!

DISCUSSION PAPERS IN ECONOMICS

Working Paper No. 24-10

! "#$%&'()*+,&-#,./#.,0()*10-#%0*#-(.*20,(&(3 4 56#$0,(
7 510,*%0*#(8#,./#.,0($*(#90(7'5:&'(;/5*5%<(

(

Department of Economics

University of Colorado Boulder
Boulder, Colorado 80309

PTiBK AHM7` bi`m+im`2 AMp2biK2Mib mM/2` hrQ@iB2 ai`m+im`2 BM i?2 :HQ# H 1+QMQKv h?Bb p2`bBQM, P+iXkjXkyk9 JQbi`2+2Mi p2`bBQM + M #2 7QmM/ ?2`2X

q2Bx? Q aRmM

#bi` +i

h?Bb T T2` /2p2HQTb bT iB H 2[mBHB#`BmK KQ/2H iQ bim/v 2M/Q;2I /2` irQ@iB2` ;Qp2`MK2Mi bi`m+im`2 r?2`2 #2M2pQH2Mi M iBQM H ;Qp2 BMi2`2bi2/T`QpBM+B H ;Qp2`MK2Mib-QTiBK HHvbQHp2bi?2TH MM2`bö M/imMM2Hb iQ K tBKBx2 ;;`2; i2/r2H7 `2rBi?BM i?2B` Dm`Bb/B+iBQMb KBiB; iBM; 2z2+iQ7 ?B;?r vb M/imMM2Hb #v BMi`Q/m+BM; irQ MQp2H B BM+Q`TQ` iBM; #BH i2` H 2H2p iBQMX h?2 KQ/2H Bb + HB#` i2/iQ jyN T T`QpBM+2bX _2bmHibb?Qri? i-+QKT `2/iQ+QKTH2i2+2Mi` HBx iBQM- 2[m HBiv-HQr2`BM; i?2 :BMB M/h?2BHöb BM/2t #v yX9 iQ yX3 T2`+2Mi p2` ;2`2 Hr ;2 #v yX9 T2`+2MiX AM+QMi` bi-+QKTH2i2/2+2Mi` HBx iB /2+`2 b2BM p2` ;2`2 Hr ;2b M/ M3T2`+2Mi BM+`2 b2BM BM2[m HBivX

E2vrQ`/b, bT iB H 2[mBHB#`BmKc 2M/Q;2MQmb BM7` bi`m+im`2c irQ iBQMc imMM2H

C1G *H bbB}+ iBQM, _Rj-_9k-_8j->89-6Rk

Rk8d*"- "QmH/2`-*P 3yjyN-q2Bx? QXamM!+QHQ` /QX2/mX

R AMi`Q/m+iBQM

>B;?r v BM7` bi`m+im`2 Bb ivTB+ HHv i?2 `2bmHi Q7 +QHH #Q` iBp2 T
;Qp2`MK2MibX AM i?2 lMBi2/ ai i2b- i?2 62/2` H >B;?r v /KBMBbi` iBQ
M/ 7mM/BM; Q7 i?2 AMi2`bi i2 >B;?r v avbi2K- r?BH2 bi i2 i` MbTQ`i iB
?B;?r vbX bBKBH ` /BpBbBQM Q7 `2bTQMbB#BHBiB2b 2tBbib BM :2`
Qp2`b22b i?2 miQ# ?M M2irQ`F- M/ bi i2 ;Qp2`MK2Mib K M ;2 i?2 G M
AM *?BM - i?2 +2Mi` H ;Qp2`MK2Mi TH Mb i?2 M iBQM H 2tT`2bbr vb- r
`2bTQMbB#H2 7Q` T`QpBM+B H 2tT`2bbr vbX h?Bb irQ@iB2` ;Qp2`MK2
+QmMi`B2b- TH vb +`m+B H v2i mM/2`bim/B2/ `QH2 BM b? TBM; BM7
BM i?2 +QMi2ti Q7 i` /2 KQ/2HbX >B;?r vb M/ imMM2Hb `2 irQ +`m+B
i?Qm;? i?2 2+QMQKB+ #2M2}ib Q7 ?B;?r vb- T `iB+mH `Hv BM `2/m+BM;
bim/B2/- imMM2Hb `2K BM `2H iBp2Hv mM/2`2tTHQ`2/ #v i?2 HBi2` im`
hmMM2Hb `2 2bb2MiB H 7Q` Qp2`+QKBM; ;2Q;` T?B+ Q#bi +H2b M/ 2M
`2 KQ`2 +QbiHv iQ #mBH/X

h?Bb T T2` 2t KBM2b ?Qr i?2 BMi2`TH v Q7 +2Mi` HBx iBQM M/ /2-
T`QpBbBQM Q7 ?B;?r vb M/ imMM2Hb M/ i?2 +QMb2[m2Mi 2z2+ib QM
[m MiBi iBp2 bT iB H KQ/2H r?2`2 #2M2pQH2Mi M iBQM H ;Qp2`MK2
T`QpBM+B H ;Qp2`MK2Mib- QTiBK HHv BMp2bib BM ?B;?r vb M/ imMM
7 `2 rBi?BM i?2B` Dm`Bb/B+iBQMbX h?2 KQ/2H bbmK2b i? i ;Qp2`MK
BM ?B;?r vb M/ imMM2Hb QM T `iB+mH ` `Q / ? p2 /Bz2`2MiB i2/ BKT
M/ T`QKQiBM; `2;BQM H M/ BMi2`M iBQM H i` /2X >Qr2p2`- i?2 KQ/2
;Qp2`MK2Mib 7Q+mb QMHv QM i?2B` Dm`Bb/B+iBQMb- /Bb`2; `/BM; i?
BMp2biK2Mib BKTQb2 QM Qi?2` T`QpBM+2bX h?Bb T T2` }M/b i? i +2Mi
iQ /Bp2`;2Mi BM7` bi`m+im`2 Qmi+QK2b /2bTBi2 bbmKBM; B/2MiB+ H
+QKTH2i2 BM7Q`K iBQMX +QHH #Q` iBp2 2zQ`i#2ir22M M iBQM H M
i`m+im`2 TH MMBM; T`2b2`p2b Km+? Q7 i?2 2{+B2M+v ; BMb 7`QK +2M
T`QpBM+B H ;Qp2`MK2Mib iQ //`2bb HQ+ H M22/b M/ KBiB; i2 BM2[m
h?2 bT iB H KQ/2H 72 im`2b b2i Q7 HQ+ iBQMb +QMM2+i2/ #v i?2 i
rQ`F2`b rBi? ?2i2`Q;2M2Qmb T`272`2M+2b +`Qbb HQ+ iBQMbX GQ+ i
iBpBiv- `2bB/2MiB H H M/- 2H2p iBQM H2p2H- M/ ;2Q;` T?B+ TQbBiBQ
+QKT2iBM; }`Kb T`Q/m+2 M 2M/Q;2MQmb K2 bm`2 Q7 /Bz2`2MiB i2/ p `
URN3yVX h?2b2 ;QQ/b `2 i` /2/ #2ir22M HQ+ iBQMb- BM+Hm/BM; i?2 `
+Qbib BM~m2M+2/ #v /Bbi M+2 M/ #BH i2` H 2H2p iBQMX h?2 H ii2`

`2~2+ibm+Fbö +Qbib r?2M ;QBM; mT?BHHb M/ /QrM?BHHb 7`QK Q`B;BM
Ukyk9VX GQ+ iBQMb+ M2M; ;2 BM BMi2`M iBQM Hi` /2i?`Qm;? TQ`ib
i iBp2 bT iB H KQ/2Hb-i?Bb bim/v Bb T `iB+mH `Hv HB;M2/rBi?_2//BM
2ti2M/BM;i?2 7` K2rQ`F #v HHQrBM;7Q` QTiBK H BMp2biK2Mi /2+BbB
M/i?2 7QHHQrBM;T`QpBM+B H ;Qp2`MK2Mib BM H2 /2`@7QHHQr2` I
i2`KBM2/#m/;2ibX A T`QTQb2 bQHmiBQM iQ i?2 TH MM2`öb T`Q#H2K
h?2 bQHmiBQM H;Q`Bi?K BM+Hm/2b i? i-BMBiB HHv-i?2 M iBQM H ;Q
mM/2` b+2M `BQ rBi?MQ BM7` bi`m+im`2 BMp2biK2Mi M/ HHQ+ i2b 7
+Q`/BM;iQ M 2tQ;2MQmb TH MX am#b2[m2MiHv-i?2 M iBQM H ;Qp2`M
M/imMM2Hb +`Qbb HH HQ+ iBQMb-bm#D2+i iQ bT iB H 2[mBHB#`Bm

Q7Q+F iQ +QMbi`m+i i?2 Ao 7Q` imMM2HbX *Qbi@KBiB; iBM; 2z2+ib Q7
h?2 `2bmHib BM/B+ i2 i? i ?B;?r v /2MbBiv `2/m+2b i?2 +Qbi bbQ+B i2
/2MbBiv /2+`2 b2b i?2 +Qbi Q7 #BH i2` H 2H2p iBQMX yXyR mMBi BM+
+Qbi Q7 /Bbi M+2 #v yXyRRd9 T2`+2Mi ;2 TQBMib- r?BH2 yXyR mMBi
i?2 +Qbi Q7 #BH i2` H 2H2p iBQM #v yXyyR9R T2`+2Mi ;2 TQBMibX hQ
`2 BM ?B;?r v /2MbBiv- 7Q` 2t KTH2- +QMbB/2` i?2 + b2 Q7 "2BDBM;
? / 3RN FBHQK2i2`b Q7 ?B;?r v- M/ hB MDBM ? / R-Rk3 FBHQK2i2`bX
/2MbBiv #2ir22M i?2 irQ +BiB2b #v yXyR mMBib- i?2 iQi H BM+`2 b2 BM
TT`QtBK i2Hv kd8Xe8 FBHQK2i2`bX

hrQ +QmMi2`7 +im H M Hvb2b `2 +QM/m+i2/X h?2 }`bi +QmMi2`7 +i
}+B2M+v M/ 2[m HBiv Qmi+QK2b Q7 i?2 irQ@iB2` bi`m+im`2 rBi? i?Qb2
h?2 }M/BM;b bm;;2bi i? i i?2 irQ@iB2` bi`m+im`2 T`QKQi2b ;`2 i2` 2[m H
+B2Mi #v yX9 T2`+2Mi M/ h?2BHöb BM/2t #v yX3 T2`+2MiX h?Bb BKT`Q
;Qp2`MK2Miöb i2M/2M+v iQ BMp2bi BM +2Mi` H `2 b rBi?BM i?2B` Dm
M iBQMi`2;BQMb i? i rQmH/ HBF2Hv #2 M2;H2+i2/ mM/2` +2Mi` HBx iB
BM2[m HBiv +QK2b i i?2 2tT2Mb2 Q7 2{+B2M+v- K2 bm`2/ #v `2 H r ;2b
T2`+2Bp2b T`QpBM+B H `2 HHQ+ iBQMb b KBb HHQ+ iBQMbX *QMb2[
yX9 T2`+2Mi /2+`2 b2 BM i?2 p2` ;2 `2 H r ;2 `2H iBp2 iQ 7mHHv +2Mi

h?2 b2+QM/ +QmMi2`7 +im H M HvbBb bb2bb2b i?2 2z2+ib Q7 +QK
i? i 7mHHv /2+2Mi` HBx2/ b+2M `BQ `2bmHib BM HQr2` ;;`2; i2 r2H7 `
iQ i?2 irQ@iB2` bi`m+im`2X h?2 p2` ;2 `2 H r ;2 /2+`2 b2b #v kXje T2`+
BM/B+2b BM+`2 b2 #v TT`QtBK i2Hv 3 T2`+2Mi- / KT2MBM; BM2[m HB
T`QpBM+B H ;Qp2`MK2Mib 7 BH iQ BMi2`M HBx2 i?2 bTBHHQp2` 2z2+ib

U HbQ22 J2m`2`b M/ JQ2MBmb UkyR3V M/ 6 D;2H# mK M/ a+? H Ukyky
iQ i?Bb bi` M/ #v BMi`Q/m+BM; irQ@iB2` ;Qp2`MK2Mi bi`m+im`2 iQ i
T`Q#H2KX

a2+QM/- i?Bb T T2` Bb `2H i2/ iQ i?2 H `;2 HBi2` im`2 QM 2biBK iBM
QM i` /2X Ua22 6 #2` UkyR9V- .QM H/bQM UkyR3V- bim`B b 2i HX Uk
C rQ`bFB M/ EBi+?2Mb UkyRNV- " M2`D22 2i HX UkykyV- " mK@aMQr 2
: HH2M M/ qBMbiQM UkykRV- GQmK2 m UkykjV- 1;;2` 2i HX UkykjVXV
bi` M/ #v BMp2biB; iBM; i?2 BKT +i Q7 ?B;?r vb M/ imMM2Hb QM BMi2
BMi`Q/m+BM; irQ MQp2H BMbi`mK2Mi H p `B #H2b iQ 2p Hm i2 i?2 BKT
Bb # b2/ QM ?BbiQ`B+ H +Qm`B2` `Qmi2b 7`QK i?2 JBM; /vM biv- M/ i?2
/Bbi`B#miBQM[k] Q7 *?BM X

h?B`/- i?Bb T T2` Bb +QMM2+i2/ iQ i?2 HBi2` im`2 QM i?2 TQHBiB+ H
im`2X 6Q` BMbi M+2- "`m2+FM2` M/ a2HQ/ UkyyeV 2t KBM2 ?Qr i?2 bQ
+QMi` bib rBi? i?2 QM2 b2H2+i2/ i?`Qm;? i?2 pQiBM; T`Q+2bb- /2KQMbi
H2 /iQ i` MbTQ`i iBQM bvbi2K i? i Bb bHQr2` M/ H2bb +QbiHv i? M i?2
SQMx2iiQ UkyR3V BMp2biB; i2b ?Qr pQi2`bnT2`+2TiBQMb Q7 p `BQmb
/BbiQ`i i?2 ivT2b Q7 T`QD2+ib +?Qb2M #v TQHBiB+B MbX //BiBQM HH
?Qr TQHBiB+ H T`272`2M+2b BM~m2M+2/ i?2 /2p2HQTK[j] 2M?iBQ 7T*@HB7Q
T2` +QMi`B#mi2b iQ i?Bb HBi2` im`2 #v 2tTHQ`BM; ?Qr i?2 BMi2` +iBQ
;Qp2`MK2Mib z2+ib BM7` bi`m+im`2 BMp2biK2Mi /2+BbBQMbX

G biHv- i?Bb T T2` Bb `2H i2/ iQ i?2 `2b2 `+? i? i miBHBx2b bT iB H
i` /2 Qmi+QK2b Ub22 _2//BM; UkyReV- _2//BM; M/ _QbbB@> Mb#2`; Uk
6 D;2H# mK M/ a+? H UkykyV- HH2M M/ `FQH FBb UkykkV- M/ " `rB
+QMi`B#mi2b iQ i?Bb HBi2` im`2 #v BM+Q`TQ` iBM; 2H2p iBQM b HQ+
2H2p iBQM b M 2/;2 ii`B#mi2- M/ HHQrBM; Bi iQ TH v `QH2 BM i` /2

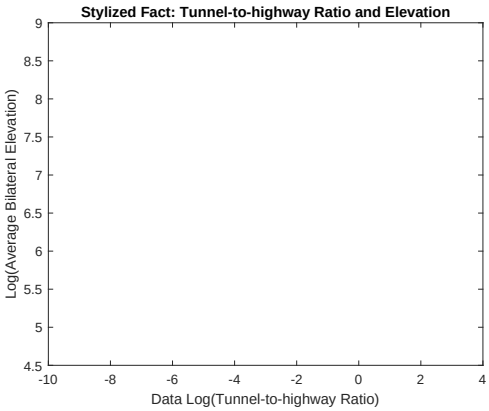
h?2 `2bi Q7 i?2 T T2` Bb Q`; MBx2/ b 7QHHQrb, a2+iBQM k BMi`Q/m
?B;?r v bvbi2KX a2+iBQM j b?Qrb i?2 bivHBx2/ 7 +ibX a2+iBQM 9 BMi`
KQ/2H- i?2 ;Qp2`MK2Mi bi`m+im`2- M/ i?2 bQHmiBQM H;Q`Bi?KX a2
T`Q+2bbX a2+iBQM e T`2b2Mib i?2 # b2HBM2 M/ +QmMi2`7 +im H `2bn

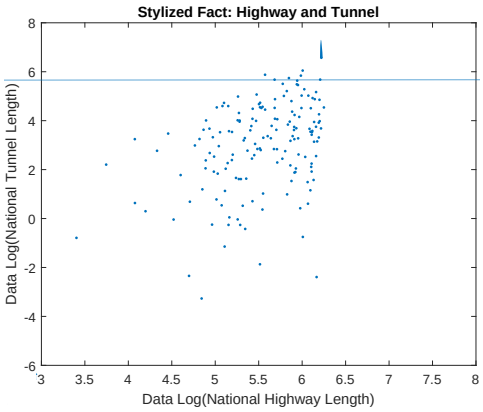
[k] HbQ b22 GBK Q M/ o2M #H2b UkyyRV- hm`M2` UkyyeV- JºHH2` M/ wB2`2` UkyR3V-
.m` MiQM M/ hm`M2` UkyRRV- M/ .m` MiQM 2i HX UkyR9V- " M2`D22 2i HX UkykyVX
[j] HbQ b22 * bi2HHb M/ aQHû@PHHû Ukyy8V r?Q @ Ð+ DÐðb2 QM mi P°°°°° i–rà“Q

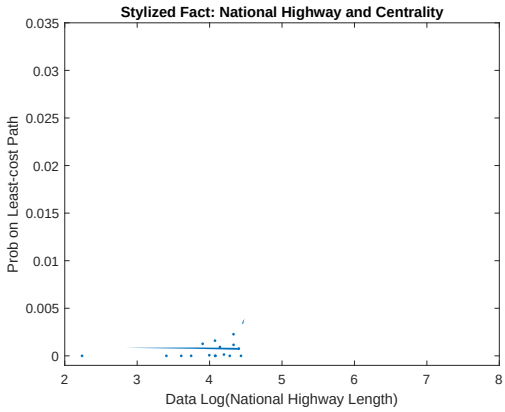
k " +F;`QmM/

kXR *?BM öb L iBQM H M/ S`QpBM+B H 1tT`2bbr v avbi2K

h?2/2p2HQTK2Mi Q7 ?B;?r v BM7` bi`m+im`2 BM *?BM 7`QK RNNy iQ
H2 /2`@7QHHQr2` bivH2X AM i?Bb TT`Q +?- i?2 M iBQM H ;Qp2`MK2M


Stylized Fact: Tunnel-to-highway Ratio and Elevation
Log(Average Bilateral Elevation)
Data Log(Tunnel-to-highway Ratio)
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
-10
-8
-6
-4
-2
0
2
4


Stylized Fact: Highway and Tunnel
Data Log(National Tunnel Length)
Data Log(National Highway Length)
8
6
4
2
0
-2
-4
-6
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8


Stylized Fact: National Highway and Centrality
Prob on Least-cost Path
Data Log(National Highway Length)
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
2
3
4
5
6
7
8

i?2HBF2HB?QQ/ Q7 #2BM; QM i?2 H2 bi@+Qbi T i?- K2i`B+ `2T`2b2M
T`272+im`2b rBi?BM *?BM X h?2b2 H2 bi@+Qbi T i?b- + H+mH i2/ mbB
i` MbTQ`i iBQM +Qbib /m2 iQ /Bbi M+2 M/ #BH i2` H 2H2p iBQM- b bT
7mM+iBQM BM 1[m iBQM UkjVX h?2 T`Q# #BHBiB2b `2~2+i M im` H ;2
BM7` bi`m+im`2 BMp2biK2MiX

6B7i?- S M2H U7V /2KQMbi` i2b i? i i?2 H2M;i? Q7 T`QpBM+B H ?B;?
+Q``2H i2/ rBi? i?2 HBF2HB?QQ/ Q7 #2BM; QM i?2 H2 bi@+Qbi T i? rB
#BHBiB2b- + H+mH i2/ bBKBH `Hv iQ i?Qb2 BM S M2H U2V- `2 +QMbi`
rBi?BM i?2 b K2 T`QpBM+2- + Tim`BM; rBi?BM@T`QpBM+2 ;2Q;` T?B+
i i?2 KQ/2H bbmKTiBQM i? i +2Mi` HBiv b?QmH/ #2 F2v /2i2`KBM Mi
/2+BbBQMbX JQ`2 +2Mi` H `2;BQMb- r?2i?2` BM `2H iBQM iQ i?2 +QmM
HBF2Hv iQ ii` +i ;`2 i2` BMp2biK2Mi BM ?B;?r vb M/ imMM2Hb #2+ mb
BM `2/m+BM; i` /2 +Qbib 7Q` Qi?2` `2;BQMbX

9 h?2Q`v

9XR aT iB H 1[mBHB#`BmK JQ/2H

h?2 KQ/2H 7QHHQrb _2//BM; UkyReV M/ a MN +1`B2;BQMb BX h?2 KQ/2
N `2;BQMb rBi?BM i?2 +QmMi`v- M/ QM2 //BiBQM H `2;BQM `2T`2b2Mi
1 +? HQ+i;BQM+1 - Bb 2M/Qr2/ rBi? 2tQ;2M-2mQ;2MQ+mb 2H2p iBQM H2p
M/ 2tQ;2MQmb T`Q/X +i?2 B2L`r2Q`F2`b rBi?BM i?2 +QmMi`vX qQ`F2`b
KQ#BH2 +`Qbb HQ+ iBQMb rBi?BM i?2 +QmMi`v rBi? MQ KB;` iBQM +Q

h?2 bbmKTiBQM Q7 T2`72+iHv KQ#BH2 H #Q` BM *?BM Bb bBKTHB
;` iBQM +Qbib rBi?BM *?BM `2 r2HH@/Q+mK2Mi2/ M/ rB/2Hv `2+Q;M
QM i?Bb bbmKTiBQM- i?2 KQ/2H HBF2Hv mM/2`2biBK i2b i?2 i`m2 TQi
bi`m+im`2 iQ KBiB; i2 BM2[m HBivX AMi`Q/m+BM; KB;` iBQM +Qbib rQ
BiB2b i? i + MMQi #2 2 bBHv KBiB; i2/ #v H #Q` KQp2K2MibX b i?2 M
iQ 7Q+mb Bib BMp2biK2Mib QM +2Mi` H `2;BQMb- i?2 `2bmHiBM; r ;2 B
2t +2`# i2/- rBi? 72r2` Qzb2iiBM; H #Q` BM~Qrb iQ / KT2M i?2 `Bb2X
bvbi2K r?2`2 T`QpBM+B H ;Qp2`MK2Mib HHQ+ i2 KQ`2 `2bQm`+2b iQ T
Q7 BM7` bi`m+im`2 BMp2biK2Mib +QmH/ ? p2 Km+? ;`2 i2` BKT +i QM
i?2 KQ/2H HBF2Hv T`QpB/2b HQr2` #QmM/ 7Q` i?2 irQ@iB2` ;Qp2`MK2
BM2[m HBivX >Qr2p2`- i?2 mi?Q` #2HB2p2b i? i `2H tBM; i?2 bbmKTi
+? M;2 i?2 /B`2+iBQM Q7 i?2 }M/BM;bX

AMi?Bb KQ/2H-rQ`F2`b 2Bi?2` T`Q/m+2;QQ/b BM2H biB+ HHv BMi?2B
b+QMbi`m+iBQM rQ`F2`b 7Q` BM7`! b/î`mbh(n)-2XM 1B/+B?QvMF2` iB+ T`272
T` K2i2` 7Q` 2+? HQ+iBQM-7`QK 6`û+?2i/Bbi`B#miBQMX

$$G_{b_n}(b) = prob(b_n \quad b) = e^{B_n b} \qquad (R)$$

r?2`2Bb i?2 b? T2T` KB2iBb iM2 HQ+iBQM T` K2i2`X h?2 T`2!7-2`2M+2 T
HBpBM;BMnHQ2+T2BMQbMQM+QMC(n)K?iBQMB(M);-M/B/BQbvM+`iB+T`272
b?Q+F 7Q`i?2 HQ+iBkQ(M)X7`2bB/2M+2

$$U_n(!) = b_n(!)\left(\frac{C_n(!)}{\quad}\right)\left(\frac{H_n(!)}{1}\right)^1 \qquad (k)$$

r?2`2T` K2i2;Qp2`Mbi?2b?`2Q7i`/#H2;QQ/bX h?2+QMnbQKTiBQM E
/2T2M/bQM2M/Q;2MQmbHv@M2iQ7K/BMi2`/2[miBMiBzX`B2iB2b

$$C_n = \sum_{i}^{N} \int_{0}^{M_i} c_{in}(z)^{\frac{1}{\quad}} dz^{\frac{1}{\quad}} \qquad (j)$$

r?2`2 1 Bb?2 2H biB+BivQ7bm#biBimiBQM #2ir22M;QQ/bX h?2 T`Q/m+i
M/Bb+?`+i2`Bx2/#vKQMQTQHBbiB++QKT2iBiBQMX 1l_n(z) }#`2K bmTTH
i?2H #Q``2[mB`2/q_n(z)TmQM/Bnib2Q7i?2 pBMB+2Qvn X1B(z)MBb;Bp2Mb,

$$l_n(z) = F + \frac{q_n(z)}{A_n} \qquad (9)$$

h?2T`Q}iKtBKBxiBQMT`Bz+µ(z)7Q`i?2B7iv+iQ`B2bö;i2Bb,

$$p_n(z) = \frac{w_n}{1 A_n} \qquad (8)$$

r?2`2w_n Bb?2r;2BMHQ+iBAQM

w

i /T1 1 7.97 Tf 8.182 -1.636 Td (n)Ti /T1 0 10.909 Tf 4.24257.319 Td <00TT /T1 1 7.97 Tf 5.405 75.636 Td (n)Tii /T1 0 10

r ? 2 `F2 B b? 2 } t 2 / + Q b i Q 7 T ` Q / m + i B Q M X A M 2 [m B H B # ỳ B(z) m-Kr-Bi ? 2 H Q 2 T [i m B K ` 2 H

$l_n(z)$ m M B i b Q 7 H # Q ` X

$l_n(z) =$ F U 3 V

K `2i +H2 `BM; +QM/BiBQM,

$$_{in} = \frac{X_{in}}{X_n} = \frac{M_i p_{in}^{1}}{\sum_{k2N} M_k p_{kn}^{1}} = \frac{(1 \quad) L_i}{F}\left(\frac{w_i}{1 A_i} T_{in}\right)^{1} \quad P_n^{\ 1} \qquad \text{UR8V}$$

r?2`X2$_{in} = M_i p_{in}^{1}$ Bb?2 2tT2M/Bim`2 QM ;QQi/bMT/`+QQmM+b2/mkB2XM$_n$ BMb i?2 iQi H 2tT2M/Bim`2 BMmXHQ?+2 iTBQBM+2 BM/2t Bb /2}M2/ b,

$$P_n^{1} = \sum_k M_k p_{kn}^{1} = \sum_k \frac{(1 \quad) L_k}{F}\left(\frac{w_k}{1 A_k} T_{kn}\right)^{1} \qquad \text{UReV}$$

aBKBH_`2i/QBM; UkyReV- i?2 2tT2M/Bim`2 QM H M/ BM 2 +? HQ+ iBQM B i?2 rQ`F2`b `2bB/BM; i?2`2X h?2`27Q`2- i?2 #2 7BQb`i2?@i7 tQBHM+QQK2;BM HQ

$$w_n L_n + (1 \quad) v_n L_n = \frac{w_n L_n}{} \qquad \text{URdV}$$

r?2`v2$_n = \frac{w_n}{}$ Xh?2 M iBQM H ;Qp2`MK2Mi BKTQb2b ~ i i tQM ?Qmb2?QH/ ` i2< 1X aQ- i?2 ;;`2; i2 BM+QK2 7i2`@bi tBM HQ+ iBQM

$$v_n L_n = (1 \quad) \frac{w_n L_n}{} \qquad \text{UR3V}$$

M/i?2 ;;`2; i2 i tBM+QK2 Bb

$$\sum_n \frac{w_n L_n}{} \qquad \text{URNV}$$

h?2T`Q# #BHBivi-i? i rQ`F2`?QQb2b HQBb iB?2MT`Q# #BHBiv i?;B p2BbpBM; i?2 ?B;?2bi miBHBiv,

$$_n(!) = Pr(U_n(!) \quad \max[U_k(!); 8k \ 6=n:])$$
$$= \frac{(v_n/P_n r_n^{1} \quad)}{\sum_{k2N} (v_k/P_k r_k^{1} \quad)}$$

h?2`27Q`2Q` bmTTHvBmBbH,Q+ iBQM

$$L_n = \ _n(!) \ L = \frac{(v_n/P_n r_n^{1} \quad)}{\sum_{k2N} (v_k/P_k r_k^{1} \quad)} L \qquad \text{UkyV}$$

h?22Q;` T?v Q7 i?2 KQ/2lH+1+QHQi+BiBMQMb1M2;BQMbX PM2`2;BQM +Q QM2 HQ+ iBQM- r?B+? Bb bbmK2/ iQ #2 i?2N`2;2BQ7Mb+B2Mi?2XMhi?2Q2M QM2 //BiBQM H `2;BQM `2T`2b2MiBM; i?2 `2bi Q7 i?2 rQ`H/X GQ+ iB

elev$_{ni}$ X aT2+B}+ HHvi-?7bHQB-;?2QMHiBim/2 in?-i`HpQ+BBMiQ`Q Kb+2M/BM;

mT?BHHV `2bmHib BM H `;2` 1"1 i? M i?2 è2p2<b2/BX 2h+?2 Q BM K2`MHBM

2H2p iBQM BM i?Bb T T2` Bb bBKTHB}2/ 7`QK amM Ukyk9V BM i? i Bi Q

i i?2 Q`B;BM M/ /2biBM iBQM M/ MQi QM `Q /b- b BM7` bi`m+im`2 B

//BiBQM-MQi2 i? i /Bbi M+2 M/ 1"1 QMHv HQM; i?2 2/;2 Q7 irQ /D +2

i?Bb T T2`- b b?QrM #v i?2 i` /2 +Qbi 7mM+iBQMb BM 1[m iBQMb UkjV

h?2 2H2p iBQM K2 bm`2 mb2/ BM i?Bb T T2` Bb `2H i2/ iQ LmMM M/

UkykyV- r?Q +`2 i2 K2 bm`2b iQ [m MiB7v i?2 BKT +i Q7 ;2Q;` T?B+ H

6 D;2H# mK M/ a+? H UkykyV- r?Q 2p Hm i2 i?2 BKT +i Q7 KQmMi BM

M2irQ`Fb BM [m MiBi iBp2 bT iB H KQ/2HX

1M/Q;2MQmbHv /2i2`KBM2/ BM7` bi`m+im`2 U?B;?r vb M/ imMM2Hb

`2;BQM iQ KBiB; i2 i?2 i` MbTQ`i iBQM +Qbi 7`QK $^{r}_{n}$/BMi/$^{i}_{n}$M+2MQi/2H2p

H-Q i B Q M i-n X ` -

$$t_{in} = \exp\left(\frac{1}{2}\,\frac{(\ _{dist} + \ _{dist}^{r}\ _{i}^{r})\ \log(dist_{in})}{1} + \frac{1}{2}\,\frac{(\ _{dist} + \ _{dist}^{r}\ _{n}^{r})\ \log(dist_{in})}{1}\right)$$
$$\exp\left(\frac{1}{2}\,\frac{(\ _{elev} + \ _{elev}^{t}\ _{i}^{t})\ \log(elev_{in})}{1} + \frac{1}{2}\,\frac{(\ _{elev} + \ _{elev}^{t}\ _{n}^{t})\ \log(elev_{in})}{1}\right) \qquad U\ k\ j\ V$$

9Xk:2M2` H 1[mBHB#`BmK

h?2 7QHHQrBM; 2[m iBQMb bQHp2 i?2 bT iB H ;2M2` H 2[mBHB#`BmKX

$$w_n L_n = \sum_{n2N} {}_{in} w_n L_n = \sum_{n2N} \frac{(1 \quad) L_i}{F} \left(\frac{w_i}{1 A_i} T_{in}\right)^1 \quad P_n^{\ 1} \ w_n L_n$$

h` /2 +Qbi HQM; i?2 H2 bi@+Qbi T i?,

$$`; K B_{k,i} M T = \sum_{in\ 2L} (t_{in} j I_{in}^{in} = 1)$$

G #Q` K `F2i +H2 `b,

$$L_n = {}_n(!) \quad L = P \frac{(v_n/P_n r_n^1 \quad)}{k2N\ (v_k/P_k r_k^1 \quad)} L$$

r?2`2M/ $P_i L_i$ = L X S`B+2 BM/2t,

$$P_n^1 \quad = \sum_k \frac{(1 \quad) L_k}{F} \left(\frac{w_k}{1 A_k} T_{kn}\right)^1$$

_2Mi,

$$r_n = \frac{1}{\quad} \frac{w_n L_n}{H_n}$$

h?27Qm` 2[m iBQMb #Qfw2 Lb QPH p2 X?2,

9Xj :Qp2`MK2Mi ai`m+im`2

AM7` bi`m+im`2 Bb /2i2`KBM2/ #v irQ iB2`b Q7 ;Qp2`MK2Mi, i?2 M iBQM
;Qp2`MK2MiX h?2 M iBQM H ;Qp2`MK2Mi +QHH2+ibi t BM+QK2 M/ `2 H
;Qp2`MK2MiZ X 2M2Qi2 i?2 i t BM+QK2 i?2 M iBQM H ;Qp2`MK2Mi F22Tb
/2MQi2 i?2 BM/2t 7Q` TZ p2 M+2 b X BM2+QK2 HHQ+ i2/ iQ i?2 T`QpBM+B
pX q?BH2 i?2 iQi H #m/;2i Bb 2M/Q;2MQmbHv bQHp2/- i?2 #m/;2i HHQ+
#2 + HB#` i2/ iQ K i+? i?2 Q#b2`p2/ T`QpBM+B H ?B;?r v /Bbi`B#miBQM
`2 HHQ+ iBQM TH M 2tQ;2MQmb Bb +`m+B H BM Q`/2` iQ bim/v Bib BKT
1[m iBQM UkeV b?Qrb i? i i?2 iQi H ;Qp2`MK2Mi BM+QK2 Bb bTHBi #2ir

$$Z + \sum_p Z_p = \sum_n \frac{w_n L_n}{\quad} \qquad \text{UkeV}$$

Re

G 2 i r upper;n # 2 i ? 2 B M p 2 b i K 2 M i Q M ? B ; ? r 7 v b Q K M ? H 2 Q M + i B Q M H ; Q p 2 ` M K 2 M i X G r lower;n
2 i ? 2 T ` Q p B M + B H B M p 2 b i K 2 M i Q M X ? G 2 t i ? r v b M M H Q # 2 i B ? 2 M B M p 2 b i K 2 M i b
B M i m M M 2 H b 7 ` Q K M i B Q M H M / T ` Q p B M + B H ; r n Q p 2 / t n K 2 M ? b 2 - i ` 2 i b T 2 + i B
B M p 2 b i K 2 M i B M ? B ; ? r v b M / i m X M H 2 H b B M p 2 b i K 2 M i Q M ` 2 K 2 b m ` 2 / B M F B

$$r_n = r_{upper;n} + r_{lower;n} \qquad \text{U k d V}$$

$$t_n = t_{upper;n} + t_{lower;n} \qquad \text{U k 3 V}$$

q B i ? # m / ; 2 7 - Q i ? 2 M i B Q M H ; Q p 2 ` M K 2 M i b Q H p 2 b i ? 2 7 Q H H Q r B M ; b Q +
K t B K B x B M ; i ? 2 2 t T 2 + i 2 / m i B H B i v 7 Q ` i ? 2 + Q m M i ` v ,

$$\underset{(r_{upper;n};\, t_{upper;n})}{\text{Max}} U = \left(\frac{1}{\quad}\right) \sum_{n2N} (v_n / P_n r_n^1)^{\frac{1}{\quad}} \qquad \text{U k N V}$$

b m D # 2 + i i Q i ? 2 # m / ; 2 i + Q M b i ` B M i B M 1 [ m i B Q M U j y V M / i ? 2 + Q M b i ` m + i
b i ` B M i B M 1 [ m i B Q M U j R V X A M T ` + i B + 2 - i ? 2 H # Q ` b m T T H v + Q M b i ` B
h ? B b B b # 2 + m b 2 i ? 2 i t ` i 2 r B H H # 2 + H B # ` i 2 / i Q # 2 ` 2 H i B p 2 H v b K H H
N V

w ° D€ Đp cĐ €D€ X D € + i

; Qp 2 ` M K 2 M i b B b ; B p 2 M b

$$\underset{(r_{lower;n};\ t_{lower;n})}{\mathrm{Max}} U_p = \left(\frac{1}{\quad}\right) \sum_{n}^{p} (v_n / P_n r_n^{1} \quad)^{\frac{1}{\quad}}$$

9X8JQ/2H S`2/B+iBQMb

$U_n = v_n/P_n r_n^1$ Xh ? 2 K `; B M H m i B H B i v 7 ` Q K B M p 2 b i K 2 M i Q M ? B ; ? r v b B b ,

$$\frac{@U}{@r_{upper;m}} = \frac{1}{2} C_1 C_2 \sum_i^N x_{in} \sum_x^V I_{kl}^{xm} \frac{r_{dist} \log(dist)_{xm}}{area_m} + \sum_x^V I_{kl}^{mx} \frac{r_{dist} \log(dist)_{mx}}{area_m} \qquad U j d V$$

r ? 2 ` $C_1 = (U)^1 P_n U_n P_n^1$ M / $C_2 = \frac{1}{1} X I_{kl}^{xm} = 1$ B 7 2 / x, m 2 B b Q M i ? 2 H 2 b i @ + Q b i T

7 ` Q k K i Q X $I_{kl}^{xm}$ + M # 2 p B 2 r 2 / b K 2 b m ` 2 Q 7 ; 2 Q ; ` T ? B + + 2 M i B b H K Q v ` # 2 + m

H B F 2 H v i Q # 2 Q M Q M 2 Q 7 i ? 2 H 2 b i @ + Q b i T V i B b i ? 2 i b ? 2 i H Q 7 + H B Q H M Q B b i B + Q M

m

`2~2+iB?M;T`QTQ`iBQM Q7 M iBQM H 2tT`2bbr vb BM kyRNX h?2 `2K BI
KQM; kj T`QpBM+2b- T`QTQ`iBQM H iQ i?2B` b? `2 Q7 T`QpBM+B H ?I

+ T i m `#2v/ i ? 2 + Q 2 { + B 2 M i -

o _ A " G 1 a	H ij M V U s
H M U ij / V B b i	@ R X k 3 9
	U y X y d 9 V
H M U ij 2 V H 2 p	@ y X y R 8
	U y X y y 8 V
H M U ij / V B b ? r y ij	R X R d 9
	U y X k 8 9 V
H M U ij 2 V H 2 p M ij M H	y X R 9 R
	U y X y d d V
P # b 2 ` i p B Q M b	d j - 9 j k
J Q / 2 H	A o
P ` B ; B M	

2+QMQTKB+K2i2`b + HB#` i2/ iQ #2 T`QTQ`iBQM H iQ *?BM öb `2H iBp2
K2Mi BM i?2 `2bi Q7 i?2 rQ`H/ Bb b2i b *?BM öb iQi H 2KTHQvK2Mi KmH
TQTmH iBQM iQ i?2 ;HQ# H TQTmH iBQMX h?2 r ;2 H2p2H BM i?2 `2bi
QM *?BM öb :.S T2` + TBi `2H iBp2 iQ i?2 rQ`H/öb :.S T2` + TBi BM ky
rBi? i?2 ?B;?2bi +QMi BM2` i?`Qm;?TmiBM kyRN `2 b2H2+i2/- M/ i?2
i?2 `2bi Q7 i?2 rQ`H/- HHQrBM; BMi2`M iBQM H i` /2X h #H2 U3V BM
TQ`ib M/ i?2B` +QMi BM2` i?`Qm;?TmiX AM kyRN- a? M;? B TQ`ib HQ
*?BM öb iQi H i` /2 p Hm2 U2tTQ`ib M/ BKTQ`ibV UaJPSa UkykyVVX *
TQ`ib ? M/H2/ i?2 p bi K DQ`Biv Q7 *?BM öb BMi2`M iBQM H i` /2X A K
i? i i?2 /Bbi M+2 M/ #BH i2` H 2H2p iBQM 7`QK i?2 TQ`ib iQ i?2 `2bi Q
QM2X h?Bb bbmKTiBQM Bb K /2 iQ 7Q+mb QM ?Qr ;Qp2`MK2Mib KBiB
i? M BMi2`M iBQM H QM2bX aBM+2 ;QQ/b Kmbi biBHH #2 i` MbTQ`i2/ iQ
i` /2 BMpQHp2b bB;MB}+ Mi +Qbib- i?Bb bBKTHB}+ iBQM /Q2b MQi bB;
M H i` /2 Q` i?2 /Bbi`B#miBQM Q7 BMi2`M H BM7` bi`m+im`2X //BiBQ
i?2 `2bi Q7 i?2 rQ`H/ Bb 2t+Hm/2/- M/ BMi2`M iBQM H BKKB;` iBQM Bb

8Xk AMbi`mK2Mi H o `B #H2b

h?Bb b2+iBQM BMi`Q/m+2b irQ b?B7i@b? `2 BMbi`mK2Mi H p `B #H2bX
K2Mi 7Q` ?B;?r vb BM *?BM mbBM; i?2 JBM; .vM bivöb *Qm`B2` `Qmi2
U8XkXkV BMi`Q/m+2b M BMbi`mK2Mi 7Q` imMM2Hb BM *?BM mbBM; G
/ i2/ b2/BK2MibX

8XkXR JBM; *Qm`B2` _Qmi2b

h?2 }`bi BMbi`mK2Mi bi2Kb 7`QK i?2 *?BM2b2 JBM; /vM bivöb ?BbiQ`B
bi iBQMbX .m`BM; i?2 JBM&¶.Rv9 9v- UkRBeV /2p2HQT2/ M 2ti2MbBp2 +
FMQrM b i?2 ôJBM; AKT2`B H SQbiô 7Q` #2ii2` +QKKmMB+ iBQM M/ /K
h?Bb bvbi2K 72 im`2/ M2irQ`F Q7 `2H v bi iBQMb- Q` ôTQbi bi iBQMb
?Q`b2b M/ `2bi- 2Mbm`BM; i?2 2{+B2Mi i` MbKBbbBQM Q7 Q{+B H /Q+
+QMM2+i2/ i?2 + TBi H- "2BDBM;- rBi? F2v +BiB2b BM HH /B`2+iBQM
M/ snBMX LQi #Hv- K Mv Q7 i?2 +`m+B H +BiB2b BM i?2 JBM; .vM biv
lbBM; i?Bb / i b2i iQ bim/v *?BM öb BM7` bi`m+im`2 Bb `2+QKK2M/2/ #v
2i HX UkykjVXV h?2 / i +QK2b 7`QK > `p `/ . i p2`b2- M/ i?Bb T T2`
BHHmbi` iBQM Q7 i?2 / i Bb b?QrM BM 6B;m`2 9X h?2 BMbi`mK2Mi Bb B

##`2pB	iBQM	L K2	S`Q#H2Kb
bm	lM+QMbQHbB2//B2K2Mi62		r T`Q#H2Kb 7QmM/
bb	aBHB+Bb+2HBbK2Mi	`v `Q+Fb>	`/
Tv	Sv`QH biB+b		> `/
bK	JBt2b2/BK2Mi	`v `Q+Fbi2`@bQHm#H2	
b+	* `#QM i2 b2/BK2Mi	`v `Q+Fb@bQHm#H2	
2p	1pTQ`Bi2b		q i2`@bQHm#H2
p	+B/pQH+ MB+	`Q+Fb>	`/
pB	AM2`K2/B i2 pQH+ MB+	`Q+F/b	
p#	" bBpQH+ MB+	`Q+Fb >	`/
T	+B/THmiQMB+	`Q+Fb>	`/
TB	AM2`K2/B i2 THmiQMB+	`Q+F/b	
T#	" bBTHmiQMB+	`Q+Fb >	`/
Ki	J2i KQ`T?B+b		> `/
B;	A+2M/:H +B2`b		J2Hi #H2

h #H2 j, G2p2H@R GBi?QHQ;v hvT2b M/ S`Q#H2Kb 7Q` hmMM2

LQi2, h?Bb i #H2 bmKK `Bx2b i?2 H2p2H@R HBi?QHQ;v ivT2b M/ i?2B` bbQ+ iBQMX h?2 `Q+F ivT2 M K2b M/ ##`2pB iBQMb `2 bQm`+2/ 7`QK > `iK MM ;2M2` H +? HH2M;2b TQb2/ #v 2 +? `Q+F ivT2 `2 # b2/ QM K2+? MB+ H 2M;BM iQ MQi2 i? i r?BH2 i?2 +? HH2M;2b HBbi2/ ;2M2` HHv TTHv iQ bm#+ i2;Q`B2b Q7 i?2b2 +? HH2M;2b + M p `v +`Qbb /Bz2`2Mi bm#+ i2;Q`B2bX

BM+Hm/BM; imMM2H +QMbi`m+iBQMX 6Q` BMbi M+2- r2 F `Q+Fb i? i ` i2MbBp2 bmTTQ`ibvbi2Kb r?BH2 /B;;BM; imMM2HbX SQ`Qmb `Q+Fb K v M/ r i2`T`QQ}M; K2 bm`2b #2+ mb2 TQ`Qmb `Q+Fb ? p2 KBMmi2 bT +2b K v T bbX > `/`Q+Fb + M + mb2 2t+2bbBp2 r2 ` QM imMM2H@#Q`BM; K ?B;?Hv `2H2p Mi 7Q` imMM2H +QMbi`m+iBQMX h #H2 UjV bmKK `Bx2b 1 `i? U> `iK MM M/ JQQb/Q`7 UkyRkVV M/ i?2B` T`Q#H2Kb- BM bBKT Ub22 HBi2` im`2 BM K2+? MB+ H 2M;BM22`BM;, w? M; Ukyy9V- hm`M2` :mM ` iM2 UkyR3VVX 6B;m`2 U8V b?Qrb i?2 HBi?QHQ;B+ H /Bbi`B#mi 7`QK > `iK MM M/ JQQb/Q`7 UkyRkV M/ p BH #H2 QM 1b`BX

.m2 iQ i?2B` BM?2`2Mi ? `/M2bb- bQK2 `Q+Fb BM h #H2 UjV `2 +? H aBHB+B+H biB+ b2/BK2Mi `v `Q+Fb- Tv`Q+H biB+b- pQH+ MB+ `Q+Fb U `Q+Fb U +B/- BMi2`K2/B i2- M/ # bB+V- M/ K2i KQ`T?B+b `2 HH 2t //BiBQM HHv- K i2`B Hb HBF2 B+2 M/ ;H +B2`b `2 T`Q#H2K iB+ #2+ iQ mMbi #H2 7QmM/ iBQMb M/ r i2` BM;`2bb- r?BH2 r i2`@bQHm#H2 ` + `#QM i2 b2/BK2Mi `v- M/ 2p TQ`Bi2b- T`2b2Mi +? HH2M;2b /m2 iQ i? 2tTQb2/ iQ r i2`X

lM+QMbQHB/ i2/ b2/BK2Mi Bb b2/BK2Mi i? i Bb HQQb2Hv `` M;2/Q` `2 MQi +2K2Mi2/ iQ;2i?2`- 7QmM/ 2Bi?2` i i?2 bm`7 +2 Q` i /2Ti?X h? i?2 *2MQxQB+ ;2X 1t KTH2b Q7 mM+QMbQHB/ i2/ b2/BK2Mib `2 b M/b HQ2bb- M/ #2 +? b M/bX *QKT `2/ iQ i?2 Rj Qi?2` ivT2b Q7 `Q+Fb- mM

6B;m8 2GBi?QHQ;B+ H .Bbi`B#miBQM Q7 *?BM
LQi2, h?Bb };m`2 /2TB+ib i?2 HBi?QHQ;B+ H /Bbi`B#miBQM Q7 H2p2H@R HBi
Bb bQm`+2/ 7`QK > `iK MM M/ JQQb/Q`7 UkyRkVX h?2 mM+QMbQHB/ i2/ b2/B

72r T`Q#H2Kb M/ `2 i?2 2 bB2bi iQ rQ`F QM r?2M /`BHHBM; imMM2HbX
lM+QMbQHB/ i2/ b2/BK2Mib BM *?BM - /2TB+i2/ BM "H +F BM 6B;m`2
BM i?2 LQ`i? *?BM SH BM- i?2 u M;ix2 _Bp2` .2Hi - i?2 h `BK " bBM B
" bBM BM MQ`i?2 bi *?BM M/ i?2 GQ2bb SH i2 m BM +2Mi` H@MQ`i?
rB/2 ` M;2 Q7 +HBK i2b M/ T`2+BTBi iBQM T ii2`MbX h?2 LQ`i? *?BM
.2Hi 2tT2`B2M+2 i2KT2` i2 KQMbQQM +HBK i2 +? ` +i2`Bx2/ #v ?Qi
/`v rBMi2`b- rBi? MMm H T`2+BTBi iBQM ` M;BM; 7`QK eyy iQ R-8yy KI
bmKK2` KQMi?bX AM +QMi` bi- i?2 h `BK " bBM- bBim i2/ BM sBMDB M
rBi? p2`v HQr T`2+BTBi iBQM- Q7i2M H2bb i? M Ryy KK T2` v2 `- K FBI
BM *?BM X h?2 aQM;HB Q " bBM BM i?2 MQ`i?2 bi 2tT2` # ĐR k2` b€

+QMbQ7bimM+QMbQHB/ i2/ b2/BK2MibX

:Bp2M i?2 `2H iBp2 2 b2 Q7 /`BHHBM; imMM2Hb BM mM+QMbQHB/ i2

ivT2 Q7 `Q+F rBHH #2 mb2/ iQ +QMbi`m+i i?2 BMbi`m$Z_{it}^{Lithology}$K2Mi #2pi?B #H2 7

b?B7i@b? `2 Ao `2T`2b2MiBM; i?2 H2M;i? Q7 ?B;?r v imMM2Hb T`2/B+

mM+QMbQHB/ i2/ b2/BK2MibUalVX A 2biBK i2 i?2 7QHHQrBM; mbBM; P

mbBM; b? `2b Q7 mM+QMbQHB/ i2/ b2/BK2MibUalVX

$$hmMM2H_{i;2014}a? = `2_0 + {}_1 \frac{`2\ Q7_i\ al}{{}_i\ `2\ Q7_i\ al} + {}_i \qquad U93V$$

r?2`i2bi M/b 7Q` T`272+im`2b $M/_{i;2014}$hmMM2Hb a? `2 Q7 i?2 H2M;i? Q7 ?B;?r

BM T`272+imk2yR9 rBi? `2bT2+i iQ i?2 iQi H H2M;i? Q7 ?B;?r v imMM2H

i?2 HBi?QHQ;B+ H BMbi`mK2Mi H p `B #H2 7Q` imMM2Hb Bb + H+mH i2

$$Z_{it}^{Lithological} = hmMM2H_{i;2014}a? \ `2mMM2H_t G2M;i? \qquad U9NV$$

r?2`2mMM2H$_{i;2014}$a? B2b i?2 T`2/B+i2/ imMM2H b? `2 7`QK 2[m iB$_t$QMbU93V

i?2 iQi H H2M;i? Q7 ?B;?r v imMMt2Hb B2 2t+HmbBQM v2 2`bi`B+iBQM 7Q` i

Ao `2[mB`2b i? i i?2 imMM2H b? `2b T`2/B+i2/ #v i?2 b? `2 Q7 mM+QMb

QMHv i?`Qm;? i?2B` T`2/B+iBp2 TQr2` QM i?2 2 bBM2bb Q7 imMM2H +

i? i i?2 2t+HmbBQM `2bi`B+iBQM ?QH/bX

8Xj * HB#` iBQM 6Bi

h #H2 U9V b?Qrb i?2 K2 M M/bi M/ `//2pB iBQM 7Q` ?B;?r vb M/imMM

#v i?2 # b2HBM2 KQ/2HX b mMK i+?2/ KQK2Mib- i?2 K2 Mb M/bi M/ `/

imMM2Hb T`2/B+i2/ #v i?2 KQ/2H /Q MQi HB;M T2`72+iHv rBi? `` i À À

imMM2HbBiBp2 `2H iBQMb BM 6B;m`2UdV +QM}`K i? i i?2 KQ/2H ;2M2
/ i X

o `B #H2b	KQ.K2Mi"	b2HBQ/2H
>rvG2M;i?	J2 jdkX8	j83XR
a.	kkRX9	j8yXy
LiM>Hrv G2M;i?	J2 k38X3	kedX8
a.	kj3Xe	jk8X8
S`pM>rv G2M;i?	J2 RRyXN	NyXe
a.	RkyX8	R3jXN
hMMH G2M;i?	J2 jXy	NX9
a.	R9NXj	RRX9
LiMhHMMH G2M;i?	J2 NXR	eXd
a.	RjyXk	RyXd
S`pkMMMH G2M;i?	J2 eXe	kX3
a.	jeXN	8Xd

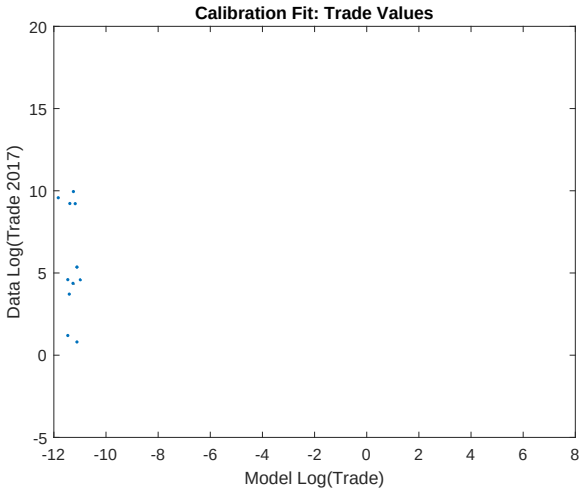
h #H2 9, * HB#` iBQM 6Bi, AM7` bi`m+im`2 G2M;i? BM . i M/ "

LQi2, h?Bb i #H2 bmKK `Bx2b i?2 K2 M M/ bi M/ `/ /2pB iBQM Q7 i?2 BM7`
T`2/B+i2/ #v i?2 # b2HBM2 KQ/2HX h?2 mMBi 7Q` H2M;i? Bb R FBHQK2i2`X h
?B;?r v H2M;i?- M iBQM H ?B;?r v H2M;i?- T`QpBM+B H ?B;?r v H2M;i?- imMM
M/ T`QpBM+B H imMM2H H2M;i?X PMHv imMM2Hb QM ?B;?r vb `2 BM+Hm/2/

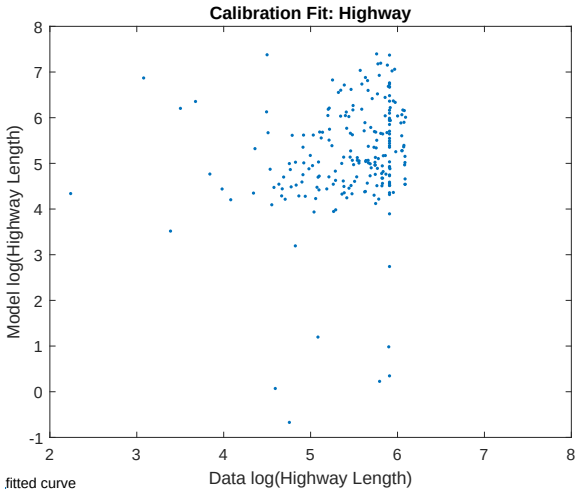
U V2 H q ;2 U#Q V #Q`

6B;m`2 e, * HB#` iBQM 6Bi, h `;2i2/ JQK2Mib

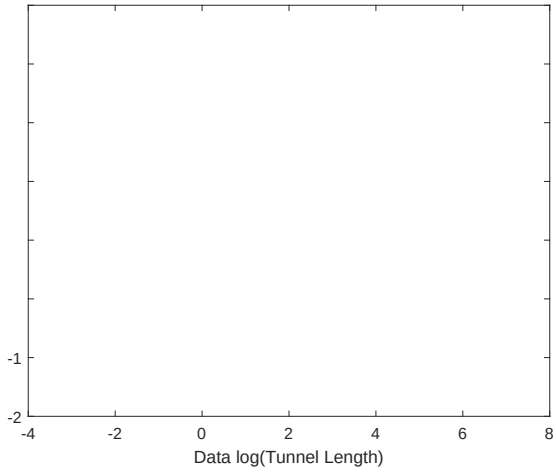
LQi2, h?2b2 };m`2b b?Qr i?2 + HB#` iBQM }i 7Q` i?2 i `;2i2/ KQK2MibX Ai +
i?2 KQ/2H T`2/B+i2/ `2 H r ;2 HB;Mb rBi? i?2 ;`Qbb `2;BQM H T`Q/m+i T2` T2
i?2 KQ/2H T`2/B+i2/ H #Q` Bb BM HBM2 rBi? i?2 MmK#2` Q7 2KTHQv2/ T2QTH
T`272+im`2 H2p2HX . i QM BM+QK2 M/ 2KTHQvK2Mi `2 bQm`+2/ 7`QK T`272



U V h` /2



U #>VB;?r v



U +hVm M M 2 H

6 B;m`2 d, * HB#` iBQM 6Bi, lM@i `;2i2/ JQK2Mib

LQi2, h?2b2 };m`2b b?Qr i?2 + HB#` iBQM }i 7Q` i?2 mMi `;2i2/ KQK2MibX aT
i?2 H2M;i? Q7 ?B;?r v U#V- M/ i?2 H2M;i? Q7 imMM2H U+V `2 BM HBM2 rBi? i
. i QM i` /2 p Hm2 +QK2b 7`QK *?BM öb +Biv UT`272+im`2V H2p2H KmHiB@`
7`QK w?2M; 2i HX UkykkVX . i QM ?B;?r vb M/ imMM2Hb `2 bQm`+2/ 7`QK P

e " b2HBM2 _2bmHib M/ *QmMi2`7 +im H M HvbBb

eXR " b2HBM2 _2bmHib

AM i?2 # b2HBM2 b2imT- #Qi? M iBQM H M/ T`QpBM+B H;Qp2`MK2Mib

?B?vb M/imMM2Hb /Bb+mbb2/ BM b2+iBQM U9VX AM 2bb2M+2-`2;BQ
? p2 KQ`2 imMM2HbX h?2 BM7` bi`m+im`2 /Bbi`B#miBQM # b2/ QM i?2 /
i?2 TT2M/BtX h?2 QTiBK H H2M;i?b Q7 ?B;?r vb M/imMM2Hb #v T`Qp
`2 /2i BH2/ BM h #H2b URRV- URkV- M/URjV- HbQ 7QmM/ BM i?2 TT
bBp2Hv +QKT `2 i?2 BM7` bi`m+im`2 HHQ+ iBQM +`Qbb T`QpBM+2b B
#2ir22M M iBQM H M/T`QpBM+B H ?B;?r vb M/imMM2HbX

eXk *QmMi2`7 +im H M Hvb2b

hrQ +QmMi2`7 +im H b+2M `BQb `2 2t KBM2/X 6B`bi- A M Hvx2 i?2 BK
r?2`2 i?2 M iBQM H ;Qp2`MK2Mi 2t+HmbBp2Hv /2i2`KBM2b QTiBK H BM
b+2M `BQ- T`QpBM+B H ;Qp2`MK2Mib `2 T`Q?B#Bi2/ 7`QK BMp2biBM;
iQ i?2 M iBQM H ;Qp2`MK2MiX a2+QM/- A 2tTHQ`2 i?2 2z2+ib Q7 7m
r?B+? 2 +? T`QpBM+B H ;Qp2`MK2Mi BM/2T2M/2MiHv QTiBKBx2b BM7
Dm`Bb/B+iBQM- M/ i?2 M iBQM H ;Qp2`MK2Mi /Q2b MQi BMi2`p2M2X
T`QpBM+2 `2+2Bp2b b? `2 Q7 i?2 iQi H #m/;2i T`QTQ`iBQM H iQ Bib +
BM kyRNX AM #Qi?T`V™P ™P•Q19•À •T`V™P ™V
BM i`70° p +Q`À€@ @• p• B`À Ð° GÐ°ð +Rx;PBM+Rx;}?0H i?B p T

U 1VQi H >B;?r v U#hVQi H hmMM2H

U+LV iBQM H >B;?r v U/V L iBQM H hmMM2H

U2SV`QpBM+B H >B;?r v UV7 S`QpBM+B H hmMM2H

6B;m`2 3, " b2HBM2 _2bmHib

LQi2, h?Bb};m`2 /BbTH vb i?2 /Bbi`B#miBQM Q7 ?B;?r vb M/ imMM2Hb BM T`2
/QrM #v iQi H- M iBQM H- M/ T`QpBM+B H BMp2biK2MibX S M2H U V b?Qrb i
S M2H U#V BHHmbi` i2b i?2 iQi H imMM2HbX S M2H U+V 7Q+mb2b QM i?2 ?B;?
K2MiX S M2H U/V /2TB+ib imMM2Hb +QMbi`m+i2/ #v i?2 M iBQM H ;Qp2`MK2M
/2p2HQT2/ #v T`QpBM+B H ;Qp2`MK2MibX S M2H U7V b?Qrb imMM2Hb +QMbi`

B M

; BMBbM p2` ;2 `2 H r ;2b- r?BH2 Qi?2` T`QpBM+2b bmz2` r ;2 /2+HBM
/Bbi`B#miBQM Q7 #2M2}ib mM/2` /2+2Mi` HBx2/ bi`m+im`2X AM ;2M2`
`B2M+2/ KQ`2 T`QMQmM+2/ /2+HBM2b BM `2 H r ;2b- r?BH2 2 bi2`M +Q

`2 H;2b mM/2` /2+2Mi` HBx iBQMX

d *QM+HmbBQM

h?Bb T T2` /2p2HQTb [m MiBi iBp2 bT iB H 2[mBHB#`BmK KQ/2H iQ
i`m+im`2 mM/2` irQ@iB2` ;Qp2`MK2Mi bi`m+im`2- r?2`2 #2M2pQH2M
BMi2`2bi2/ T`QpBM+B H ;Qp2`MK2Mib BMp2bi BM ?B;?r vb M/ imMM2H
`2bT2+iBp2 Dm`Bb/B+iBQMbX h?2 bim/v 2t KBM2b ?Qr i?2 BMi2`TH v #
i` HBx iBQM b? T2b BM7` bi`m+im`2 BMp2biK2Mi/2+BbBQMb M/ i?2B`
}M/BM;b bm;;2bi i? i+QHH #Q` iBp2 TH MMBM;#2ir22M M iBQM H M/ T
Km+? Q7 i?2 2{+B2M+v ; BMb 7`QK +2Mi` HBx2/ TH MMBM;r?BH2 HbQ
iQ //`2bb HQ+ H M22/b M/ `2/m+2 BM2[m HBivX .2bTBi2 ? pBM; +QKT

_272`2M+2b

HH2hM2# M/*Qbi b `FQH FBb UkykkV óh?2 r2H7 `2 2z2+ib Q7 i` MbTQ
T`Qp2K2Mi?2-ô2pB2r Q7 1+QMQKB+Uaiv-/kN2R kN8dX

bim`B b-CQb2-J Mm2H: `+Q @a Mi M - M/_Q#2`iQ _ KQb UkyRNV ó
; BMb 7`QK i` MbTQ`i iBQM BM7` bi`m+im`2, 1pB/2M+2 7`QK i?2 :Q
CQm`M H Q7 i?2 1m`QT2 M 1+QMQKB+ RbQ+RBRiN9yX

" H#QMB-*H `2 H2t AM`?UkyRNrVv\ BM7` bi`m+im`2 BMp2biK2Mib M/ i
+Q bi H +B?iX.2b/Bbb2`i iBQM-GQM/QM a+?QQH Q7 1+QMQKB+b M/ S

" M/ ` -LBb? Mi? M/J MD`BF2`:m2Qi`2+?2MBkyHR3bVT2+ib Q7 S p2K2Mi
BM;JQK2MimK S`2bbX

3p `•3C€ÀP{ X3 Mb2•BQ2 9+R#)?Ò,DbB-™pi?2` .m~Q- M/L M+v ZB M GQMPb™p Ð° Ð 2`•PPb

.m` iQM- :BHH2b- S2i2` J JQ``Qr- M/ J ii?2r hm`M2` UkyR9V ó_Q /b
7`QK i?2 la2-pB2r Q7 1+QMQ-KBR aikm/-Be23bR dk9X

.m` MiQM- :BHH2b M/ J ii?2r hm`M2` UkyRRV óh?2 7mM/ K2Mi HH rQ
7`QK la +BiK2bB- M 1+QMQ-KBR+y_R2pB2r- keRe ke8kX

——— UkyRóK V# M ;`Qri? M/i` MbT_Q2pB2rQM7-1+QMQ-KBN-a9m/-BR29yd R99y

1;;2`- S2i2` >- : #`B2H GQmK2 m- M/ LB+QH2 GQmK2 m UkykjV ó*?
BM7` bi`m+im`2 ;`Qri?, J2 bm`2KC2Qm`M/H2 Q27+ iAbMô2`M iB-QRM9 k- 1+QM
Ryjdj9X

6 #2`- "2MD KBM UkyR9V óh` /2 BMi2;` iBQM- K `F2i bBx2- M/ BM/m
*?BM öb L iBQM H h`mMF >B_;?prBv2 a Qb7 21K-ôMQ-KBR aijm/-BR2yb9e RydyX

•Đ`2f-Đ d`6RQ $v° `b–› @ MU™ iB,0 †HyGL #i `d BQ- #2• 2•†Hyl#S&/8p /4 "y• ô•hQ À3

CrQ`bFB- h vHQ` M/ * `H h EBi+?2Mb UkyRNV óL iBQM H TQHB+v 7Q` `
2pB/2M+2 7`QK TT H +?B 2M 2r; 7v +QMQKB+b M/ ai iBbiB+b- RyR U

E`m;K M- S mH URN3yV óa+ H2 2+QMQKB2b- T`Q/m+i /Bz2`
K2`B+ M 1+QMQK- y 8 N8NX

Em`B M- L BM MUkyRV jQ/m+iBQM iQ KQ/2`M i2+?MB[m2b BM ;2Qi2+?MB
M22`BMH;T? a+B2M+2 AMi2`M iBQM HX

GBK Q- LmMQ M/ Mi?QMv C o2M #H2b UkyyRV óAM7` bi`m+im`2- ;2Q;`
+Qbib- M/ i?2 -Q`H/ # MF 2+QM- 8 9dNX

GQmK2 m- : #`B2H UkykjV ó_2;BQM H "Q`/2`b- *QKKmiBM; M/ h` Mb
_2pB2r Q7 1+QMQKB+b M/ ai iBbiB+b- R 98X

J2m`2`b- J `iBM M/ CQ? MM2b JQ2MBmb UkyR3V óPTiBK H Tm#HB+ BM
i?2 T2`BT?2`vXô

JºHH2`- CQ +?BK M/ J `+mb wB2`2` UkyR3V ó miQ# ?Mb M/ DQ#b, `2
BMbi`mK2Mi H pC Q 7 l`# M- 1R+yQ 3 Bj+Xb

L._* UkyR V E ? Z ¿ ê ¾ 1 ¿ / b † s Œ Y [" , » ƒ „ e Ä , » ñ ½ ¥ Y © ULQiB+2
7`QK i?2 L iBQM H .2p2HQTK2Mi M/ _27Q`K *QKKBbbBQM QM .2H2;
aQK2 h` MbTQ`i iBQM S`QD2+ib M/ aBKTHB7 BMQMTH`Q2p2HSQ`TK2Mm`
_27Q`K *QKKBbbBQM Q7 *?BM X

——— UkyRdV E ? Z ¿ ê ¾ 1 ¿ É B „ / b Ÿ © g ' Œ Y [" , » ƒ ¥ Y © ULQiB+2
QM 6m`i?2` .2H2; iBM; i?2 TT`Qp H mi?Q`Biv 7Q` :Qp2`MK2Mi AMp
S`QD2+ibV QM H .2p2HQTK2Mi M/ _27Q`K *QKKBbbBQM Q7 *?BM X

LmMM- L i? M M/ .B2;Q Sm; UkyRkV ó_m;;2/M2bb, h?2 #H2bbBM; Q7
_2pB2r Q7 1+QMQKB+b M/ ai iBbiB+b- N9 URV- ky jeX

_2//BM;- ai2T?2M C UkyReV ó:QQ/b i` /2- 7 +iQ
1+QMQ- B+b- R93 RedX

_2//BM;- ai2T?2M C M/ 1bi2# M _QbbB@> Mb#2`; UkyRdV
_2pB2r Q7 1+QMQKB+b

a Mi K `B - J `i UkykyV ó_2b? TBM; AM7` bi`m+im`2, 1pB/2M+2 7`QK i

a*UkyRëV©ó ¥g'[""c UkyRe VU* i HQ; Q7 :Qp2`MK2Mi@ TT`Qp2/ A
S`QD2+ib UkyRe ai/ i2B*QMmW+ B HXQ7 *?BM

aJPSa UkykyVMó ZgRÁ ö1” d9V UkyRN J BM ai iBbiB+ H . i Q7 a? M;?

amM- q2Bx? QhU?k1 9V? Ab LQi 6H i, "BH i2` H 1H2p iBQM b *QKTQM
S?X.X /Bbb2`i iBQM- lMBp2`bBiv Q7 *QHQ` /Q- "QmH/2`X

hm`M2`- CQ?M _SQ+Fy@eV Q+F2i2/ b? 7ib 7Q` ?B;?r v- bi`m, +i`m`M2b 7Q`m iMBQM
_2b2 `+? "Q `/X

sm-> M;iB M M/E2Mi `QL F DBK UkyRdVó>B;?r vb M/BM/mbi`B H/2
`2;BQMb Q7S?T2Mb- BM _2;BQM NHeaU+kBV2-Mk+2 j8eX

w? M;- GB Mv M.;`BkyHy2/Vb? 7ib BM `Q+F, M, *H_vbT`2bMX /2bB;M

w?2M;- >2` M- CQ? MM2b hº##2M- 1`BF .B2ix2M# +?2`- . MB2H JQ` M-
M/ . #Q :m M UkykkVó1Mi`QTv@# b2/ *?BM2b2 +Biv@1H2pMQKJB+AP i
avbi2Kb _2b2 9`U?9V- 8RN 899X

h ? 2 Q ` v

X R 6 P * M / J ` ; B M H l i B H B i v 7 Q ` S H M M 2 ` ö b S ` Q # H 2 K b

h ? 2 M i B Q M H ; Q p 2 ` M K 2 M i ö b T ` Q # H 2 K B b b 7 Q H H Q r b ,

$$\max_{(r_{upper;n};\, t_{upper;n})} U = \left(\frac{1}{\quad}\right) \sum_{n2N} (v_n/P_n r_n^1)^{\frac{1}{\quad}}$$

b m D # 2 + i i Q U V # m / ; 2 i + Q M b i ` B M i

$$Z \sum_{n2N} w_n L_n^{infra}$$

U # V + Q M b i ` m + i B Q M r Q ` F 2 ` b m T T H v + Q M b i ` B M i

$$\frac{P_{n2N} L_n^{infra}}{P_{n2N} L_n} \quad 1$$

U + ; V Q Q / b K ` F 2 i + H 2 ` b ,

$$w_n L_n = \sum_{n2N} {}_{in} w_n L_n = \sum_{n2N} \frac{(1 \quad) L_i}{F} \left(\frac{\quad}{1} \frac{w_i}{A_i} T_{in}\right)^1 \quad P_n^{\ 1} \ w_n L_n$$

U / V ` / 2 + Q b i H Q M ; i ? 2 H 2 b i @ + Q b i T i ? b ,

$$` ; K B_{kl} M = \sum_{in\ 2L} (t_{in}\, j I_{kl}^{in} = 1) \quad 8k; l\ 2\ N$$

U 2 V H # Q ` K ` F 2 i + H 2 ` b ,

$$L_n = {}_n(!) \quad L = P \frac{(v_n/P_n r_n^1)}{{}_{k2N} (v_k/P_k r_k^1)} L \qquad U\ 8\ R\ V$$

r ? 2 ` L ? 2 T ` B + 2 B M / 2 t À

h ? 2G ; ` M ; B M Q 7 i ? 2 M i B Q M H ; Q p 2 ` M K 2 M i ö b T ` Q # H 2 K B b b 7 Q H H Q

$$L = \left(\frac{1}{\quad}\right) \sum_{n2N} (v_n/P_n r_n^1)^{\frac{1}{\quad}}$$

$$\sum_{n}^{N} {}_{n;1} w_n L_n \sum_{i2N} \frac{(1 \quad) L_i}{F} \left(\frac{w_i}{1 A_i} T_{in}\right)^1 P_n^{\ 1} w_n L_n$$

$$\sum_{n}^{N} {}_{n;2} P \frac{(v_n/P_n r_n^1)}{k2N (v_k/P_k r_k^1)} \frac{L_n}{L}$$

$$\sum_{kl2L} {}_{kl;3} \sum_{in\,2L} (t_{in}\, jI_{kl}^{in} = 1) \quad T_{kl}$$

$$4\left(\sum_{n2N} w_n (c_n^r \ {}^r_{upper;n} + c_n^t \ {}^t_{upper;n}) \quad Z\right)$$

$$5\left(\frac{P_{n2N} L_n^{infra}}{P_{n2N} L_n} \quad 1\right)$$

U 8 k V

r ? 2 ` 2 $_{n;1}$ - $_{n;2}$ - $_{kl;3}$ - $_4$ M / $_5$ ` 2 i ? 2 G ; ` M ; B M K m H i B T H B 2 ` b X A M T ` + i B + 2

r Q ` F 2 ` b m T T H v + Q M b i ` B M i B b M $_5$ = 0 # K h M ? / 2 B M ; b i @ Q i ? 2 i ` + Q M / B i B Q M r B i ? `

$^r_{upper;n}$ B K T H B 2 b ,

$$\frac{@L}{@\,{}^r_{upper;m}} = 0 :$$

$$\frac{@U}{@\,{}^r_{upper;m}} + \sum_{n} \sum_{i} {}_{n;1} \frac{@x_{in}}{\quad}$$

| — {Z — } TTj /T1_4 7.97 Tf 6.5737 22.9077.422 Tdk_4 10- Tf(lTj /T Td <0042004B00540048004200320062002C>Tj /T1_3110569.

. B ` 2 + 1iz 2 + i

X

n

h ? 2

T`Q#H2hK?b2X/Bz2`2M+2 Bb i? i T`QpBM+B H ;Qp2`MQ`b QMHv +QMbB/2`
i?2B` ;Qp2`M2/pTX QpB$^0_1$M+2 $(U_p)^1$ P_{n2p} $U_nP_n^1$ - r?2 U_p^2 Bb i?2 2tT2+i2/ miBHB
rBi?BM T`Q pBM+2 $(\frac{1}{\ })$ $P_{n2p}(v_n/P_n r_n^1)^{\frac{1}{\ }}$ X

$$\frac{@U_p}{@^r_{lower;m}} = \frac{1}{2}C_1C_2 \quad X^p_i \; x_{in} \quad X^{V^0 2p}_x \; I^{xm}_{in} \frac{^r_{dist}\log(dist)_{xm}}{area_m} + X^{V^0 2p}_x \; I^{mx}_{in} \frac{^r_{dist}\log(dist)_{mx}}{area_m} \qquad U8dV$$

$$\frac{@U_p}{@^t_{lower;m}} = \frac{1}{2}C^0_1C_2 \quad X^p_i \; x_{in} \quad X^{V^0 2p}_x \; I^{xm}_{in} \frac{^t_{elev}\log(elev_{xm})}{area_m} + X^{V^0 2p}_x \; I^{mx}_{in} \frac{^t_{elev}\log(elev_{mx})}{area_m} \qquad U83V$$

r?2`V$^0$ Bb i?2 b2i Q7 HH HQ+ ixBQM/b B/iD B+2 M`pQQ BM+2
h?2 `2H iBp2 K `;BM H miBHBiv T2` /QHH ` #2ir22M T`QpBM+B H M/

$$\frac{MU^r_{lower;m}/MC^r_n}{MU^r_{upper;m}/MC^r_n} = \frac{C^0_1 \quad P^p_i \; x_{in} \quad P^{V^0 2p}_x \; I^{xm}_{in} \frac{^r_{dist}\log(dist_{xm})}{area_m}}{C_1 \quad P^N_i \; x_{in} \quad P^V_x \; I^{xm}_{in} \frac{^r_{dist}\log(dist_{xm})}{area_m}} \qquad U8NV$$

r?2`2 i?2 K `;BM H +Qbib + M+2H Qmi #2+ mb2 i?2 +QMbi`m+iBQM +Q
;Qp2`MK2MiX

Xk 1[mBp H2M+2 o `B iBQM

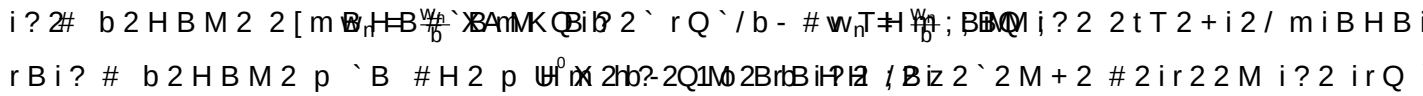
h?Bb T T2` /2}M2b 2[mBp H2M+2 p `B iBQM U1oV b i?2 +? M;2 BM `2 K
i? irQmH/ +?B2p2 i?2 b K2 miBHBiv H2p2H 7i2` +QmMi2`7 +im H +? M
*QMbB/2`irQ 2[mBHB#`BmK BM7` bi`m+im`2 BMp2biK2Mi Qmi+QK2b, $_{n}$ $_{upper;n}$
$_{lower;n}$ M/ i?2 +QmMi2`7 +im$^0_n$ H $^0_{upper;n}$ +Q$^0_{lower;n}$ K2 X h?2v H2 / iQ irQ /Bz2`2Mi H2
Q7 2tT2+i2/ miBHBiv 7U`MU^{0}2 X Q2mM^{0}2 vo X bBM; i?2 2tT2+i2/ miBHBiv BM 2
UR9V- QM2 + M + H+mH i?2 ii?2 rB 22p2b i?2 +QmMi2`7 +im H 2tT2+i2/ mi
b2HBM2 2[mBHB#`BmKX

$$U^0 = \frac{U}{b} = \left(\frac{1}{\ }\right) \quad X_{n2N} \; (v_n/P_n r_n^1)^{\frac{1}{\ }} \quad b^1$$

$$= \left(\frac{1}{\ }\right) \quad X_{n2N} \; (w_n^{\ 1} b^1)/P_n r_n^1)^{\frac{1}{\ }} \qquad UeyV$$

r?2`v$_n^2$ = $\frac{w_n}{\ }$ Bb i?2 iQi H H M/HQ`/ BM+QK2- BM+Hm/BM; Bb#iQ2 MQ`K2Mi BM
r ;2X 1[m iBQM UeRV b?Qrb i? i i?2 r ;2 i? i +?B2p2b i?2 +QmMi2`7 +i

pBBB



" h #H2b M/ 6B;m`2b

6B;mÑ2 p2` ;2 "BH i2` H 1H2p iBQM

LQi2, h?Bb };m`2 b?Qrb 2 +? T`272+im`2öb p2` ;2 2z2+iBp2 #BH i2` H 2H2p i
i?2 b KTH2X h?2 `2;BQMb BM HQr2` T2`+2MiBH2b ? p2 `2H iBp2Hv ~ ii2` `Qmi
i? i i?2 #BH i2` H 2H2p iBQM BM i?Bb T T2` Bb bBKTHB}2/ 7`QK amM Ukyk9VX

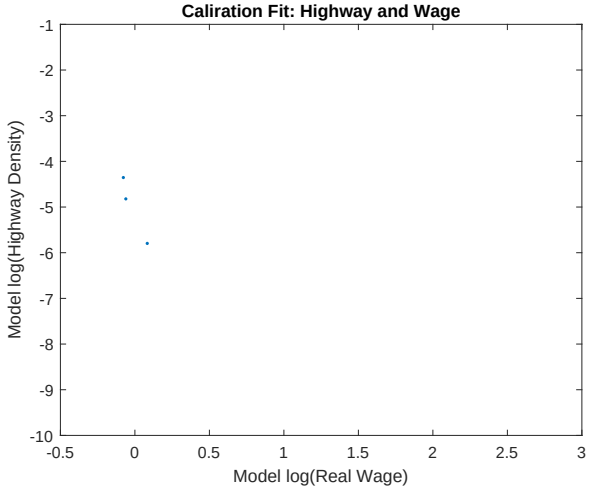
LQX	SQ`i L K2	o Hm2URy-yyy h1lV
R	a? M;? B	9jjy
k	LBMQ#	kd8j
j	a?2Mx?2M	k8dd
9	:m M;x?Qm	kk3j
8	ZBM;/ Q	kRyR
e	hB MDBM	Rdjy
d	sB K2M	RRRk
3	. HB M	3de
N	uBMQFm	893
Ry	GBvMM; M;	9d3
RR	_Bx? Q	98y
Rk	"2B#:mmH7UBM+Hm/BM; ZBMx?Qm- 6	M;+?2jMk; M;- "2B? BV
Rj	.QM;;m M	je3
R9	6mx?Qm	j89
R8	u Mi B	jRy
Re	h M;b? M	kN9
Rd	Zm Mx?Qm	k83
R3	w?m? B	k8e
RN	> BQFm	RNd
ky	CBMx?Qm	R33
kR	CB tBM;	R3d
kk	w?QM;b? M	R9R
kj	a? MQm	Rj8
k9	w? MDB M;	RRk
k8	q2B? B	Ryj

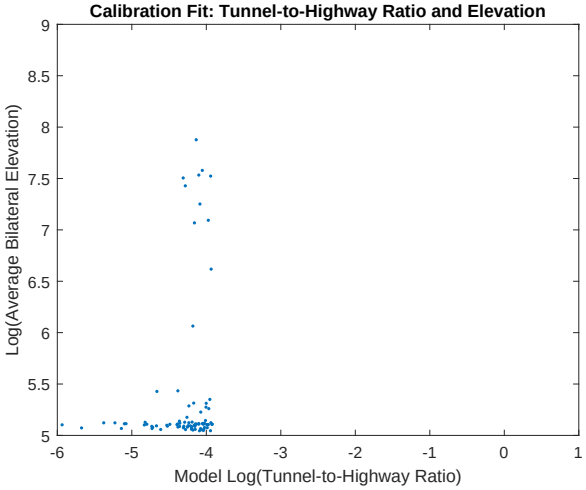
h #H2 3, *QMi BM2`h?`Qm;?TmiQ7 hQT k8 *Q bi H SQ`ib BM *?

h?Bbi #H2 T`QpB/2bi?2 kyRN +QMi BM2`i?`Qm;?TmiUK2 bm`2/BM Ry-yyy h1
7Q`i?2 iQT k8 +Q bi H TQ`ib BM *?BM X "2B#m :mH7- `2T`2b2Mi +QK#BM2/};
6 M;+?2M;; M;- "2B? BVX . i +QK2b 7`QK JBMBbi`v Q7 h` MbTQ`iQ7 *?BM X

o `B #H2b	J Q K 2 b M i H B M Q m i 2 M 7 +im *QRm2M7 +im H k			
>rvG2M;i?	J2 Mj83XRR	kejXdN	RN3XeN
a.	j9NXNN	jRdXd9	R33Xk3
LiM>Hrv G2M;i?	J2 Mked X8j	kejXdN	yXyy
a.	jk8X8y	jRdXd9	yXyy
S`pMrv G2M;i?	J2 MNyX83	yXyy	RN3XeN
a.	R3jXN9	yXyy	R33Xk3
hMMH G2M;i?	J2NMX9j	dXk8	8XyR
a.	RRX9j	RyXee	eXeR
LiMhMMH G2M;i?	J2eMed	dXk8	yXyy
a.	RyXd8	RyXee	yXyy
S`pMMMH G2M;i?	J2kMd8	yXyy	8XyR
a.	8Xd9	yXyy	eXeR

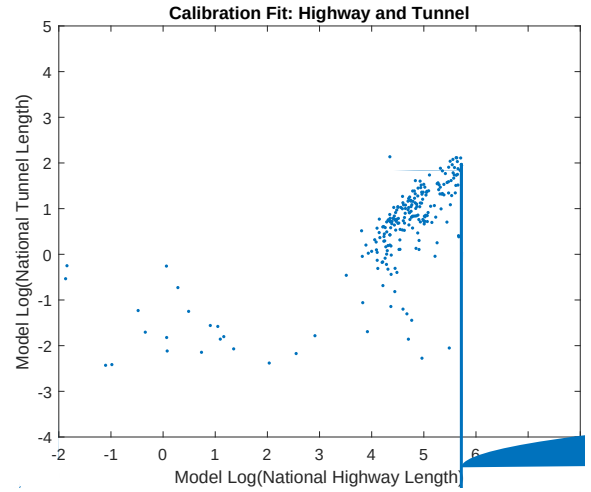
h

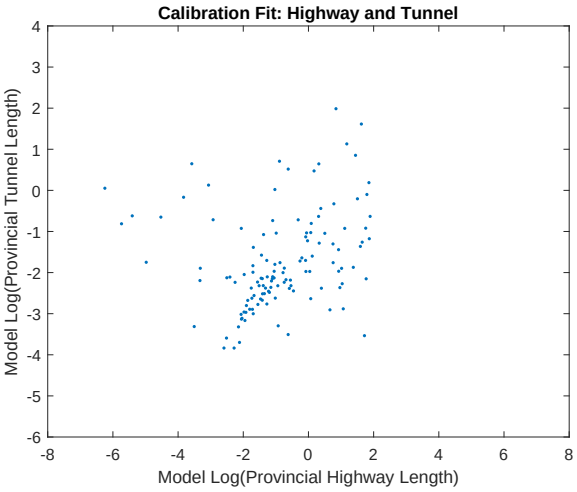




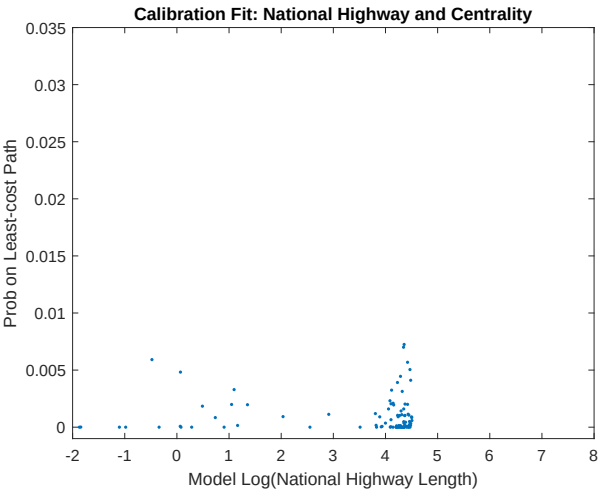
U V>B;?r v M/ AM+QK2

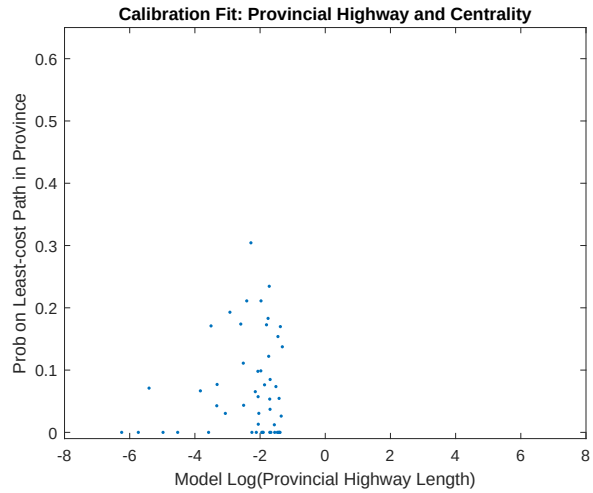
U#hVmMM2H >B;?r v M/ 1H2p iBQM





U+LV iBQM H >B;?r v M/ hmMM2HU/V S`QpBM+B H >B;?r v M/ hmMM2Hb





U2LV iBQM H >B;?r v M/ *2Mi` HBiuV7 S`QpBM+B H >B;?r v M/ *2Mi` HBiv

6B;m`2 Ry, JQ/2H _2THB+ iBQM Q7 aivHBx2/ 6 +ib

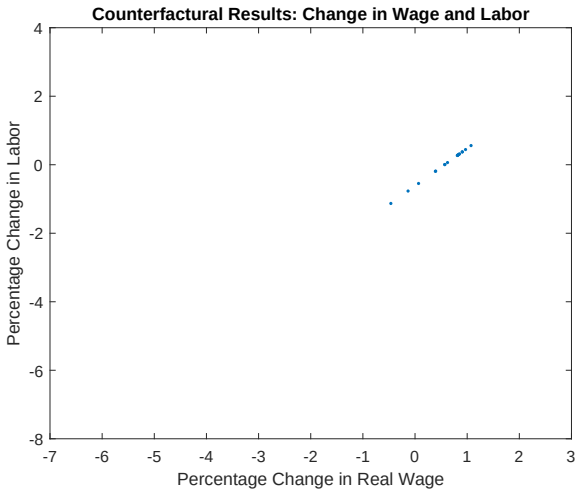
LQi2, h?Bb };m`2 T`2b2Mib bBt T M2Hb BHHmbi` iBM; ?Qr i?2 # b2HBM2 KQ/2
UjVX HB;M2/ rBi? i?2 / i - i?2 KQ/2H T`2/B+ib i? i U V ?B;?r vb `2 TQbBiBp2
imMM2H@iQ@?B;?r v ` iBQ Bb TQbBiBp2Hv +Q``2H i2/ rBi? p2` ;2 #BH i2` H
?B;?r vb `2 TQbBiBp2Hv +Q``2H i2/ rBi? imMM2Hb 7`QK U+V M iBQM H TH MI
?B;?r vb `2 TQbBiBp2Hv +Q``2H i2/ rBi? +2Mi` HBiv rBi?BM i?2 Dm`Bb/B+iB
T`QpBM+B H H2p2HX

tBB

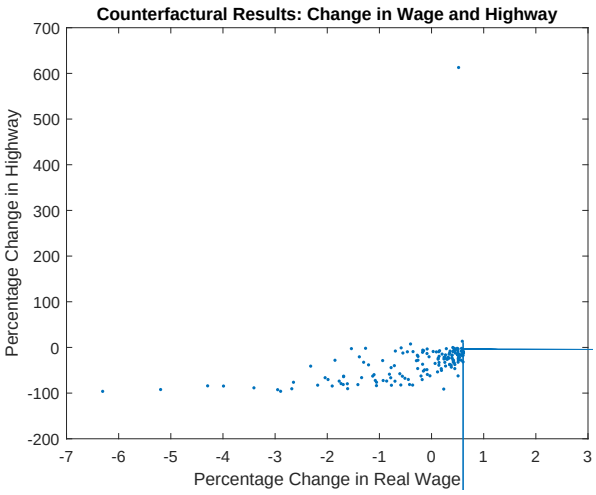
U V2 H q ;2 U#G #Q`

U+>VB;?r v U/YimMM2H

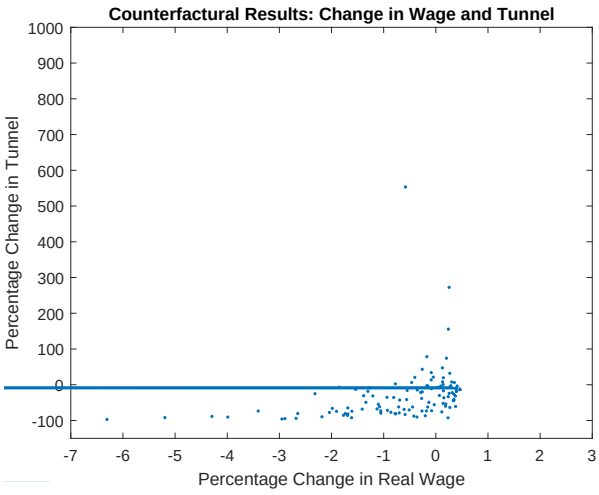
6B;m`2 RR, *QmMi2`7 +im H _2bmHi, .Bbi`B#miBQM Q7 *? M;2b lM/2
LQi2, h?Bb };m`2 BHHmbi` i2b i?2 /Bbi`B#miBQM H BKT +ib Q7 +QKTH2i2 +2M
+`Qbb 7Qm` F2v p `B #H2b, U V `2 H r ;2- U#V H #Q`- U+V ?B;?r v- M/ U/V im



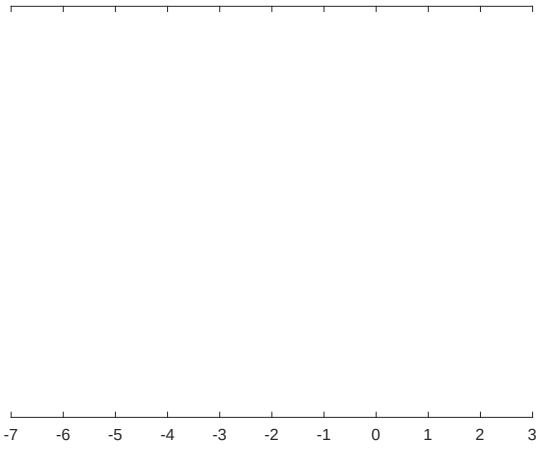
U Vq ; 2 M / G # Q `



U #qV ; 2 M / > B ; ? r v



U +qV ; 2 M / h m M M 2 H

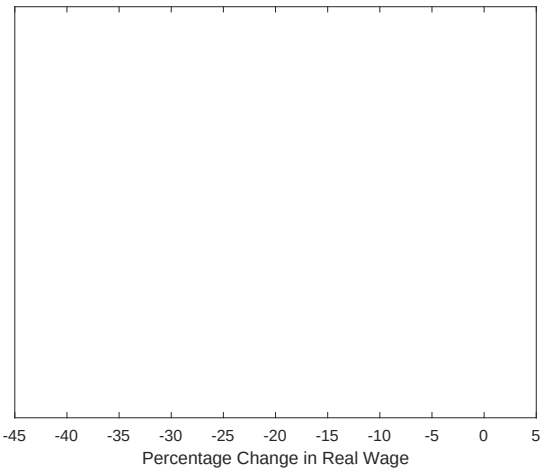


U / Vq ; 2 M / * 2 M i ` H B i v

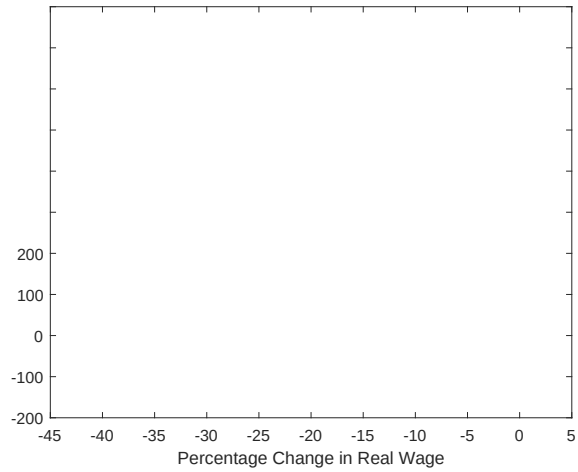
U V2 H q ;2 U#V G #Q`

U+>VB;?r v U/V im M M2H

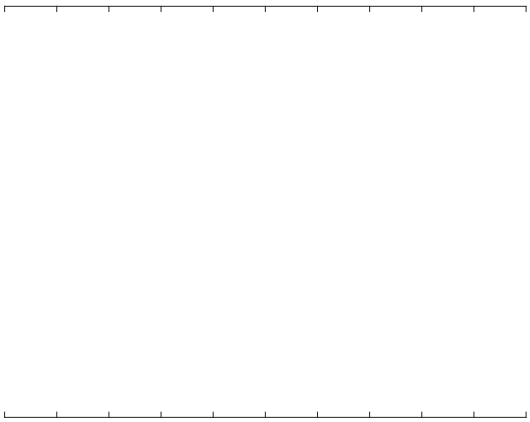
6B;m`2 Rj, *QmMi2`7 +im H _2bmHi, .Bbi`B#miBQM Q7 *? M;2b lM/2`
LQi2, h?Bb};m`2 BHHmbi` i2b i?2 /Bbi`B#miBQM H BKT +ib Q7 +QKTH2i2 /2+2
+`Qbb 7Qm` F2v p `B #H2b, U V `2 H r ;2- U#V H #Q`- U+V ?B;?r v- M/ U/V im



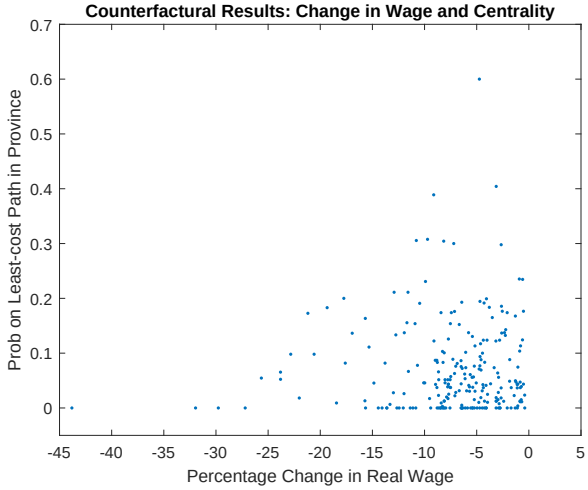
U V2 H q ;2 M/ G #Q`



U#V2 H q ;2 M/ >B;?r v

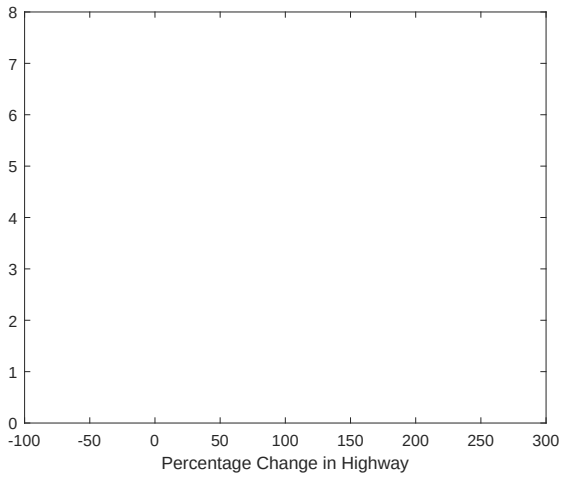


U+V2 H q ;2 M/ hmMM2H



U/V2 H q ;2 M/ *2Mi` HBiv

6B;m`2 R9, *QmMi2`7 +im H _2bmHi, _2H iBQMb?BT Q7 *? M;2b lM/2 h?Bb };m`2 T`2b2Mib i?2 `2H iBQMb?BT #2ir22M `2 H r ;2 +? M;2b M/ p `BQm imMM2H- M/ +2Mi` HBivV mM/2` i?2 +QKTH2i2 /2+2Mi` HBx iBQM b+2M `BQX i2`7 +im H +? M;2- H #Q` Bb KB;` i2/ iQ i?2 `2;BQMb rBi? ?B;?2` +? M;2b BM 2tTH BM i?2 K2+? MBbK Q7 +? M;2 BM `2 H r ;2, _2;BQMb i? i2tT2`B2M+2/ ; BMp2biK2Mi b22 ;`2 i2` `Bb2b BM `2 H r ;2X S M2H U/V 7m`i?2` 2tTH BMb i?2 / _2;BQMb rBi? ;`2 i2` T`Q# #BHBiv Q7 #2BM; QM i?2 H2 bi T i? BM i?2 T`QpBM +? M;2b BM i?2 `2 H r ;2X

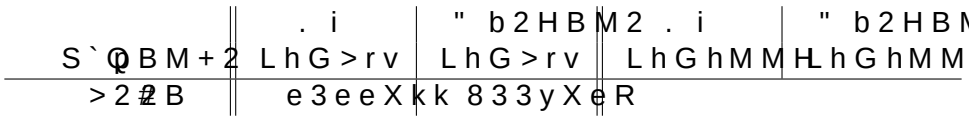

8
7
6
5
4
3
2
1
0
-100
-50
0
50
100
150
200
250
300
Percentage Change in Highway

U V

S`QpBM+2	. i	>rv	" b2HBM2	>rv	. i	hMMH	" b2HBM2	hMMH
>2#2B	3kedXkN	ekykXej	RRReXeN	R98X99				
a? MtB	9y9yXR9	jkjeXyk	RNkNXdk	RyRX83				
AMM2`QM;QHB	83NdXkj	9RR3X8N	jj8Xkd	RR8Xy9				
GB QMBM;	je3jXkR	j3dyXNd	93NX8e	N3Xjj				
CBHBM	kNRjXjN	k9N3X93	Rd9Xkj	83XyR				
>2BHQB M;	98kyXNe	jjd8XRR	3dX83	33X3d				
CB M;bm	8d3eXd9	3jy8XR9	RjjX3R	R98Xk3				
w?2DB M;	k8NRXye	999RXyN	Ree9Xj9	NjX9k				
M?mB	9d9jXye	9eRNX89	9RyXdy	NyXje				
6mDB M	kRdkXe8	9yjjXe9	k9edXyd	RyjXee				
CB M;tB	83R8XjR	jdk3X38	9djXdy	NdX38				
a? M/QM;	eyNkXk8	eR3dXRy	RkeX9d	R8kXj8				
>2M M	dkRkXyR	eRkyXkk	k8kXRy	RejXk3				
>m2#B	e9ddX9j	8ddRXNj	RkRyXN3	R9jXy8				
>mM M	ej8NXyR	8yeeXRy	eRRXNN	Rk8X89				
:m M;/QM;	djjdXRN	dRReX8R	RReNXjy	R9NX3j				
:m M;tB	8RjeX8j	dR3yX8R	9jyXye	k98Xe9				
aB?+m M	3k89Xd9	Njk3Xej	jekyX3d	jRRXkj				
:mBx?Qm	jeekX8y	99ydXeN	3ddXky	RedXNk				
umMM M	8jykXey	9e99Xej	RkjkXk3	RjdXdj				
a? MtB	jedeX38	jeyeXyk	k8RkX89	RyjXd3				
: Mbm	j8NyXyj	kRN9Xdj	RReNX89	eyXy3				
LBM;tB	R883XN3	eykXj9	eNXdk	R9XNd				

h #H2 RR, * HB#` iBQM }i, BM7` bi`m+im`2 H2M;i?b #v T`Q

h?Bb i #H2 T`QpB/2b /2i BH2/ Qp2`pB2r Q7 i?2 H2M;i?b Q7 ?B;?r vb M/ imM
*?BM - +QKT `BM; +im H / i U. i >rv M/ . i hMMHV rBi? # b2HBM2 KQ/2H T
M/ " b2HBM2 hMMHVX h?2 mMBi Bb BM FBHQK2i2`bX



	. i	" b2HBM2	. i	" b2HBM2
S`QBM+2	S`pM+rv	S`pM+rv	S`pMMMH	S`pMMMH
>2#2B	k8RdXde	jkkXyR	j9eX8N	RjX3N
a? MtB	kjNeXyR	9N3Xyk	N9jXNk	kRX9j
AMMJ2QM;QHBR	ykjXj8	ek9Xyd	yXyy	kjXR3
GB QMBM;	edRXy9	338X8k	NRXNR	RNX3y
CBHBM	8jRX9y	eNkXj8	jdXj3	ReXN3
>2BHDQBMM;	39eX88	R9e3Xy8	yXyy	93Xde
CB M;bm	kRydX9j	kRRjXd8	93Xye	jeXN3
w?2DB M;	Rj8eX3y	RedjX89	dkkXdN	93XRd
M?mB	R8d9XdN	R8d9Xjy	dyX88	98XjN
6mDB M	RjdjXye	Ry3eX3d	3yRX3e	R3X9R
CB M;tB	kkd3Xjj	kkdXj9	kk3Xee	3Xk8
a? M/QM;	R3k8Xjy	ky9yX83	k8X83	89XRe
>2M M	jy8NX8j	RdddXe9	ddX88	d8Xdk
>m#2B	R99NXN8	RdR8Xd9	keNXyy	eRXjd
>mM M	k99yX38	RNj3XkR	kk8X9j	8yXe9
:m M;/QM;	k33kXde	j99yX39	9RNXye	ddX8d
:m M;tB	R8kRXRk	j83XR3	3RXyk	3Xd9
aB?+m M	kNkyX3R	jj9dXNd	938XR8	RkNXyN
:mBx?Qm	ekdX98	R8Xj9	R89XN8	9X98
umMM M	ReRX9N	d9jXNd	9yXd8	jRXj3
a? MtB	j9dX8d	djeXN8	RkXkN	jyXjk
: Mbm	edX9e	9e3Xek	eXRy	RNXk8
LBM;tB	k3yXyk	k9yXkj	j8XeN	eX39

h #H2 Rj, * HB#` iBQM }i, T`QpBM+B H BM7` bi`m+im`2 H2M;i

h?Bbi #H2 T`QpB/2b /2i BH2/Qp2`pB2r Q7 i?2 H2M;i?b Q7 ?B;?r vb M/imMM M2irQ`F +`Qbb p `BQmb T`QpBM+2b BM *?BM - +QKT `BM; +im H / i rBi? # b Bb BM FBHQK2i2`bX

U V Q i H > B ; ? r v

U # V Q i H h m M M 2 H

U + L V i B Q M H > B ; ? r v

U / L V i B Q M H h m M M 2 H

U 2 S V ` Q p B M + B H > B ; ? r v

U V 7 S ` Q p B M + B H h m M M 2 H