Drive of Nodes/ Hybrid Nodes

Drive (Formerly, NormIncan)

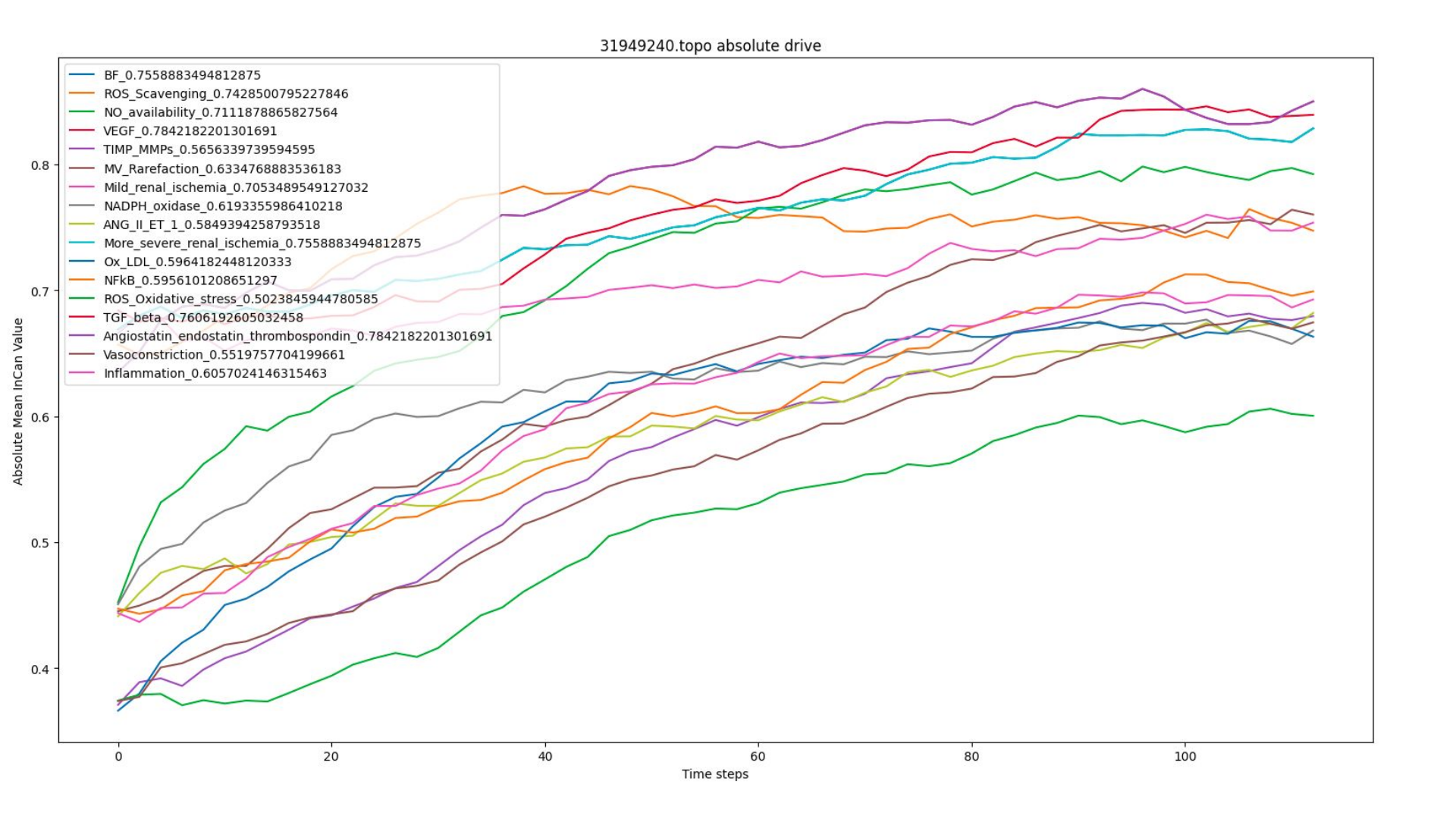
It quantifies how much “effective” regulation a node is under at a certain time step. It is defined as follows for J’th node. Here I_j is the indegree of the node and S_i is the state of I’th node at the time step considered.

$$\frac{|\sum_i adj[i][j] * S_i|}{I_j}$$

“Hybrid” nodes found in other networks with high team strength (> 0.2) from the given paper

A meta-analysis of Boolean network models reveals design principles of gene regulatory networks

Claus Kadelka[a,*], Taras-Michael Butrie[b,1], Evan Hilton[c,1], Jack Kinseth[a,1], Haris Serdarevic[a,1]


31949240.topo absolute drive
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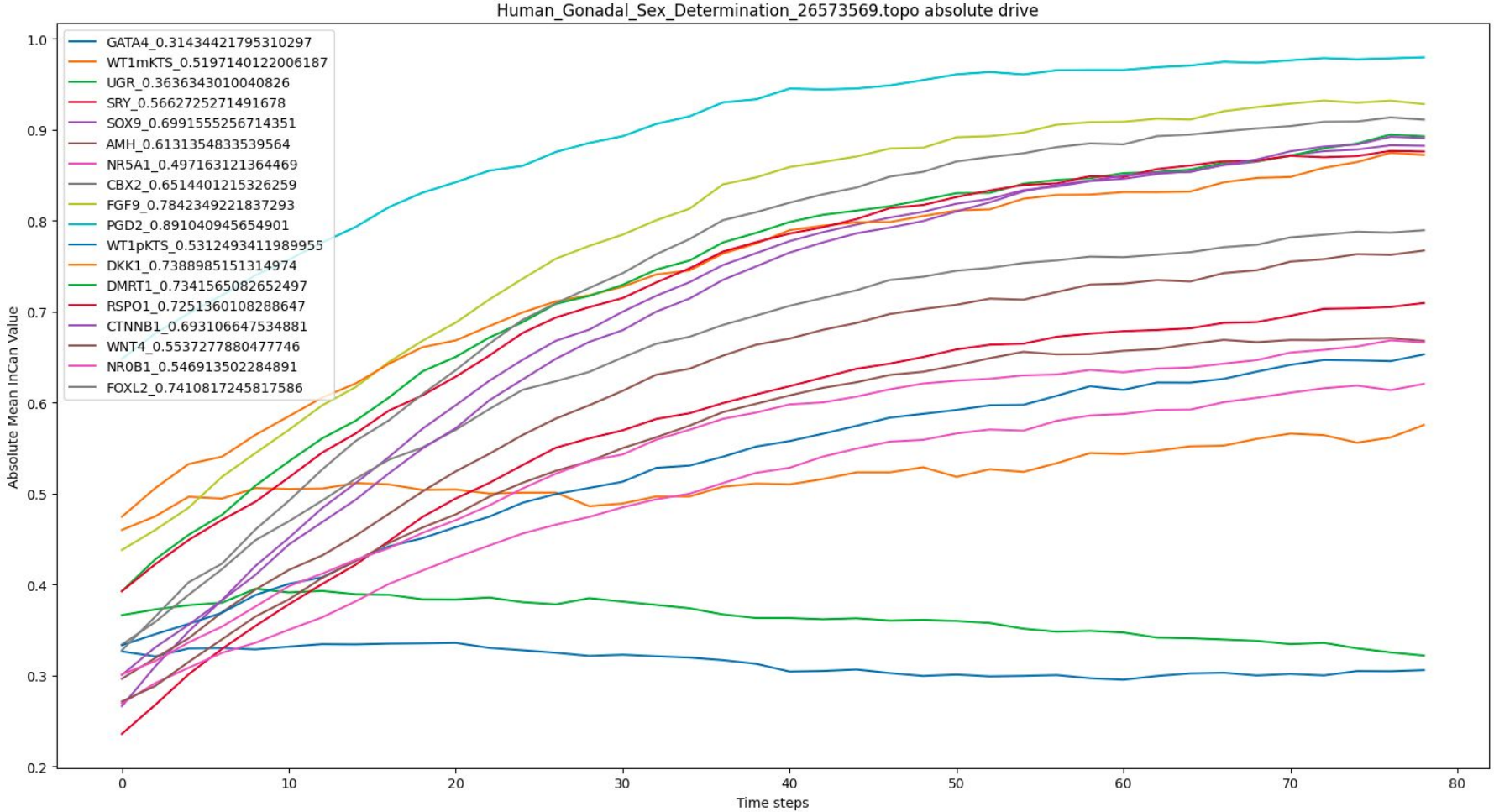
ROS_Scavenging_0.7428500795227846
NO_availability_0.7111878865827564
VEGF_0.7842182201301691
TIMP_MMPs_0.5656339739594595
MV_Rarefaction_0.6334768883536183
Mild_renal_ischemia_0.7053489549127032
NADPH_oxidase_0.6193355986410218
ANG_II_ET_1_0.5849394258793518
More_severe_renal_ischemia_0.7558883494812875
Ox_LDL_0.5964182448120333
NFkB_0.5956101208651297
ROS_Oxidative_stress_0.5023845944780585
TGF_beta_0.7606192605032458
Angiostatin_endostatin_thrombospondin_0.7842182201301691
Vasoconstriction_0.5519757704199661
Inflammation_0.6057024146315463
Absolute Mean InCan Value
0.4
0.5
0.6
0.7
0.8
0
20
40
60
80
100
Time steps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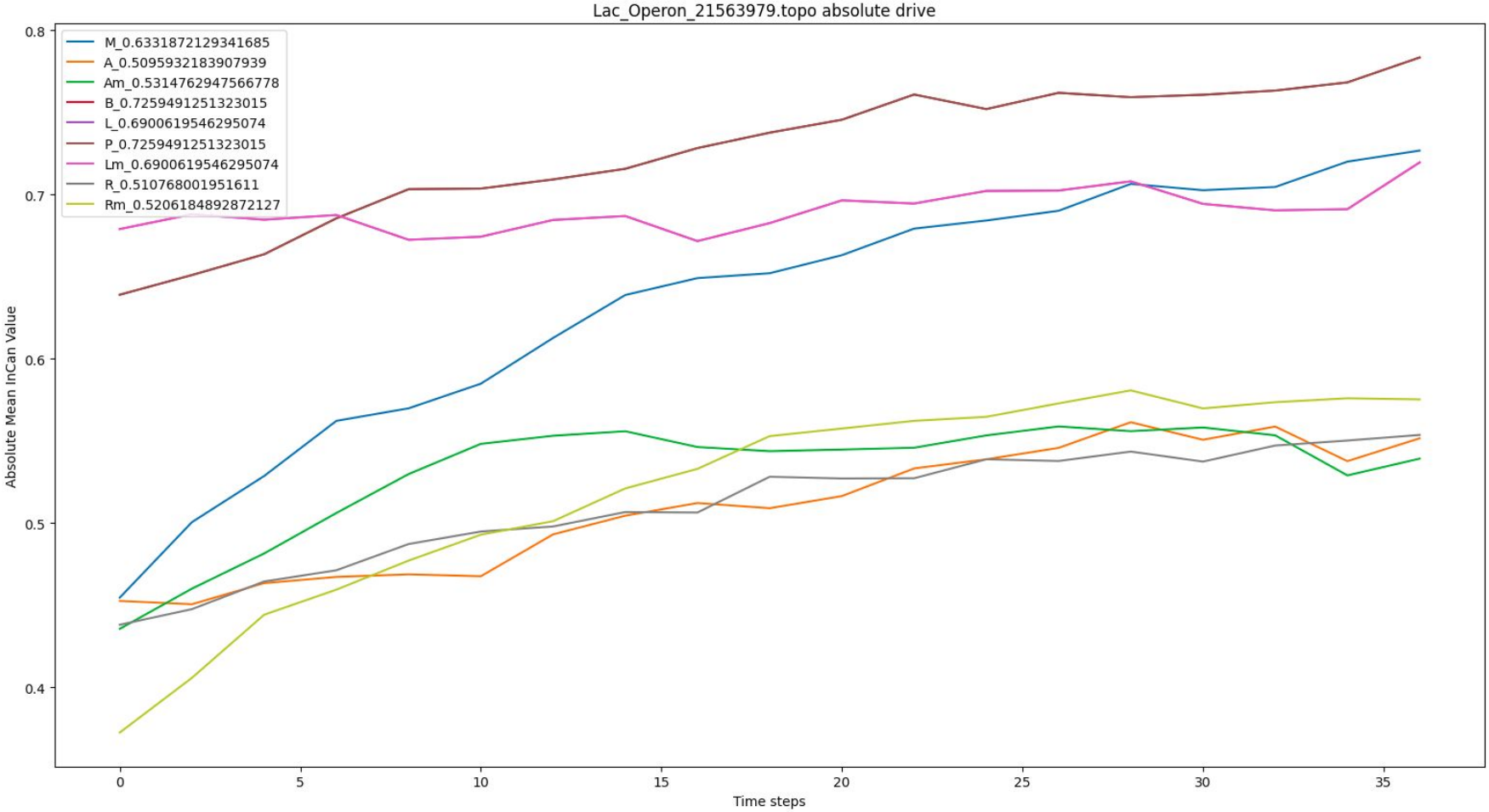
GATA4_0.31434421795310297
WT1mKTS_0.5197140122006187
UGR_0.3636343010040826
SRY_0.5662725271491678
SOX9_0.6991555256714351
AMH_0.6131354833539564
NR5A1_0.497163121364469
CBX2_0.6514401215326259
FGF9_0.7842349221837293
PGD2_0.891040945654901
WT1pKTS_0.5312493411989955
DKK1_0.7388985151314974
DMRT1_0.7341565082652497
RSPO1_0.7251360108288647
CTNNB1_0.693106647534881
WNT4_0.5537277880477746
NR0B1_0.546913502284891
FOXL2_0.7410817245817586
Absolute Mean InCan Value
Time steps
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
10
20
30
40
50
60
70
80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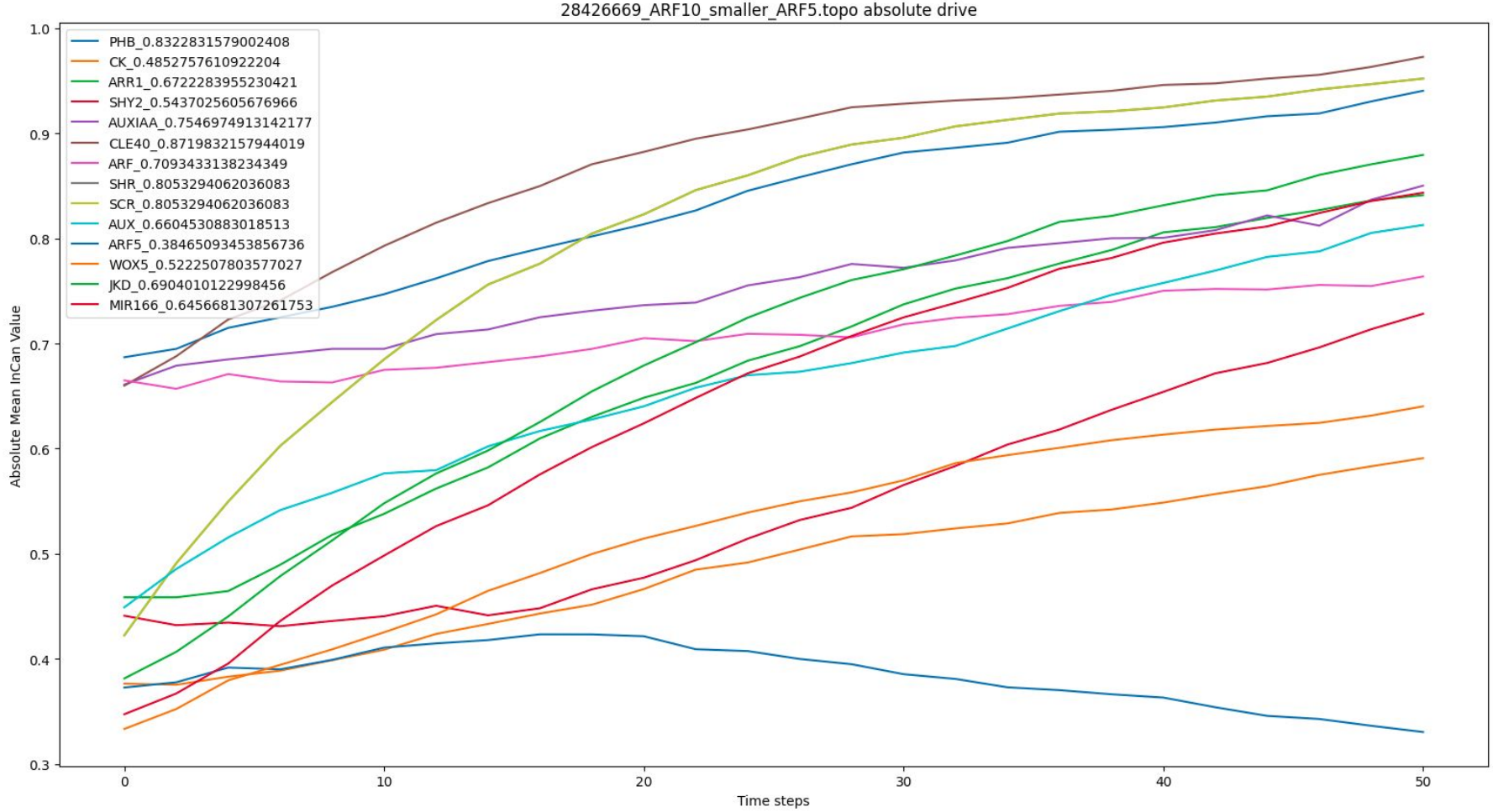
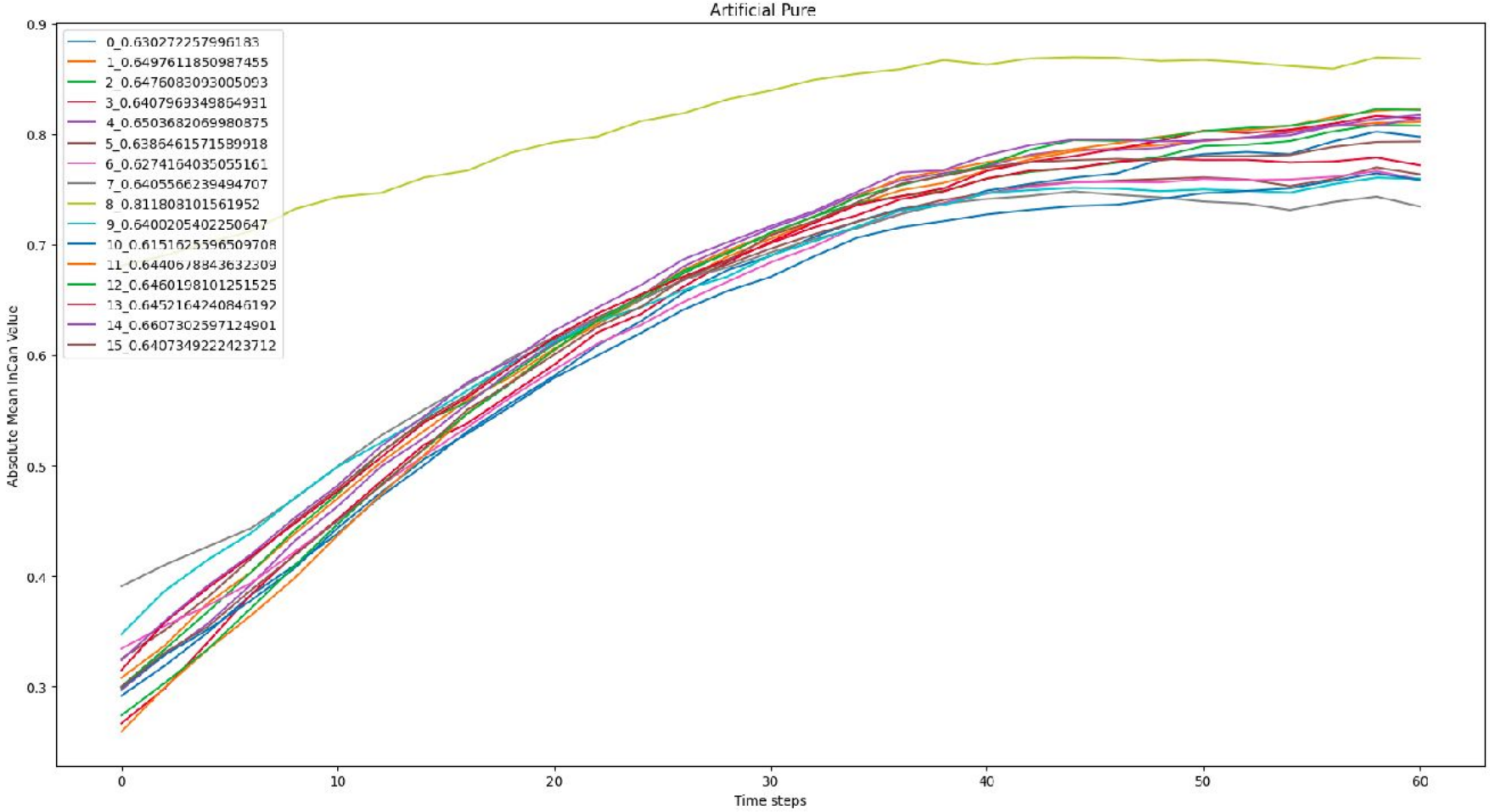
A_0.5095932183907939
Am_0.5314762947566778
B_0.7259491251323015
L_0.6900619546295074
P_0.7259491251323015
Lm_0.6900619546295074
R_0.510768001951611
Rm_0.5206184892872127
Absolute Mean InCan Value
Time steps
0.8
0.7
0.6
0.5
0.4
0
5
10
15
20
25
30
35

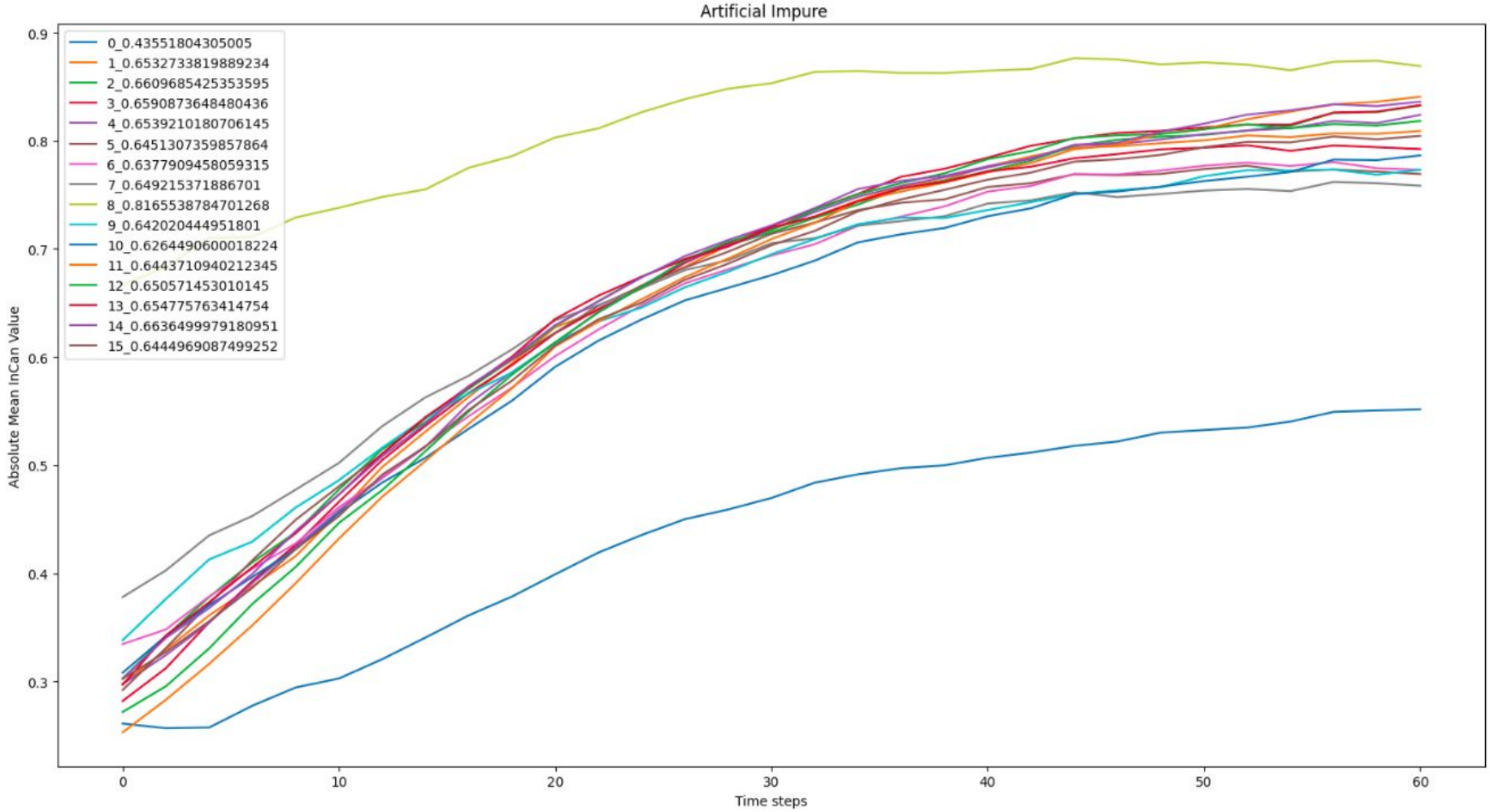

28426669_ARF10_smaller_ARF5.topo absolute drive
PHB_0.8322831579002408
CK_0.4852757610922204
ARR1_0.6722283955230421
SHY2_0.5437025605676966
AUXIAA_0.7546974913142177
CLE40_0.8719832157944019
ARF_0.7093433138234349
SHR_0.8053294062036083
SCR_0.8053294062036083
AUX_0.6604530883018513
ARF5_0.38465093453856736
WOX5_0.5222507803577027
JKD_0.6904010122998456
MIR166_0.6456681307261753
Absolute Mean InCan Value
Time steps
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
10
20
30
40
50

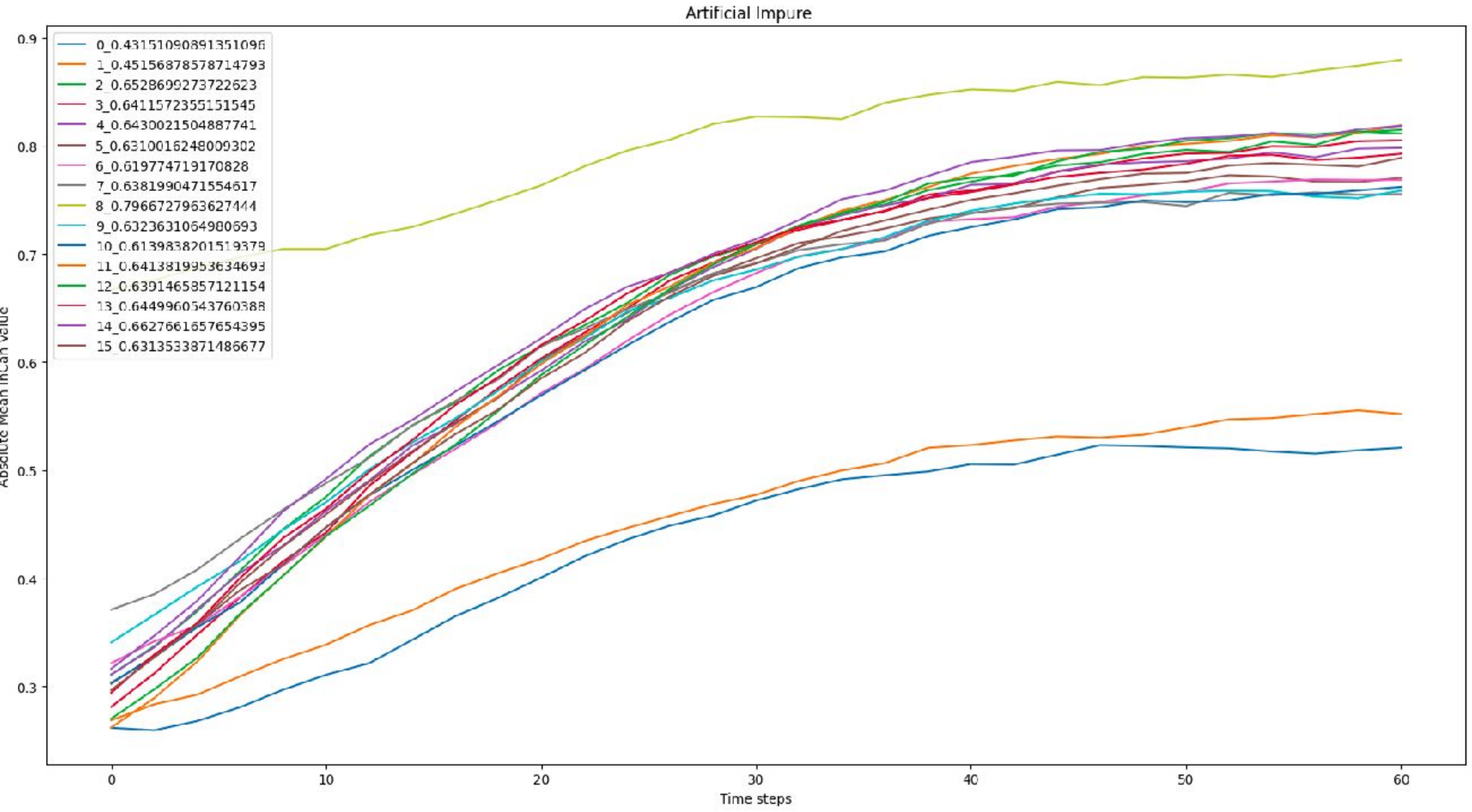
Pure artificial networks do not have any hybrid nodes

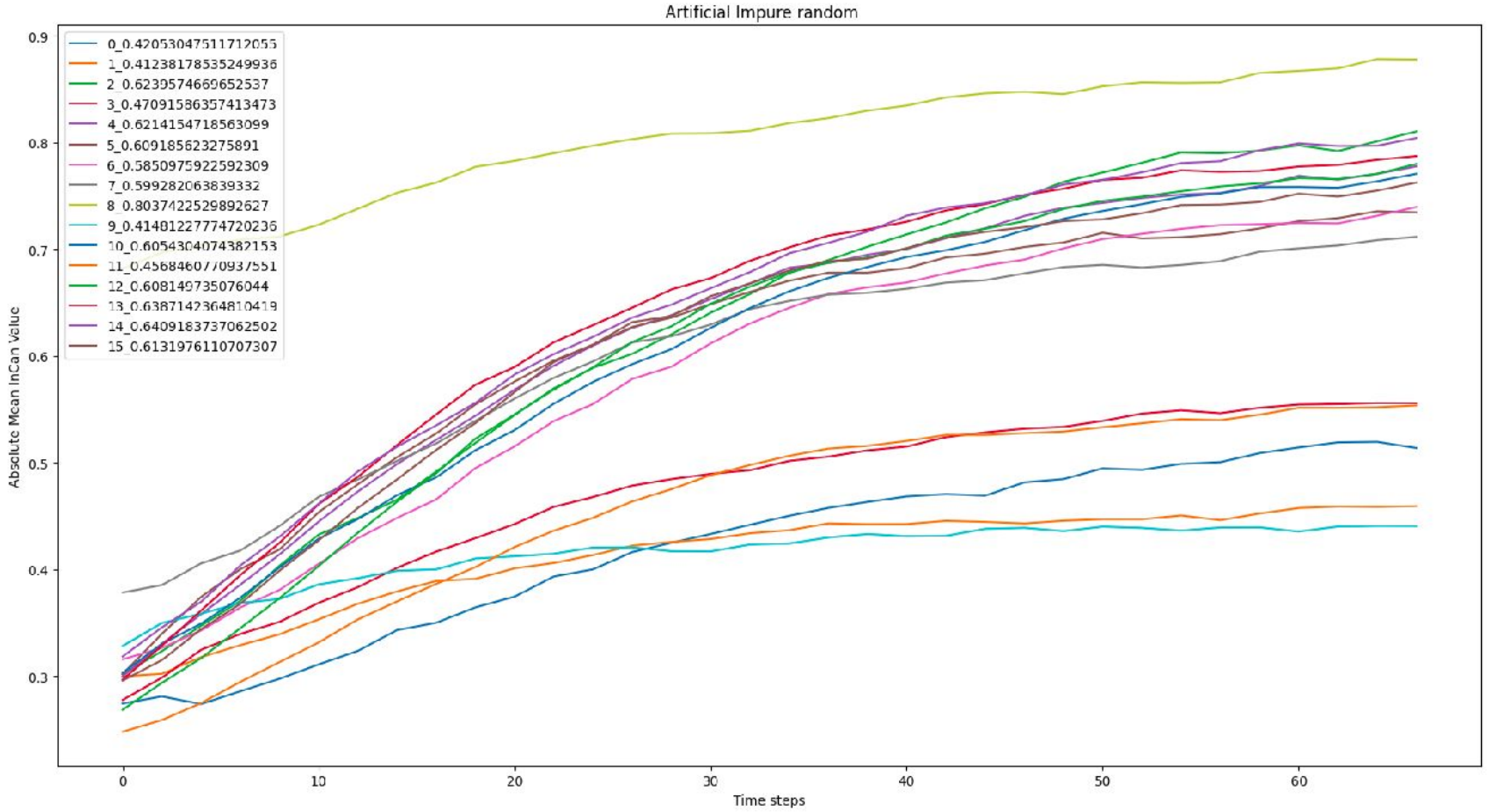

Artificial Pure
0_0.630272257996183
1_0.6497611850987455
2_0.6476083093005093
3_0.6407969349864931
4_0.6503682069980875
5_0.6386461571589918
6_0.6274164035055161
7_0.6405566239494707
8_0.811808101561952
9_0.6400205402250647
10_0.6151625596509708
11_0.6440678843632309
12_0.6460198101251525
13_0.6452164240846192
14_0.6607302597124901
15_0.6407349222423712
Absolute Mean InCan Value
Time steps
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
10
20
30
40
50
60

Impure artificial networks have hybrid nodes

On adding a few impurities I could see some hybrid and inconsistent nodes.

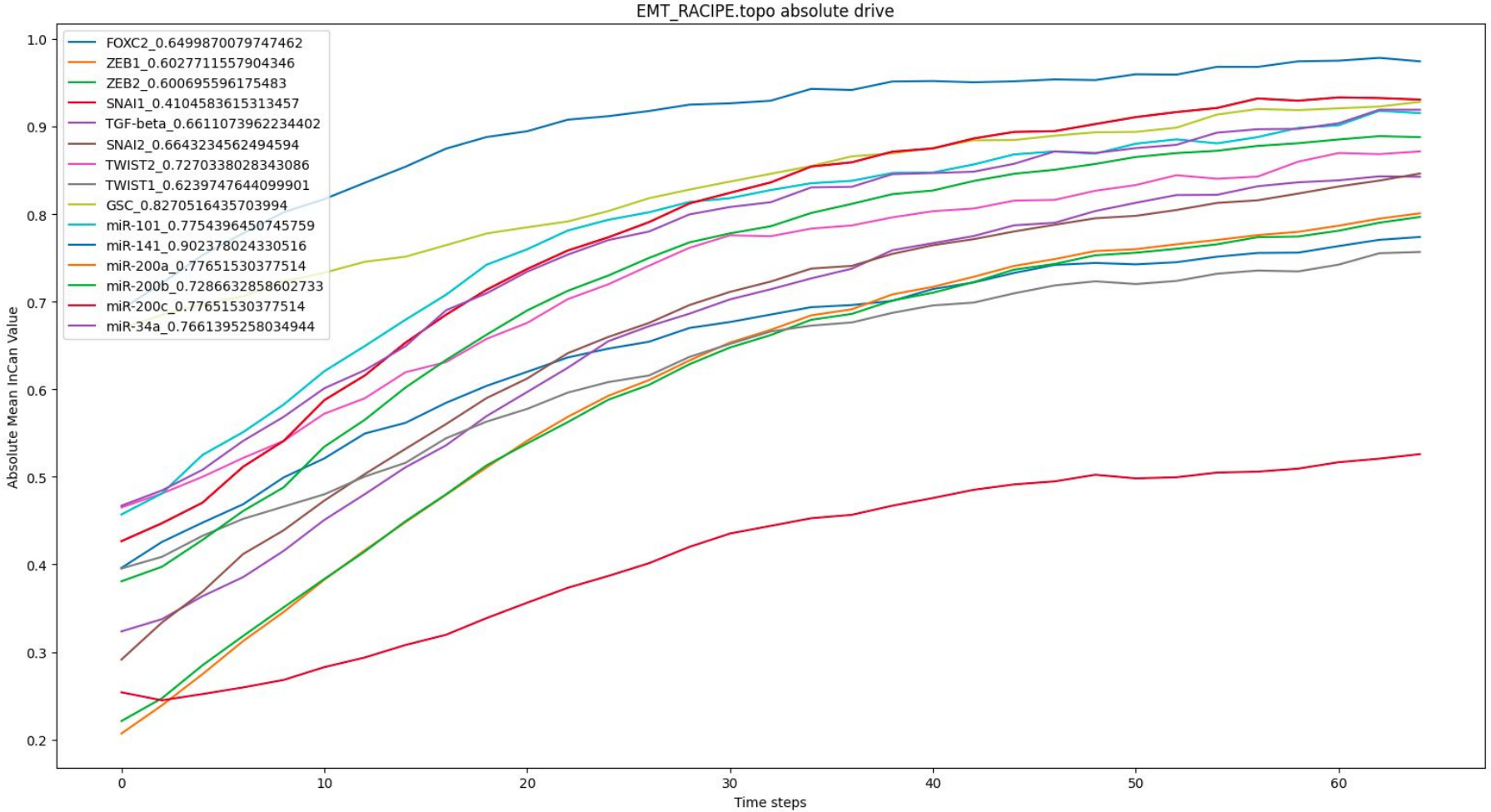

Artificial Impure
0_0.43551804305005
1_0.6532733819889234
2_0.6609685425353595
3_0.6590873648480436
4_0.6539210180706145
5_0.6451307359857864
6_0.6377909458059315
7_0.649215371886701
8_0.8165538784701268
9_0.642020444951801
10_0.6264490600018224
11_0.6443710940212345
12_0.650571453010145
13_0.654775763414754
14_0.6636499979180951
15_0.6444969087499252
Absolute Mean InCan Value
Time steps
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
10
20
30
40
50
60

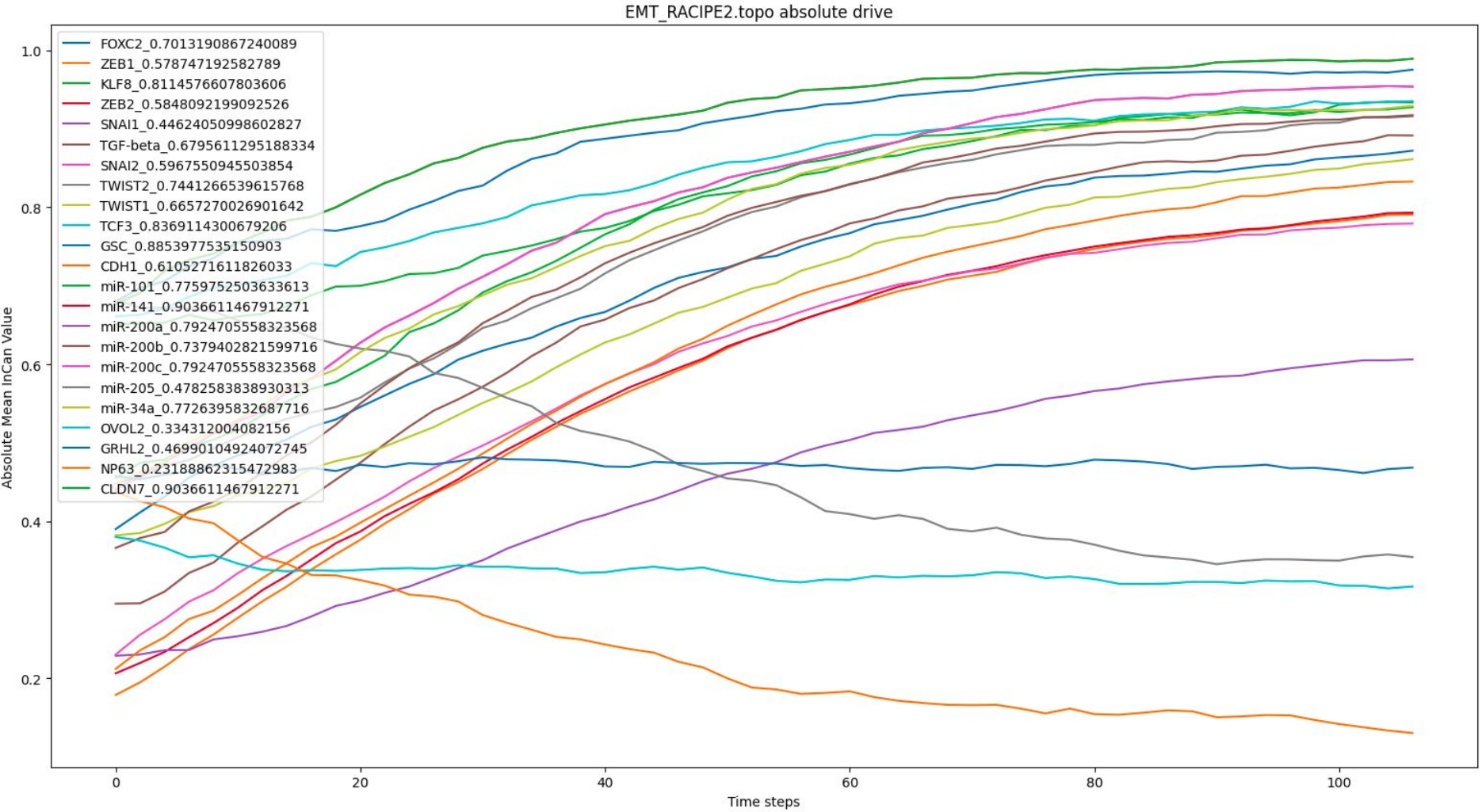

Artificial Impure
0_0.43151090891351096
1_0.45156878578714793
2_0.6528699273722623
3_0.6411572355151545
4_0.6430021504887741
5_0.6310016248009302
6_0.619774719170828
7_0.6381990471554617
8_0.7966727963627444
9_0.6323631064980593
10_0.6139838201519379
11_0.6413819953634693
12_0.6391465857121154
13_0.6449960543760388
14_0.6627661657654395
15_0.6313533871486677
Absolute Mean Incan value
Time steps
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
10
20
30
40
50
60


Artificial Impure random
0_0.42053047511712055
1_0.41238178535249936
2_0.6239574669652537
3_0.47091586357413473
4_0.6214154718563099
5_0.609185623275891
6_0.5850975922592309
7_0.599282063839332
8_0.8037422529892627
9_0.41401227774720236
10_0.6054304074382153
11_0.4568460770937551
12_0.608149735076044
13_0.6387142364810419
14_0.6409183737062502
15_0.6131976110707307
Absolute Mean InCan Veluc
Time steps
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
10
20
30
40
50
60

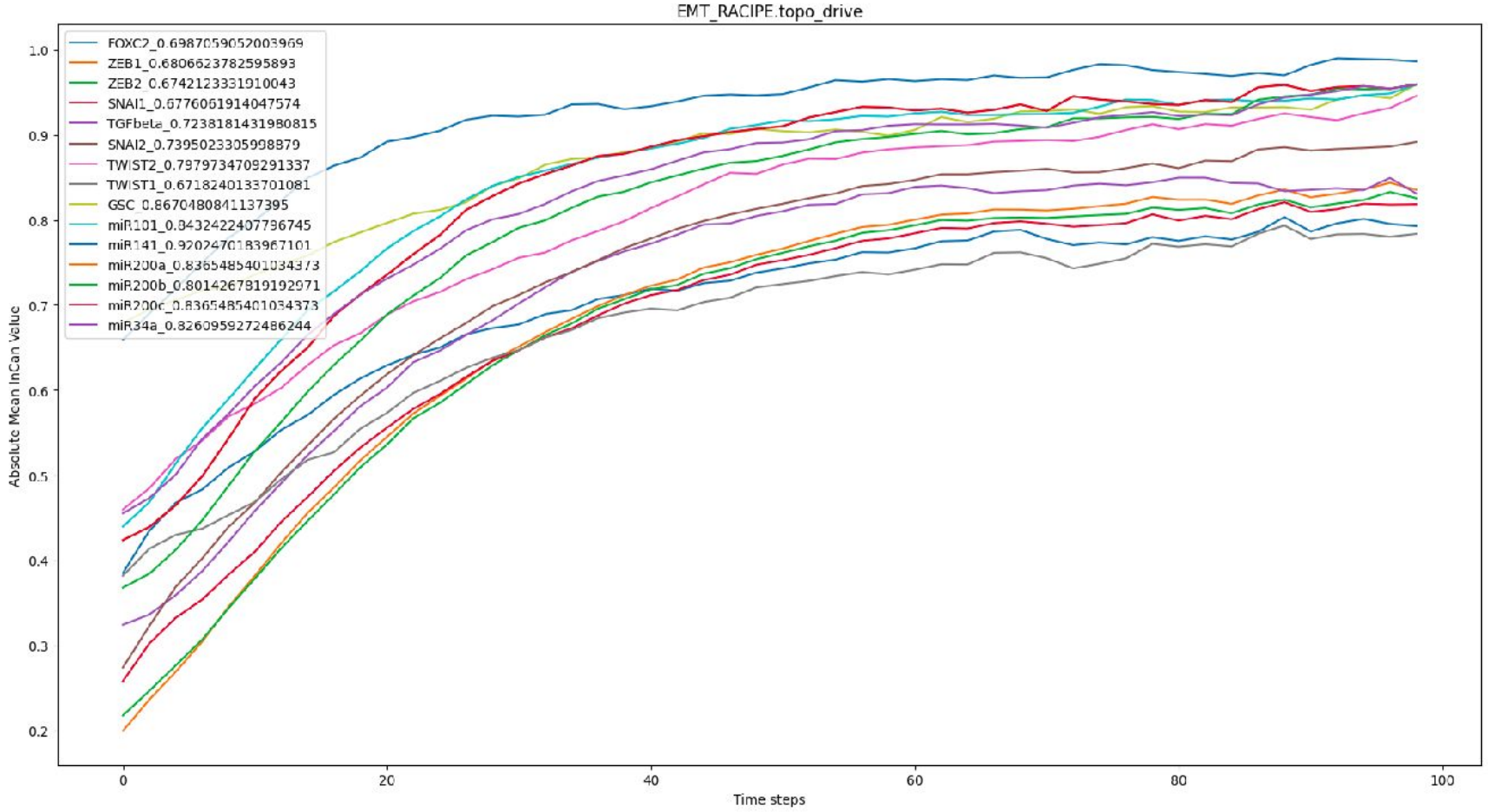
Upon conversion of impure edges to pure edges in biological networks we see that hybrid nodes disappear

Impure/Wild type


EMT_RACIPE.topo absolute drive
FOXC2_0.6499870079747462
ZEB1_0.6027711557904346
ZEB2_0.600695596175483
SNAI1_0.4104583615313457
TGF-beta_0.6611073962234402
SNAI2_0.6643234562494594
TWIST2_0.7270338028343086
TWIST1_0.6239747644099901
GSC_0.8270516435703994
miR-101_0.7754396450745759
miR-141_0.902378024330516
miR-200a_0.77651530377514
miR-200b_0.7286632858602733
miR-200c_0.77651530377514
miR-34a_0.7661395258034944
Absolute Mean InCan Value
Time steps
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
10
20
30
40
50
60


EMT_RACIPE2.topo absolute drive
FOXC2_0.7013190867240089
ZEB1_0.578747192582789
KLF8_0.8114576607803606
ZEB2_0.5848092199092526
SNAI1_0.44624050998602827
TGF-beta_0.6795611295188334
SNAI2_0.5967550945503854
TWIST2_0.7441266539615768
TWIST1_0.6657270026901642
TCF3_0.8369114300679206
GSC_0.8853977535150903
CDH1_0.6105271611826033
miR-101_0.7759752503633613
miR-141_0.9036611467912271
miR-200a_0.7924705558323568
miR-200b_0.7379402821599716
miR-200c_0.7924705558323568
miR-205_0.4782583838930313
miR-34a_0.7726395832687716
OVOL2_0.334312004082156
GRHL2_0.46990104924072745
NP63_0.23188862315472983
CLDN7_0.9036611467912271
Absolute Mean InCan Value
1.0
0.8
0.6
0.4
0.2
0
20
40
60
80
100
Time steps

“Purified”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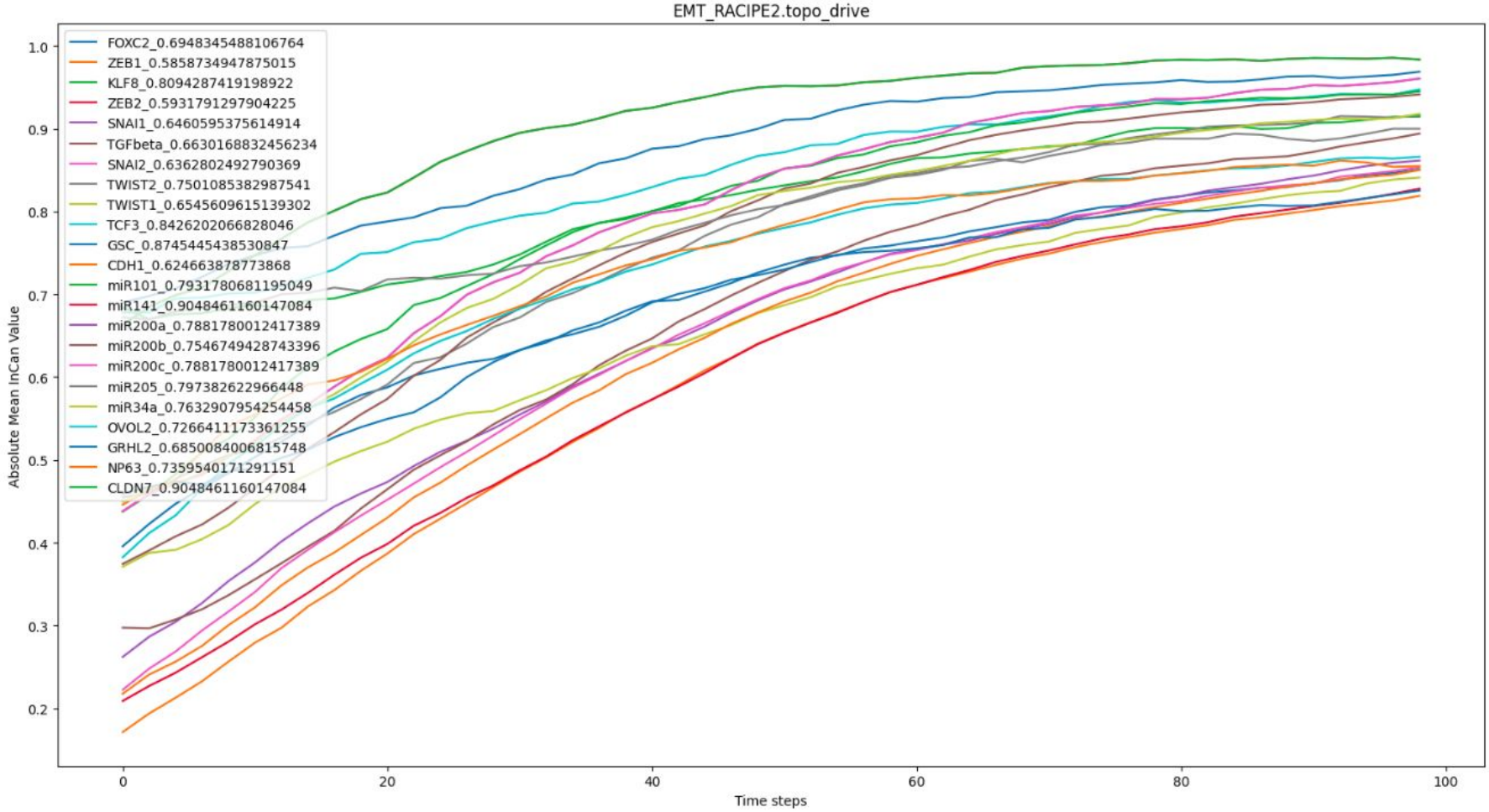
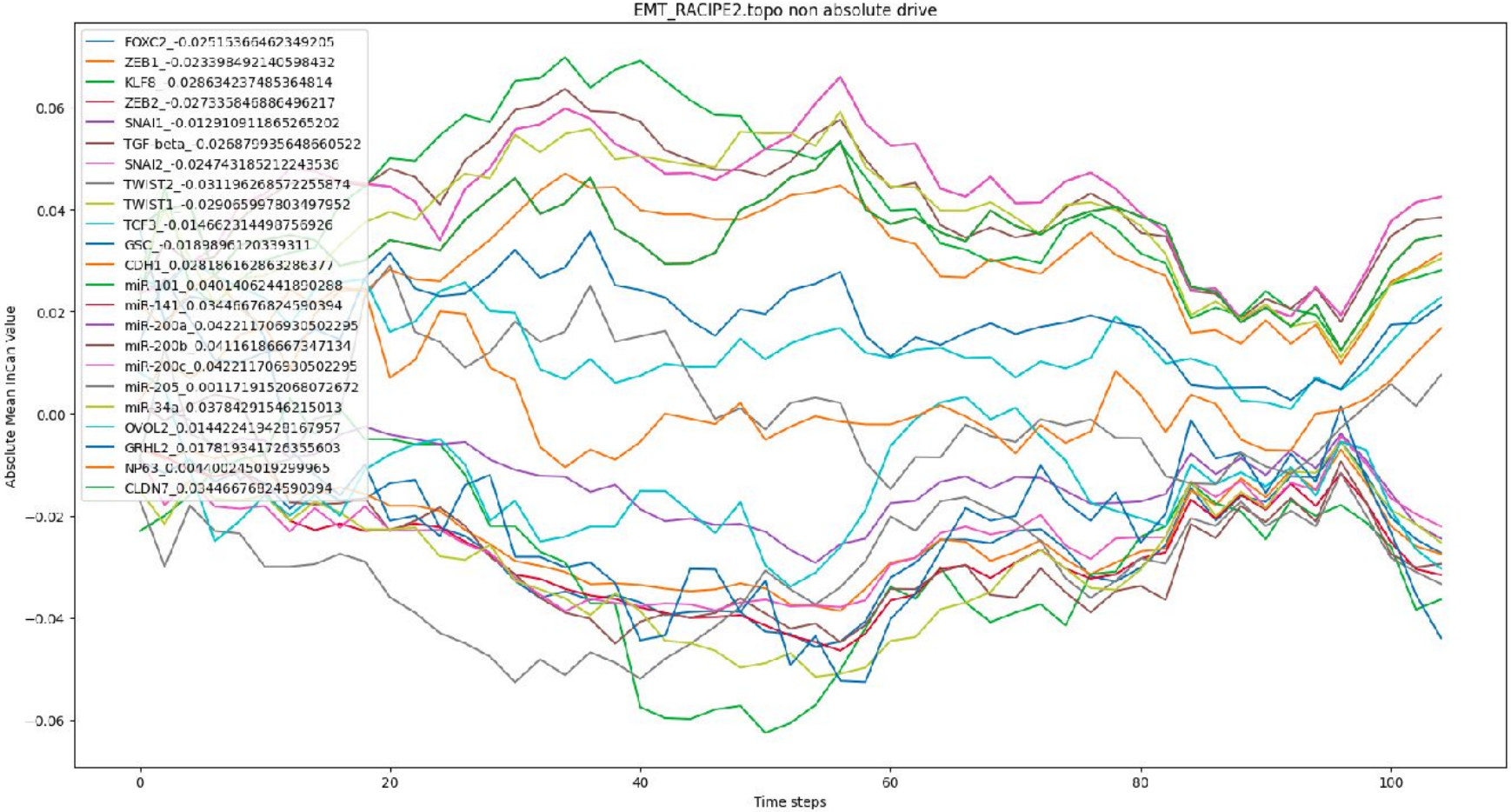
ZEB1_0.6806623782595893
ZEB2_0.6742123331910043
SNAI1_0.6776061914047574
TGFbeta_0.7238181431980815
SNAI2_0.7395023305998879
TWIST2_0.7979734709291337
TWIST1_0.6718240133701081
GSC_0.8670480841137395
miR101_0.8432422407796745
miR141_0.9202470183967101
miR200a_0.8365485401034373
miR200b_0.8014267819192971
miR200c_0.8365485401034373
miR34a_0.8260959272486244
Absolute Mean InCan Value
Time steps
0
20
40
60
80
100
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


EMT_RACIPE2.topo_drive
FOXC2_0.6948345488106764
ZEB1_0.5858734947875015
KLF8_0.8094287419198922
ZEB2_0.5931791297904225
SNAI1_0.6460595375614914
TGFbeta_0.6630168832456234
SNAI2_0.6362802492790369
TWIST2_0.7501085382987541
TWIST1_0.6545609615139302
TCF3_0.8426202066828046
GSC_0.8745445438530847
CDH1_0.624663878773868
miR101_0.7931780681195049
miR141_0.9048461160147084
miR200a_0.7881780012417389
miR200b_0.7546749428743396
miR200c_0.7881780012417389
miR205_0.797382622966448
miR34a_0.7632907954254458
OVOL2_0.7266411173361255
GRHL2_0.6850084006815748
NP63_0.7359540171291151
CLDN7_0.9048461160147084
Absolute Mean InCan Value
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
20
40
60
80
100
Time steps

Non absolute drive? Hard to paint a coherent picture.

$$\frac{\sum_i adj[i][j] * S_i}{I_j}$$


EMT_RACIPE2.topo non absolute drive
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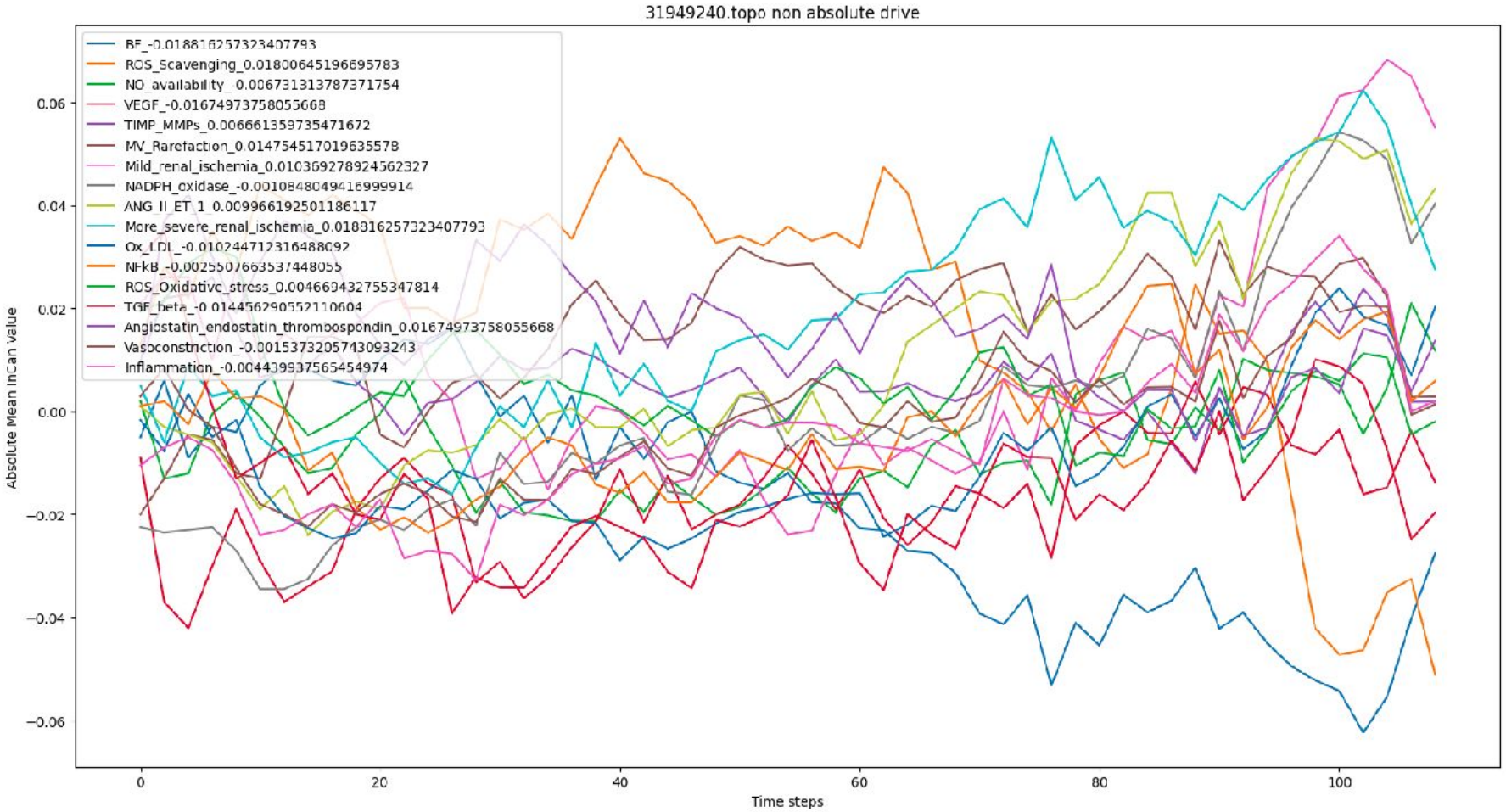
KLF8_0.028634237485364814
ZEB2_-0.027335846886496217
SNAI1_-0.012910911865265202
TGF beta_0.026879935648660522
SNAI2_-0.024743185212243536
TWIST2_-0.031196268572255874
TWIST1_-0.029065997803497952
TCF3_-0.014662314498755926
GSC_-0.0189896120339311
CDH1_0.028186162863286377
miR 101_0.04014062441890288
miR-141_0.03446676824590394
miR-200a_0.042211706930502295
miR-200b_0.041161866673471314
miR-200c_0.042211706930502295
miR-205_0.0011719152068072672
miR 34a_0.03784291546215013
OVOL2_0.014422419428167957
GRHL2_0.017819341726355603
NP63_0.0014002245019299965
CLDN7_0.03446676824590394
Absolute Mean InCan Value
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
0
20
40
60
80
100
Time steps


31949240.topo non absolute drive
BF_-0.018816257323407793
ROS_Scavenging_0.01800645196695783
NO_availability_0.006731313787371754
VEGF_-0.01674973758055668
TIMP_MMPs_0.006661359735471672
MV_Rarefaction_0.014754517019635578
Mild_renal_ischemia_0.010369278924562327
NADPH_oxidase_-0.0010848049416999914
ANG II_ET_1_0.009966192501186117
More_severe_renal_ischemia_0.018816257323407793
Ox_LDL_-0.010244712316488092
NFkB_-0.0025507663537448055
ROS_Oxidative_stress_0.004669432755347814
TGF_beta_-0.014456290552110604
Angiostatin_endostatin_thrombospondin_0.01674973758055668
Vasoconstriction_-0.0015373205743093243
Inflammation_-0.004439937565454974
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
Absolute Mean InCan Value
0
20
40
60
80
100
Time steps