

,VFKDHPLF +HDUW 'LVHDTV 5LVN 6FRUHV DQG 5HYLHZ

*ULPD .%HJ]LQDQG 5DLQIRUG /

'HSDUWPHQW RI 5DGLRJUDSK\)DFXOW\ RI +HDOWK 6FLHQFHV 8QLYHUVLW\ RI 0DOWD %1.DUD %\SDVV 0
'HSDUWPHQW 5DGLRJUDSK\ 'LDJQRVWLF ,PDJLQJ 8&' 6FKRRO RI 0HGLFLQH 8QLYHUVLW\ &ROOHJH 'XEO
&RUUHVSRRGLQJDDXK&BUJ *ULPD 'HSDUWPHQW RI 5DGLRJUDSK\)DFXOW\ RI +HDOWK 6FLHQFHV 8Q
(PDLOUHQ ERUJ JULPD#XP HGX PW

5HFHLYHG-0GDWH \$FFHSWHG GDWH)HE)B&EOLVKHG GDWH

&RS\ULJKW *ULPD .% 7KLW LV DQ RSHQ DFFHVV DUWLFOH GLVWULEXWHG XQGHU WKH WHUPV RI WKH &U
GLVWULEXWLRQ DQG UHSURGXFWRQ LQ DQ\ PHGLXP SURYLGHG WKH RULJLQDO DXWKRU DQG VRXUFH D

,QWURGXFWLRQ

1XPHURXV GLDJQRVWLF VWUDWHJLHV WR ERUJ XVXOWV DQG SRVVLEOH SHFLVHG
VXVHUIURP FRURQDU\ DUWHU\ GLVHDTV '&\$' DOVR UHIHUHG WR DV

LVFKDHPLF KH DUW GLVHDTV ,+' > @ &RURQDU\ DQJLRJUDSK\ LV FXUUHQW\
VWLOO FRQVLGHUHG DV WKH JROG VWD
FDXVLQJ REVWUXFWLYH ,+' \HW FRURQ
FRWO\ DQG PD\ VWLOO QRW EH DEOH
&\$' ZKLFK DOWKRJK UDUH PD\ VWLOO
> @ 6LQFH WKH RYHUDOO ULVN RI ,+' L
ULVN IDFWRUV VHYUDO ULVN DVVHVV
HVWLPDWH WKH ULVN RIGW KLW DSDWKXSR

0HWKRGV

(YLGHQFH DFTXLVLWLRQ

35,60\$ 3UHIHUHG 5HSRUWLQJ ,WHPV
0HWD \$QDO\HV JXLGHOLQH > @ DI
V\WHPDWLF UHYLHZ \$ VHDFK RI WL
FRQGXFWHG RQ 3XE0HG 6FLHQFH 'LUHF
&RFKUDQH GDWDEDVH WR\WVWGLQJ

FULWHULD 00RZLQJ VHDFK WHUPV ZHUH
SUHGLFWLRQ PRGHO FDUGLDF ULVN

SUHGLFWLRQ LQGH[LQ FRPELQDWLRQ ZLWK WKH WHUP LVFKDHPLF KH DUW
GLVHDTV ZHUH FURVV VHDFKHG XVLQJ WKH IROORZLQJ DOJRULWKP FDUGLDF UL

SUHGLFWLRQ PRGHO \$1' LVFKDHPLF KH DUW GLVHDTV FDUGLDF ULVN
SUHGLFWLRQ IDFWRU \$1' LVFKDHPLF KH DUW GLVHDTV LVFKDHPLF KH DUW

GLVHDTV \$1' FDUGLDF ULVN SUHGLFWLRQ LQGH[\$Q DGGLWRQDO VHDFK
WHUP ,VFKDHPLF KH DUW GLVHDTV DQG ULVN VFRUHV ZDV XVHG IRU 6FLHQFH
'LUHF GDWDEDVH WR FRYHU PRUH SRWHQWLDV VHDFK SUREDELWLWLV IRU V

VLWH ZKLFK KDG RYHUDOO VHXOWV ZHUH cKLWVd
UHPRYHG WKH WLWOHV DQG DEVWUDFWV RI WKH VHDFK UHVXOWV ZHUH VFUHHG

RQH RI WKH DXWKRUV WR GHWHUPLQH WKHLU HOLJLELWLW\)LXUH 3UHIHUH
5HSRUWLQJ ,WHPV IRU 6\WHPDWLF UHYLHZV DQG 0HWD \$QDO\HV 35,60\$

-R&KDUW \$OO VWXGLHV WKDW PHW WKH LQFOXVLRQ FULWHULD UHJDUGOHVV R
VDPSOH VLJH ZHUH LQFOXGHG

,QFOXVLRQ FULWHULD

\$UWLFOHV SXEOLVKHG IURP -DQXDU\ XQWLO 2FWREHU ZDV
FRQVLGHUHG IRU UHYLHZ

H VHDFK ZDV OLPLWHG WR (QJOLVK ODQJXDJH DUWLFOHV SXEOLVKHG LQ
SHHU UHYLHZHG MRXUQDOV

(OLJLEOH VWXGLHV QHHGHG WR GLVFXVV RQH RU PRUH FDUGLDF ULVN VFRUH
SUHGLFWLRQ PRGHOV LQ UHODWLRQ WR LVFKDHPLF KH DUW GLVHDTV



7DEOH IRU DOO GDWDEDVHV OLVWH DUWLFOH VGHV WDUWUHTXQBGLXUWHUWUZH
DSSOLHG WR UHPRYH FRPPHQWDULHV RU HGLWRULDOV RU VWXGLHV WKDW LQFO
RQO\ WKH DEVWUDFW ZLWK QR LQGLFDWLRQ RI WKH W\SH RI PHWKRGRORJ\
IROORZHG 'XSOLFDWHG DUWLFOHV ZHUH DOVR UHPRYHG OHDYLQJ D WRWDO RI

	1HZ 5LVN 6WUDWLILFDWLRQ VFRUH	3DOPH6LQL HW DO
	&OLQLFDO 6<17\$; VFRUH &66	:DQJ HW DO
	676 3520	\$G HW DO
	(XUR6&25(, ,)DUURNK\DU HW DO
	\$PEOHU VFRUH	6XOOLYDQ HW DO
	3URYLGHQFH VFRUH	6LRQWLV HW DO
	9HWHUDQV \$GPLQLVWUDWLRQ VFRUH	
	\$66,*1 VFRUH	
	3URVSHFWLYH FDUGLRYDVFXODU	PXQVWHU
	352&\$0 VFRUH	
	5H\QROGV ULVN VFRUH	
3DWLHQWV XQGHUJRLQJ VWUHV GLDJQRVWLF SURFHGXUH	VXFKDV WKH VFRUHSDUW RI D	.ZRN HW DO
	0RULVH VFRUH	/DL HW DO
	7KH 'XNH\ VFRUH	0RULVH DQG -DOLVL
	3UHWHVW DQG H[HUFLVH (&* VFRUH	

7DEOH VXPPDULQH QWLEHG VFRUHV RULJLQDO 2FWREHU

T e XVH RI ULVN VFRUHV LQ LVFKDHF FRPSDUWLRQ WR DERXW WKH HQGH VFRUHV
PDMRU VXUJHU\ KLJKHU SRVLWLYH SUHGLFWLYH YDOXH R
IRU WKH *ROGPDQ VFRUH DQG H IRU
5LVN VFRULQJ V\WHPV VXFK DV WKRVH SURSRVHG LEA WKH \$RUVHWG XVLQ
6RFLHW\ RI \$QDHVWKHVLD \$6\$ *ROGPDQ HW DO WJH WLVN HW DO > @ JHH HW DO
DQG /HH HW DO > @ DOO XVH PXOWLYDUGLDF VFRUH VFRUH VFRUH VFRUH VFRUH
FOLQLFDO IDFWRUV WKDW PD\ SUHGLFW FDUGLDF PRUELGLW\ DQG PRUWDOLW\ I
SDWLHQWV DERXW WR XQGHSSR PDURUSXEOLWKHG
LQ E\ \$6\$ ZDV WKH RULJLQDO ULVN DVVHVPHQW V\WHP XVHG IRU
SUHRSHUDWLYH DVVHVPHQWV EXW DV VXFK LW KDV QRW EHHQ IRXQG WKURXJ
UHVHDFK WR EH SUHGLFWLYH HRRODQDF FRPSOLFDFWLRQV > @
5LVN 6FRUH > @ VWXGLHG D FRKRUW RI SDWLHQWV IRU WKH SUHVHQFH RU
DEVHQFH RLRMFDQG LDF ULVN IDFWRUV IRU HDFK SDWLHQW
ULVN VFRUH WKRXJK KDYLQJ HDVZHOOWLFDOO XFWHG
ZHDN PRGO DV LW SURYLGHG MXVW RYHU VL\ ULVN IDFWRUV SHU FRPSOLFDFWLR
DQG VWXGLHG D ODUJH QXPEHU RI ULVN IDFWRUV WKDW ZHUH GHSHQQGHQW RQ HD
RWKHU LQ VPH FDVHV /HH HW DO SXEOLVKHG WKH 5HYLVHG &DUGLDF 5LVN
,QGH[RU /HH ,QGH[ZKLFK LV WKH PRVW ZLGH\ XVHG ,W DVVLJQV D SRLQW
HDFK IRU WKH SUHVHQFH RI LQGSHQQGHQW ULVN IDFWRUV IRU PDMRU FDUGLDF
FRPSOLFDFWLRQV LQ SDWLHQWV XQGHUJRLQJ PDMRU VXUJHU\ > @
,QGH[LV PRUH UREXVW WKDQ WKH *ROGPDQ &DUGLDF 5LVN 6FRUH DV LQLWLDO
VWXGLHV LQYROYHG D ODUJHU FRKRUW RI SDWLHQWV ZLWK D ODUJHU LQFLGHQF
FDUGLDF HYHQWV SHUHDVHFRQGHQDOV RNDN @ V D
EURDGHU DSSURDFWLRQV EHF ULVN IDFWRUV DOWKRXJK LW
PD\ VWLOO UHTXLUH WR EH IXUWKHU XSGDWHG WR LPSURYH LWV SUHGLFWLYH
DFFXUDF\ > @

H *ROGPDQ 'HWVN\ DQG /HH FDUGLDF LQGLFHV ZHUH FRPSDUHG IRU
VHQVLYLW\ SUHGLFWLYH YDOXHV LQ D VDP SOH RI FDUGLDF
SDWLHQWV 5HVXOW RI WKLV DQDO\WLFDO VWXG\ LQGLFDWHG WKDW WKH VHQV
YDOXHV IRU WKH *ROGPDQ 'HWVN\ DQG /HH LQGLFHV ZHUH RI
DQG UHVSHFWLYHLY ZLWKH RI IRU
WKH *ROGPDQ FDUGLDF ULVN VFRUH DQG IRU WKH 'HWVN\ LQGH[LQ

SODQ VWUDWHJLHV WKDW PD\ ORZHU WKH LQFLGHQFH RI P\RFDUGLDO LVFKDHPL
DQG HYHQ P\RFDUGLDO LQIDUFWLRQ

H)UDPLQJKDP VFRUH DQG DOVR WKH V\VWHPDWLF FRURQDU\ ULVN
HYDOXDWLRQ 6&25(VFRUH VHUYH WKLW SXUSRVH EXW QHZ ELRPDUNHUV DQG
LPDJLQJ PHWKRGV KDYH HPHUJHG ZLWKLQ WKH SDVW \HDUV KLJK VHQVLWLYLW\
& UHDFWLYH SURWHLQ &53 OLSRSURWHLQ DVVRFLDWHG SKRVSKROLSDVH \$ DQG
VHFUHWRU\ SKRVSKROLSDVH \$ FRURQDU\ DUWHU\ FDOFLXP &\$& VFRUH
FDURWLG LQWLPD PHGLD WKLFNQHV DQG DQNOH EUDFKLDO LQGH[ZKLFK FDQ
DGG IXUWKHU YDOXH WR D SDWLHQW ULVN DVVHVVPHQW > @

\$FFRUGLQJ WR D FRKRUW VWXG\ E\ .DYRXVL HW DO > @ WKH)UDPLQJKDP
ULVN VFRUH)56 LV cWKH PRVW FRPPRQ\ XVHG &+' ULVN SUHGLFWLRQ
LQVWUXPHQW LQ FOLQLFDO VHWLQJ DQG FRQVWLWXWHV WKH EDVLV IRU WKH
7UHDWPHQW 3DQHO ,,, JXLGHOLQH\HURU FKROHVWHURO ORZLQJ WKHUDS\ d
)UDPLQJKDP ULVN VFRUH ZDV XVHG WR HYDOXDWH WKH LPSRUWDQFH RI
FRQVLGHULQJ QHZHU ULVN IDFWRUV WKDW PD\ EH LQGLFDWLYH RI ,+' VXFK DV
OHYHOV RI 1 WHUPLQDO IUDJPHQW RI SURKRUPRQH % W\SH QDWULXUHWLF
SHSWLGH 17 SUR%13 YRQ :LQGHUHQGHU DFWRU DQWLJHQ OHYHOV
OHYHOV FKURQLF NLGQH\ GLVHDVH &.' OHXNRF\WH FRXQW &53 OHYHOV
KRPRF\ VWHLQH OHYHOV XULF DFLG OHYHOV &\$& VFRUHV FDURWLG LQWLPD PHGLD
WKLFNQHV F,07 SHULSKHUDO DUWHULDO GLVHDVH DQG SXOVH ZDYH YHORFLV
> @H SDUWLFLSDQWV LQFOXGHG DV\PSWRPDWLF SDUWLFLSDQWV ZLWK D
PHDQ DJH RI \HDUV ,QGLYLGXDOV ZLWK D NQRZQ KLVWRU\ RI P\RFDUGLDO
LQIDUFWLRQ 0, FRURQDU\ ULVN VFRUH\SDVV
SHUFXWDQHRXV WUDQVOXPLQDO FRURQDU\ DQJLRSODVW\ 37&\$ ZHUH QRW
LQFOXGHG LQ WKLW UHVHDUFK \$ OLPLWDWLRQ RI WKLW VWXG\ ZDV LWV ODFN
DSSOLFDELOLW\ WR D \RXQJHU FRKRUW RI SDWLHQWV UHGXFHQJ LWV SRWHQWL
EH XVHG LQ GLYHUVH HWKQLF FXOWXUH 2XW RI DOO WKH QHZHU ULVN IDFWRUV
ZHUH VWXGLHG WKH FRURQDU\ DUWHU\ FDOFLXP &\$& VFRUH DSSHUHG WR EH
D JRRG SUHGLFWLYH VRIWZDVK DQG VHYHUDO RWKHU
VWXGLHV > @

,W FDQ EH DUJXH\ WKDW WKH YDULDWLRQ RI FHUWPLQULVN IDFWRUV ZLWK
VXFK DV 17 SUR%13 PD\ EH D EHWWHU SUHGLFWRU RI FRURQDU\ GLVHDVH LQ
ROGHU SRSXODWLRQ V WKDQ WKH DFWLFDO FDOFLXP VRIWZDVK > @
RH FRURQDU\ FDOFLXP VRIWZDVK VRIWZDVK VRIWZDVK VRIWZDVK VRIWZDVK
K0-7(H, (DO)-110(L/3(V)-8

L17HVX

1/26 P15D

H \$XV6FRUH ZDV GHYHORSHG E\ 5HLG HW DO > @ IRU DQ \$XVWUDOLDQ
&RKRUW RID\$BWKHHQZM@HO\ XVHG (8523(\$1 6<67(0 IRU
FDUGLDF RSHUDWLYH ULVN HYDOXDWLRQ (XUR6&25(YDOLGDWHG SRRUO\ LQ WKL
SRSXODWLRQ ZKHQ XVHG WR SUHGLFW RXWFRPHV IROORZLQJ &\$%* 2Q WKH
RWKHU KDQG WKH (XUR6&25(DSSHDUV WR EH WKH PRVW ZLGHO\ XVHG SUH
RSHUDWLYH ULVN SUHGLFWLRQ PRGHO LQ (XURSHDQ FDUGLDF VXUJHU\ > @ ,Q
ODOWD WKH (XUR6&25(LV WKH ULVN VFRUH XVHG E\ FDUGLDF VXUJHRQV LQ
SDWLHQWV DERXW WR XQGHUJR 3&, DQG &\$%* /LWHUDWXUH KDV VKRZQ
SLWIDOOV LQ WKLW ULVN VFRUH > @ VHYHUDO DXWKRUV GHVFULEH D (XUR6&25
PRUWDOLW\ RYHUHVWLPDWLRQ LQ ORZ ULVN SDWLHQWV DQG DQ XQGHUVWLPDW
RI PRUWDOLW\ LQ KLJK ULVN SDWLHQWV

2WKHU VXFK VFRULQJ V\VWHPV LQFOXGH WKH 6\QHUI\ %HWZHHQ
3HUFXWDQHRXV &RURQDU\ ,QWHUYHQWLRQ ZLWK 7D[XV DQG &DUGLDF 6XUJHU\
6<17\$; VFRUH D VHPL TXDQWLWDWLYH DQJLRJUDSKLF VFRUH GHYHORSHG WR
SURVSHFWLYHO\ DVVHV SDWLHQWV XQGHUJRLQJ FRURQDU\ UHYDVFXODULVDWLR
3&, RU &\$%* WKH \$JH &UHDWLQLQH DQG (MHFWLRQ)UDFWLRQ \$&() VFRUH
> @ XVHG WR SUHGLFW RSHUDWLYH PRUWDOLW\ LQ SDWLHQWV XQGHUJRLQJ HOH
FDUGLDF VXUJHU\6WW@MLYFRU@ (56 DQG WKH

' \$VFHQJR) %LRQGL =RFFDL * 0RUHWL & %ROODWL 0 2PHG^a 3 HW DO
7,0, *5\$&(DQG DOWHUQDWLYH ULVN VFRUHV LQ DFXWH FRURQDU\
V\QGURPHV \$ PHWD DQDO\VLV RI GHULYDWLRQ VWXGLHV RQ SDWLHQWV
DQG RI YDOLGDLWRQ VWXGLHV RQ SDWLHQWV &RQWHPSRUDU\ &OLQLFDO
7ULDOV
3ROGHUYDDUW -0 /DQJHGLMN 0 %DFNXV %('HNNHU ,0& 6L[\$- HW DO
&RPSDULVRQ RI WKH *5\$&(+(\$57 DQG 7,0, VFRUH WR SUHGLFW