) We pre-trained Machine Learning Model (MLM) to all available issuers in the mainland bond market on 4/30/20 and 4/30/21 to construct the portfolio for the next one-year holding period.
- 2) We only included bonds that traded in the 3-months prior to 4/30 of both 2020 and 2021 to get "Benchmark or Target Portfolio". The "# of bonds actually traded" are those that traded in the following year.
- 3) Sort the yields in the benchmark.
- 4) Divide issuers into 10 buckets by sorting model implied probability of default.
- 5) MLM Portfolio construction: Starting with all bonds that had both MLM and MM scores, we remove all bonds issued in the top 3 'riskiest issuers' bucket; we then select the 20% highest yielding bonds from Benchmark (excluding any bonds previously filtered out) to be target portfolio. Buy bonds within the list based on actual trading records and prices. Assume RMB amount for all purchases to be (total funds /number of bonds that traded over the next year).
- 6) P&L = repricing income + coupon income with no transaction costs and no reinvestment
- 7) Reconstitute MLM portfolio after one-year with the same rules stated above



Merton Model with Weekly Updates

1) We applied daily updates of Merton Model probability of default to all publicly available issuers in the mainland bond market. Calculate weekly average implied probability of default based on either equity option volatility (limited data) or historical volatility, using a simplified Merton Model approach (future analysis will include complete Merton model analytics).

2) Similar to MLM, we only included bonds that traded in the 3-months prior to 4/30 of both 2020 and 2021 to get “Benchmark Portfolio”.

3) Sort the yields in the benchmark.

4) Portfolio construction: Starting with the bonds actually traded in benchmark, divide issuers into 10 buckets by sorting moving average Merton probability of default at the beginning of every week. Then get a ‘risky issuer’ list from the riskiest 3 buckets. Label bond as ‘sell’ when the issuer exists in the risky list. Labeled bond as ‘buy’ when the issuer does not exist in the risky list and when the bond has high yield in top 20%. No transaction costs included.

5) Algorithm: Starting with 100,000,000 RMB

Example:

6) Portfolio week 1:

We buy all qualified (i.e., not top 3 riskiest buckets) bonds when there was a historical price. Each trade uses the same amount of cash until we don't have any funds left. From 2020-04-30 to 4/6/22, cash for each bond is 3Mn RMB.

Portfolio week 2:

We keep all bonds from both target portfolio week 1 and target portfolio week 2 at the beginning of the week 2, subject to the following rules:

We buy bonds that:

- 1, are in the week 2 target portfolio if,
- 2, we are not holding these bonds.
- 3, we still have the cash to buy.
- 4, there are market opportunities to buy.

We sell bonds that:

- 1, are not in the week 2 target portfolio (i.e., in top 3 risky buckets).
- 2, we are holding these bonds.
- 3, there are market opportunities to sell.

Otherwise, we hold.



Portfolio week 3:

Repeat the operations of portfolio week 2.

- 7) All selling income goes into cash account to have funds for the next buy signal and trading opportunity. All coupon income was stored in the separate coupon account and was not reinvested into new bonds.
- 8) The portfolio value at beginning of a week equals to the value at the end of previous week.
- 9) We do not actively adjust weights of the components
- 10) No short positions
- 11) No transaction costs
- 12) No coupon reinvestment

Appendix

Bonds Examined by both MLM and MM.

1. We only examined onshore non-financial Chinese corporate bonds for MLM but both financial and non-financial corporates for MM. We excluded the following bond types: interbank deposits, separable tradable bonds, exchangeable bonds, convertible bonds, private placement notes, sovereign bonds, ABS, government supported institution bonds and private bonds.
2. Since we had a 1 year holding period for MLM, we only selected bonds with a Maturity > 1 year as of April 30.
3. We only choose bonds issued by publicly listed companies to calculate MM.



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