Cohort mortality risk or adverse selection in the UK annuity market?

aj r ka kkl k ka F k Ql khp

J o e # o

MO I FJ FK OV K KL Q QL NRLQ T FQE L RQ M OJ FPPFL K

pqp q

Qe b j l kbv pt l oqe j b pr obe p bbk r pba ql ppbppt e bqe bo kkr fqfbp ob c foiv s ir ba ka ipl p bs fa bk b d o as bopb pbib qfl k fk qe b kkr fqv j ohbq, E l t bs bo a bqboj fk fpqf j l kbv pt l oqe i r i qfl k fp mol ibj qf col j qe b ml fkq l c s fbt l c ofph; s bopb ifcb ppr obo l o obdr i ql o t l oofba l r q qe b pl is bk v l c qe b ifcb ppr obo, Fk qe fp m mbo t b al r j bkq qe b l kpfa bo ib r k boq fkqv qe q kkr fqv mol s fa bop ka obdr i ql op c b fk mobaf qfkd il kd;or k j l oq ifqv ka pe l t qe fp cb qp j l kbv pt l oqe bpqfj qbp, T b mol s fab pfj mib j l abi l c qe b bcb q l c l e l oq j l oq ifqv ofph l k qe b j l kbv pt l oqe ka pe l t qe qt b kkl q fa bkqfcv qe b bcb q l c l r o j l abi col j qe q l c k as bopb pbib qfl k j l abi, R pfkd I bb; oqbo j l abi l c j l oq ifqv t b nr kqfcv qe b bcb q l c l e l oq j l oq ifqv ofph ka pe l t qe q fq fp nr kqfq qfs biv fj ml oq kq, T b l k ir ab qe q qe b bj mfof i cfkafkd l c a fcbobk bp fk qe b j l kbv pt l oqe cl o a fcbofkd qvmbp l c kkr fqfbp j v b ar b pj r e ql ofph pql as bopb pbib qfl k,

aj r ka kkl k R kfs bopfqv l c ofpql i P el l i l c l kl j f p Cfk k b ka J k dbj bkq 5 T l l ai ka Ol a ofpql i, P 5 QK, R kfqba Hfkdal j baj r ka, kkl k ofpql i, ,r h

F k Ql khp P el l i l c J k dbj bkq R kfs bopfqv l c qe qe #4 V, R kfqba Hfkdal j F,Ql khp qe , ,r h

Qe b r qe l op do qbcr iiv hkl t iba db pr mml oq cl o qe fp obpb o e col j K QPM O,

1. Introduction

s bo pfk b qe b a bs bil mj bkq l c qe b qe bl obqf i j l a bi l c Ol qe efia ka Pqfdifqw 6 3 fa bkqfcvfkd qe b o ib l c pvj j bqof fkcl oj qfl k fk fkpr o k b j ohbqp qe b pb o e cl o bj mfof i bs fa bk b l k as bopb pbib qfl k e p vfbia ba l kcif qfkd cfka fkdp a bmbka fkd l k qe b e o qbofpqf p l c qe b m oqf r i o j ohbq l e bk ka Pfbdbij k # ·, Qe b j ohbq cl o ifcb kkr fqfbp e p bbk pqr a fba fk kr j bo l c m mbop J fq e bii bq i 666 Cfkhbipqbfk ka M qbo # # # 1· t el e s b bu j fkba qe b mof fkd l c ifcb kkr fqfbp r pfkd qe b *money's worth* j bqof f,b, qe b o qfl l c qe b bumb qba s ir b l c kkr fqv m vj bkqp ql qe b mobj fr j m fa, Qt l pqvifpba c qp qe q bj bodb col j qe fp ifqbo qr ob ob qe q qvmf iiv f· qe b j l kbv p t l oqe fp ibpp qe k l kb ka ff· qe b j l kbv p t l oqe l c h;il a ba kkr fqfbp t e bob qe b bumb qba a r o qfl k fp il kdbo· l o ob i kkr fqfbp fp ibpp qe k qe q cl o ibs bi l o l ks bkqfl k i kkr fqfbp, Cl o bu j mib Q ib 2l c Cfkhbipqbfk ka M qbo # # obml oqp qe q qe b j l kbv p t l oqe l c ibs bi kkr fqfbp cl o 3 2vb o l ia j ibp fp , 6 r q cl o ob i kkr fqfbp fp , 5# 2 Qe bpb qt l l pbos qfl kp e s b bbk fkqbomobqba p bs fa bk b l c as bopb pbib qfl k qe q kkr fq kqp e s b j l ob fkcl oj qfl k l r q qe bfo ifcb bumb q k v qe k fkpr o k b l j m kfbp t e f e fp qe bk obcib qba fk qe b bnr fif ofr j kkr fqv mof bp,

E l t bs bo fk qe fp m mbo t b a bj l kpqo qb qe q qe bpb c qp t l r ia ipl b l kpfpqbkq t fqe j l a bi t e bob qe bob t bob kl as bopb pbib qfl k ka t e bob qe b s of qfl k fk kkr fqv o qbp cl o afccbobkq qvmbp l c kkr fqv t bob ar b ql qe b afccbobkq l pqp l c pr mmivfkd kkr fqfbp, fqe bo b r pb ifcb ppr obop ob mor a bkq l o b r pb l c obdr i ql ov obnr fobj bkqp ofphfbo if fifqfbp pr e pob i kkr fqfbp e s b ql b mof ba ql bkpr ob pr ccf fbkq obpbos bp ob s fi ib ka j q e ba ql pfj fi o ob i ppbqp ka qe bpb bccb qp j hb qe bj j l ob l pqiv, T b fa bkqfcv qe obb a afqfl k i l pqp cl o ob i kkr fqfbp dob qbo l e l oq ofph dob qbo fafl pvk o qf ofph ka dob qbo j k dbj bkq

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G j bp ka Pl kd # · mol s fa bp k fkqbok qfl k i l j m ofpl k l c j l kbv p t l oqe pqr a fbp, kkl k ka Ql khp # 5 e, 3 obml oq cr oqe bo j l kbv p t l oqe i r i qfl kp cl o qe b R kfqba Hfkdal j ka ipl obs fbt l qe bo oqf ibp l k qe b j l kbv p t l oqe cl o qe b RH J r oqe f L opw d ka L opw d 666 cl o efib Ol e ka Qe l o r ok # 3 cl o Pt fqwboi ka qibo ka Or bp e # 4· cl o r pqo if Hkl u # · ka cl o Pfkd ml ob Cl kd # #, Pfk b qe bk cr oqe bo k ivpbp e s b bbk l ka r qba cl o k a J fibs phv ka Pe l # · cl o Dboj kv H p e qwhb ka J r obo # · cl o qe b K bqe boi ka p kkl k Pqbs bkp ka Ql khp # # cl o Pfkd ml ob Cl kd J fq e bii ka Hl e # · ka cl o Pt fqwboi ka qibo ka Pq r if # ·, Qe b j l kbv p t l oqe e p ipl bbk r pba fk k ivpfpl c ab fpfl k j hfkd v Cl kd I bj fob ka Qpb # ·, l pqp, Qe b i pq qt l aafqfl k i l pqp l r ia fk mofk fmb b j b pr oba c foiv b pfiv fc abnr qb a q t bob s fi ib ka fk qe fp m mbo t b afp r pp qe b buqbkq ql t e f e qe fp fp ml ppf ib, Qe b cfopq aafqfl k i l pq t fii b pe l t k ql b j l ob mol ibj qf , Qe b ol r qb v t e f e l e l oq ofph ka as bopb pbib qfl k ccb q kkr fqv mof bp fp qe b p j b k j biv qe b ar o qfl k l c qe b kkr fqv, Qe fp j hbp fa bkqfcvfkd qe b fj ml oq k b l c qe b qt l buni k qfl kp cl o kkr fqv mof bp a fccf r iq l o fj ml ppf ib, Fk qe fp m mbo t b nr kqfcv qe b l pqp l c qe b ofphp ka pe l t qe bv ob pr ccf fbkqiv i odb ql buni fk j r e l c qe b l pbos ba s of qfl kp fk qe b j l kbv p t l oqe ib s fkd ifqqib l o kl o ib cl o as bopb pbib qfl k,

T b mmol e qe fp mol ibj v j l abiifkd bumif fqiv qe b ofphv k qr ob l c k kkr fqv if fifqv, Fk ii l c qe b m mbop qe q t b e s b fqba qe b j l kbv p t l oqe i r i qfl kp ob abqboj fkfpqf fk qe b pbkpb qe q fq fp fj mf fqiv ppr j ba qe q pr os fs i mol fifqfbp cl o qe b l e l oq l c kkr fqf kqp ob hkl t k, s bk fc ifcb ppr obo e p pr ccf fbkqiv i odb ml i l c kkr fq kqp ql a fs bopfcv t v fa fl pvk o qf ofph fq pqfii kbba p ql cl ob pq qe b cr qr ob pr os fs i mol fifqfbp ka qe b pb cl ob pqp ob l s fl r piv ofphv, l j fk ba t fqe mor a bkqf i l o obdr i ql ov ob pl kp ql s l fa al t kpfa b ofph qe fp j b kp qe q qe b dob qbo qe b ofph l c if fifqv qe b dob qbo qe b obpbos bp kbba ba v qe b ifcb ppr obo ql bkpr ob qe q qe b if fifqv k b j bq, Fk qe fp m mbo t b fkqol ar b qe b l k bmq l c qe b *stochastic money's worth* t e f e q hbp fkql l r kq qe b r k boq fkqv c ba v kkr fqv mol s fa bop mobaf qfkd il kd;or k j l oq ifqv, T b pr ddbpq qe q bpqfj qbp l c qe b pql e pqf j l kbv p t l oqe ob qe b mmol mof qb ofph j bqof cl o ifcb ppr obop,

Qe b qqfqr a b l c mr if ml if v ql qe b mof fkd l c kkr fqfbp fp j r iqf;c bqba, I l t kkr fqv o qbp obpr iq fk il t bo fk l j b pqob j p cl o mbkpfl kbop ka qe b ofph qe q qe bv t fii b bkqfqiba ql j l ob j b kp;qbpqba bkbcfqp p s l qbop qe bv j v ipl l j mi fk j l ob, Cl o qe bpb ob pl kp dl s bokj bkqp t kqp kkr fqv o qbp ql b e fde, L k qe b l qe bo e ka e fde kkr fqv o qbp l oobpml ka ql e fde bo cr qr ob kkr fqv m vl r qp v mol s fa bop cl o dfs bk mobj fr j o fpfkd nr bpqfl kp l r q qe b mol s fa bop cr qr ob pl is bk v, Fk fqp m fqv p cfk k f i obdr i ql o qe b dl s bokj bkq t l r ia kl q t kq kkr fqv o qbp ql l e fde fc qe fp j b kq qe q kkr fqv mol s fa bop j fde q bka r m c fifkd b r pb qe bk mbkpfl kbop t l r ia bka r m fk ml s boqv ka qe b dl s bokj bkq t l r ia e s b ql l j mbkp qb qe bj bfqe bo qe ol r de afob q obp r b l o v m vfkd e fde bo j b kp;qbpqba bkbcfqp,

Fk qe b R kfqba Hfkdal j t e bob qe b l j mr ipl ov kkr fqv j ohbq fp i odb t l oqe fiifl k mbo vb o E J Qob r ov # · ka mi vp k fj ml oq kq o ib fk mbkpfl k mol sfpfl k qeb dl sbokj bkq e p c ba l qe mol ibj p fk qeb ob bkq m pq ka l kqfkr bp ql a l pl , kkr fqv o qbp e s b c iibk l kpfpqbkqiv pfk b 66 t e f e e p mol s ba ml ifqf iiv pbk pfqfs b mol j mqfkd qe b bm oqj bkq l c T l oh ka Mbkpfl kp ql fks bpqfd qb k ivpb qe b r pb l c qe bpb obar qfl kp kkl k ka Ql khp # 6, Fk qe b ml mr i o mobpp il t kkr fqv o qbp e s b bbk fqba p ob pl k cl o obj l sfkd qe b l j mr ipl ov kkr fqfp qfl k obnr fobj bkq fk qe b R H, #

q qe b p j b qfj b qe b R H dl s bokj bkq fp pqfii e sfkd ql a b i t fqe qe b c fir ob l c nr fq ib I fcb ql mol s fa b pr ccf fbkq obpbos bp cl o pbq l c dr o kqbba kkr fqfbp pl ia fk qe b 65 p, Qe fp b j b mm obkq fk qe b i qb 66 p ka obpr iqba fk l r oq pb fk # nr fq ib I fcb ppr o k b Pl fbqv s E vj k · cl iil t ba v qe b Mbkol pb Obml oq l c # 1, Qe b j l pq ob bkq o e j p obml oq' M oif j bkq ov ka E b iqe Pbos f b L j r apj k # 5 cl r ka qe q qe b cfk k f i obdr i ql op fk qe b R kfqba Hfkdal j fkfqf iiv qe b bm oqj bkq l c Qo a b ka Fka r pqov QF ka qe bk qe b Cfk k f i Pbos f b r qe l ofqv · e a j a b bool op l s bo qbk;vb o mbofl a fk qe b obdr i qfl k l c nr fq ib I fcb a qfkd col j qe b qfj b l c qe b l ofdfk i mol ibj fk qe b 66 p ka l kqfkr fkd bs bk cqbo qe b l r oq pb, iqe l r de qe b mol ar qp pl ia t bob kl q l ks bkqfl k i fj j baf qb kkr fqfbp qe b l k ir pfl k fp ib o qe q j i a j fkfpqo qfl k v cfk k f i obdr i ql op k obpr iq fk dl s bokj bkq if fifqv, Qe b ql q i l pq ql qe b R H dl s bokj bkq fp bumb qba ql b , 2 fiifl k E ,J , Qob pr ov # · l o mmol ufj qbiv , mbo bkq l c R H D M,

s bk m oq col j qe b nr fq ib I fcb a z ib ka bcl ob qe b cfk k f i ofpfp l c # 4 qe b obdr i ql o t p bk l r o dfkd ifcb ppr obop ql mof b l kpbos qfs biv, Cl o bu j mib qe b e foj k l c qe b Cfk k f i Pbos f bp r qe l ofqv t ol qb ql ifcb ppr obop ob l dkfpfkd qe q l j m kfbp t l r ia r pr iiv j hb ppr j mqfl kp pba l k qe bfo l t k j l oq ifqv bumbofbk bp r q aafkd

"...if this is not possible we would expect firms to consider the different industry views in this area and to err on the side of caution." CP b o L ibqqbo mofi # 4·

cr oqe bo j l qfs qfl k cl o mmol mof qbiv ppbppfkd qe b ofphp ppl f qba t fqe kkr fqfbp fp qe b mol ml pba R;t fa b e kdbp ql fkpr o k b obdr i qfl k bkpe ofkba fk *Solvency II,* t e f e t fii q hb bccb q col j # 9 Pl is bk v FF mmifbp ql qe b fkpr o k b fka r pqov qe b ofph;pbkpfqfs b obdr i ql ov mmol e al mqba fk qe b pbi #obcl oj p cl o qe b khfkd

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[#] Cl o bu j mib *The Telegraph* #J v # # kkr fqv o qbp e s b'mir kdba ql pr e il t ibs bip qe q qe bv ob kl q kl t s f ib l mqfl k cl o j fiifl kp l c?p s bop q obqfobj bkq, fkarpqov, Rkaboqeb mol ml p i cl o Pl is bk v FF ifcb fkpr o k b l j m kfbp ob obnr foba v qeb obdr i ql ov co j bt l oh ql iil t burrif fqiv cl o r k boq fkqv fk qe bfos ir qfl kp

"the technical provision under the Solvency II requirement is the sum of the best estimate and the risk margin, . . ., the best estimate is defined as the probability-weighted average of future cash flows . . . The probability-weighted approach suggests that an insurer has to consider a wide range of possible future events: for example, a 25% reduction in mortality rates may have a small probability of occurrence but a large impact on the cash flows. However, the assumptions chosen to project the best estimated cash flows should be set in a realistic manner, whereas the prudent allowance for data uncertainty and model error should be taken into account in the risk margin calculation." Qbicl oa bq i # m o p, 4, #; ; 4, # # 0,

p fp j a b burrif fq fk qbuq l l hp pr e p l l qe bq i # 2 qr ofbp q hb ofph fkql l r kq t e bk mof fkd kkr fqfbp, T e q fp ibpp ib o fp bu qiv e l t ifcb ppr obop a l qe fp r q pl j b fa b l c qe b j dkfqr a b l c qe b fppr b k b d fkba fk qe b RH col j qe b ifcb ppr obop Obqr okp, e ifcb ppr obo j r pq abi ob qe b qr of i ppr j mqfl kp r pba ql s ir b fqp if fifqfbp v l j m ofkd qe b j l oq ifqfbp r pba fk fqp l t k i r i qfl kp t fqe qe b j l oq ifqfbp fk qe b bk e j oh q ibp mol ar ba v qe b Fkpqfqr qb l c qr ofbp l kqfkr l r p J l oq ifqv Fks bpqfd qfl k, Qe b J F l iib qp a q col j ii l c qe b j gl o ifcb ppr obop ddobd qbp ka kl kvj fpbp fq ka qe bk k ivpbp qe b ml l iba a q , Pl qe b J F q ibp l c j l oq ifqv mmol ufj qb ql qe b s bo db j l oq ifqfbp ol pp qe b t e l ib fkar pqov, Qe b cfdr obp mobpbkqba fk ifcb ppr obop CP obqr okp ob qe bk l j m oba ql qe fp s bo db ka t b pr j j ofpb qe b cfdr obp cl o qe b j gl o kkr fqv mol s fa bop fk Q ib ka fiir pqo qb fk Cfdr ob ,

[Table 1 about here]

[Figure 1 about here]

Qe b fddbpq mol ibj cl o obpb o e bop fp hkl t fkd t e f e bk e j oh pbofbp ql r pb, Cfkhbipqbfk ka M qbo # # r pba qe b ifcb l ccf b mbkpfl k'bo j l oq ifqv q ib t e f e obml oqp j l oq ifqfbp l c j bj bop l c l r m qfl k i a bcfkba; bkbcfq mbkpfl k p e bj bp aj fkfpqboba v ifcb ppr obop qe b j l pq ob bkq s bopfl k l c qe fp q ib fp M J , Pfk b kkr fq kqp ob a bcfkba; l kqof r qfl k · mbkpfl kbop qe fp fp ib oiv qe b t ol kd pbofbp, Qe b l ofdfk i mbkpfl kp obqfobj bkq kkr fqv l kqp qp cl o pbic;

bj mil vba t lohbop e s b qe bfo l t k j l oq ifqv q ibp l c t e f e qe b j l pq ob bkq ob OJ ka OJ S , [0] r q qe b j l ob ob bkq mbopl k i mbkpfl kbop ob a bp of ba v MMJ t e f e fp r oobkqiv pba l k obi qfs biv pj ii p j mib, Fk Cfdr ob t b mil q ii cl r o ml ppf ib bk e j ohp,

Rmql db 34 j l pq ifcb ppr obop ppr j b il t bo j l oq ifqv qe k qe b j l pq t fa biv r pba j l oq ifqv q ibp M J l o OJ t fqe l kiv k a I fcb ppr j fkd efde bo j l oq ifqv, r q cl o dbp dob qbo qe k 35 bs bov ifcb ppr obo ppr j bp il t bo j l oq iqv o qbp qe k ii cl r o ml ppf ib bk e j ohp, Pl bs bk fc qe bob fp pl j b al r q l r q t e f e bk e j oh j l oq ifqv q ib ql r pb bs bov ifcb ppr obo fp ppr j fkd qe q qe bfo kkr fq kqp j l oq ifqv fp il t bo qe k qe b s bo db pl ifcb bumb q k v fp dob qbo qe k s bo db·, Pl j b l c qe b s of qfl k fk ppr j mqfl kp bqt bbk l j m kfbp j r pq b ar b ql dbkr fkb s of qfl kp fk j l oq ifqv l c qe b kkr fq kqp mr o e pfkd col j b e l j m kv r q fq fp l sflr piv fj ml ppf ib qe q bs bov l j m kv e p il t bo j l oq ifqv qe k qe b s bo db, Qe fp fp *prima facie* bs fa bk b qe q cfoj p ob r fia fkd pl j b iil t k b cl o j l oq ifqv ofph fkql qe bfo s ir qfl kp iqe l r de qe bv ob ij l pq boq fkiv j hfkd buqo iil t k b bipbt e bob fk qe bfo i r i qfl kp,

Fk qe fp m mbo t b mol ml pb kl s bi mmol e ql k ivpb qe b bccb q l c ofph l k kkr fqv mof fkd, I fcb ppr obop ob qvmf iiv ib ql e ba db qe bfo kkr fqv if fifqfbp t fqe ppbqp pr e p dl s bok j bkq l o s bov efde nr ifqv l oml o qb l ka p, [1] OMF;ifkhba kkr fqfbp ob hba v fka bu;ifkhba l ka p mobal j fk kqiv fppr ba v qe b dl s bok j bkq, [2] Fq fp

[0] OJ S fp cl o mbkpfl kbop fk ob bfmq l c mbkpfl k s bpqba · ka OJ fp cl o l qe mbkpfl kbop fk ob bfmq l c mbkpfl k ka cl o qe l pb pqfii j hfkd l kqof r qfl kp l j fkba ·, ’

[1] kv l j m kv mol s fa fkd il kd;qboj ifcb ppr o k b r pfkbpp j r pq mol s fa b abq fiba l r kqp ql qe b obdr i ql o obcbooba ql p qe b CP Obqr okp, T e bob fks bpqfkd fk l oml o qb l ka p obpr iqp fk e fde bo vfbia ofph mobj fr j · ifcb ppr obop ob kl q iil t ba ql r pb qe fp ql s ir b qe bfo if fifqfbp, Cl o bu j mib pbb qe b kl qbp fk *Norwich Union Annuity Lim*fqba kkr i CP Fk pr o k b Obqr okp cl o qe b vb o bka ba opq b bj bo # 2 m db 20 Fk l oa k b t fqe ’MOR 1 , #1 O mor a bkq agr pqj bkq bu ir a fkd qe q m oq l c qe b vfbia bpqfj qba ql obmobpbkq l j mbkp qfl k cl o qe b ofph qe q qe b fk l j b col j qe b ppbq j fde qkl q b j fkq fkba l o qe q mfq i obm vj bkqp j fde qkl q b ob bfs ba p qe bv c ii ar b t pj a bq ql qe b vfbia l k ppbqp, Qe b obqr ok dl bp l k ql p v qe q ;o qba l oml o qb l ka p e a vfbia p obar ba v , 6mbo bkq ;o qb v , o#mbo bkq ka l j j bo f i j l oqd dbp v ,1 mbo bkq,

[2] Fk qe b R,H, t e bob kkr fqfbp ob pl ia qe q ob agr pqba ql fkci qfl k fq fp ml ppf ib ql e ba db fka buba kkr fqfbp v mr o e pfkd dl s bok j bkq l ka p qe q ob fka buba ql qe b p j b mof b fka bu f,b, qe b Obq fi Mof b Fka bu l o OMF·, Qe b CP Obqr okp j hb

fj ml ppf ib cl o ifcb ppr obop ql j q e qe b ar o qfl k l c qe bfo ppbqp mob fpbiv t fqe qe b ar o qfl k l c qe bfo if fifqfbp pl qe bob ob pj ii aafqfl k i l pqp ql j k dfkd pe cil t qe bpb j v b fddbo cl o OMF;ifkhba kkr fqfbp t e bob qe b j ohbq cl o l kap fp pj iibo, k fj mif fq ppr j mqfl k l c qe b obj fkfkd i odb ofph c ba v ifcb ppr obo fp qe b dol r m j l oq ifqv ofph l c qe b kkr fq kqp qe b kr j bo l c kkr fqfbp pl ia fp pr ccf fbkqiv i odb qe q fafl pvk o qf kkr fq kq j l oq ifqv ofph k b fdkl oba·, T b fkqol ar b pql e pqf j l kbv p t l oqe j bqpf ka l j mr qb qe b afpqof r qfl k l c qe b mobpbkq s ir b l c kkr fqv m vj bkqp qe q iil t p cl o r k boq fkqv fk qe b l e l oq j l oq ifqfbp,

Fq fp ml ppf ib ql nr kqfcv j l oq ifqv ofph qe ol r de obi qfs biv ob bkqiv a bs bil mba pql e pqf j l oq ifqv j l abip pr e p qe q l c I bb ka oqbo 66# t e f e iil t r p ql bpqfj qb qe b mol fifqv afpqof r qfl k l c cr qr ob j l oq ifqv, Qe b qo afqfl k i ofph; kbr qo i mmol e ql mof fkd kkr fqfbp fp ql pbq qe b mof b bnr i ql qe b bumb qba mobpbkq s ir b l c qe b mol j fpba kkr fqv m vj bkqp vfbiafkd j l kbv p t l oqe bnr i ql r kfqv l o pifde qiv ibpp qe k r kfqv oqbo iil t fkd cl o qe b il afkdp ppl f qba t fqe qe b kkr fqv mol s fpfl k·, Qe b Pl is bk v FF pbi # mmol e l oqbk r pbp qe b S ir b; q;Ofph S O· p dr fab ql pr fq ib obpbos fkd pl Obdr i ql o l r ia r pb l r o bpqfj qbp l c qe b afpqof r qfl k l c kkr fqv s ir bp ql i r i qb S Op ka bu j fkb qe b bccb q qe q S O mof fkd t l r ia e s b l k l ks bkqfl k i j b pr obp l c qe b j l kbv p t l oqe , v S O mof fkd t b j b k qe q fkpr o k b mol s fa bop mof b l cc qe b q fi l c mol fifqv afpqof r qfl k l c cr qr ob j l oq ifqv pr e qe q qe bob fp 62mbo bkq e k b l c e s fkd pr ccf fbkq ppbqp ql j bbq qe b qr i ofphv if fifqfbp, Qe fp mmol e iil t pr p ql kpt bo qt l nr bpqfl kp

Cfopq dfs bk l r o bpqfj qbp l c qe b ofphp ql ifcb ppr obop k t b p v kvqe fkd l r q e l t qe bpb t fii ccb q qe b j l kbv p t l oqe ka e l t qe b j l kbv p t l oqe t fii e kdb t e bk vfbiap e kdb

Pb l ka t e q ob qe b l kpbnr bk bp l c qe b mof fkd l c afccbobkq kkr fqv mol ar qp b,d, ob i s bopr pkl j fk i· l k qe b j l kbv p t l oqe

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bumif fq qe q qe b afccbobkq qvmbp l c kkr fqfbp ob hba v afccbobkq ppbqp, Cl o bu j mib qe b kl qb fk *Norwich Union Annuity Lim*fqba kkr i CP Fkpr o k b Obqr okp cl o qe b vb o bkaba opq b bj bo # 2 m db 2· Kl k;ifkhba ka fka'bu; ifkhba if fifqfbp ob hba v afccbobkq ppbqp ka e bk b e s b afccbobkq s ir qfl k fkqbobpq o qbp, T b pq oq v ofbciv obs fbt fkd qeb qeb bl ov l c as bopb pbib qfl k fk qeb kkr fqv j ohbq ka afp r pp t e bqe bo fq fp mmol mof qb ql e o qbofpb qeb j ohbq p bfkd pbm o qfkd bnr fif ofr j , T b qeb bk abp of b qeb l ks bkqfl k i j l kbv pt l oqe j b pr ob ka el t fq fp i r i qba fk mo qf b, Fk pb qfl k 1 t b qeb bk obs fbt qeb bs fa bk b cl o qeb j l kbv pt l oqe fk qeb RH, Fk pb qfl k 2t b pe l t e l t mol fifqv afpqof r qfl k l c qeb s ir b l c k kkr fqv k b l kpqor qba r pfkd pql e pqf j l oq ifqv j l abi, T b r pb qe fp ql j b pr ob qeb ofph cl o kkr fqfbp ka qeb l kpbnr bk bp t e bk obpb o e bo i r i qbp qeb j l kbv p t l oqe pba l k a bqboj fkfpqf mol gb qfl k l c j l oq ifqv t efib kkr fqv mol s fa bop ob mof fkd ql q hb fkql l r kq qeb cfk k f i ofph ppl f qba t fqe j l oq ifqv ofph ka dfs bk pbq l c fkqbobpq o qbp,

2. Money's Worth Calculations

2.1 The (Conventional) Money's Worth

Qeb l ks bkqfl k i j b pr ob l c qeb s ir b l c k kkr fqv fp qeb j l kbv p t l oqe T ope t phv 655 J fq e bii bq i 666, Ql cfu kl q qfl k ka co j b qeb afp r ppfl k t b l kpfa bo qeb pfj mibpq kkr fqv mol ar q *level annuity* t ef e m vp l kpq kq kl j fk i m vj bkqp q j l kqe iv fkqbos ip [3]mr o e pba v j k r oobkqiv gr pq db 32 t fqe qeb cfopq m vj bkq bfkd j ab q qeb ml fkq l c mr o e pb, Fk t l oia l c mbocb q boq fkqv qeb mobpbkq s ir b l c k kkr fqv t fqe j l kqe iv m vj bkqp t l r ia b bs ir qba q qfj b t p

$$\text{annuity value} \equiv \sum_{x=65}^{\infty} R_{t,(x-65)} I_x \qquad x = \left\{65, 65\tfrac{1}{12}, 65\tfrac{2}{12}, \ldots\right\}$$

t e bob $R_{t,j}$ fp qeb afp l r kq c ql o bs ir qba q qfj b t t e f e a bqboj fkbp qeb mobpbkq s ir b l c ob bfs ba j mbofl a p e bk b ka $I_x \in \{0,1\}$ fp k fkaf ql o s of ib pe l t fkd t e bqe bo l o kl q qeb kkr fq kq fp ifs b q db x, Kl qf b qe q t b j b pr ob db ka qfj b fk vb op r q m vj bkqp ob j l kqe iv, Qeb bumobppfl k fk · fp qeb s ir b l c k kkr fqv r pr iiv a bkl qba a fk qr of i kl q qfl k·, bcfkb qeb *annuity rate* p qeb o qfl l c kkr i m vj bkqp ql qeb qr i mr o e pb mof b l c k kkr fqv p A, Cl o bu j mib fk qeb RH fk Gr iv # 6 qeb Mor abkqf i t l r ia pbii k kkr fqv cl o ql 32 vb o l ia j k t ef e t l r ia m v j l kqe iv fk l j b l c 3 l o 4 c# kkr iiv cl o

[3] L qeb o cobnr bk fbp l c m vj bkq bd nr oqboiv· ob ml ppf ib r q o ob fk qeb RH,

ifcb qeb kkrfqv o qb t l r ia b $A_{2009,65} = 732/10{,}000 = 0.0732 = 7.32\%$, Qebk qeb j l kbv pt l oqe fk t l oia l c mbocb q boq fkqv t l r ia b

$$\text{Money's Worth}_{\text{Perfect Certainty}} \equiv \frac{A_{t,65}}{12}\sum_{x=65}^{\infty} R_{t,(x-65)} I_x \qquad x = \left\{65, 65\tfrac{1}{12}, 65\tfrac{2}{12}, \ldots\right\} \tag{\#}$$

ifcb ppr obo t fqe wbol qo kp qfl kp l pqp l r ia pbq qeb kkr fqv o qb pl qe q qeb j l kbv pt l oqe t l r ia bnr i l kb ka gr pq ob h bs bk pl j bqfj bp iiba qr of iiv c fo mof fkd, Fk ob ifqv l qe $R_{t,j}$ ka I_x ob r khkl t k, Kl q l kiv j r pq qeb ifcb ppr obo j hb ppr j mqfl kp l r q el t ql mof b qeb kkr fqv r q qeb b l kl j fpq k ivpfkd qeb a q t fqe qeb bkbcfq l c efkapfdeq j r pq qov ql ab fab t e q qeb ifcb ppr obo pel r ia e sb r pba ql i r i qb qeb j l kbv pt l oqe q qeb qfj b, Fc qeb ifcb ppr obo ka qeb b l kl j fpq t bob ql j hb qeb p j b ppr j mqfl kp qebk pbkq qo kp qfl k l pqp qeb j l kbv pt l oqe t l r ia pqfii bnr i r kfqv pl il kd p qeb ifcb ppr obo t bob ofph kbr qo i ka ebk b bumb qba mol cfqp t bob wbol ,

ob i kkr fqv j hbp m vj bkqp t ef e ofpb l sbo qfj b fk ifkb t fqe mof b fkabu, Fk qeb RH qe fp fp qeb Obq fi Mof b Fkabu OMF·,[4] Qeb dl s bokj bkq fppr bp fkci qfl k; fkabuba l ka p ipl ifkhba ql qeb OMF, bkl qfkd $R^{*}_{t,j}$ ql b qeb afp l r kq c ql o q qfj b t cl o m vj bkq l c fk qfj b t p ob i qboj p j mbofl ap ebk b ka qeb kkr fqv o qb $A^{*}_{t,65}$ p qeb kkr fqv o qb pba l k qeb fkfqf i kkr i m vj bkq afsfaba v qeb mobj fr j qeb j l kbv pt l oqe l c ob i kkr fqv fp

$$\text{annuity value} \equiv \sum_{x=65}^{\infty} R_{t,(x-65)} s_x \qquad s_x \equiv \prod_i p_{t+i,x}$$

$$\text{Money's Worth} \equiv \frac{A_{t,65}}{12}\sum_{x=65}^{\infty} R_{t,(x-65)} s_x \tag{Θ}$$

t ebob $p_{t+i,x}$ fp qeb l kb;mbofl a pr osfs i mol fifqv cl o qeb kkr fq kq t el fp db x fk mbofl a $t+i$ qe q fp qeb mol fifqv l c ifsfkd l kb j l ob mbofl a l ka fqfl k i l k bfkd ifsb q qeb bdfkkfkd l c qeb mbofl a· ka s_x fp qer p qeb mol fifqv l c qeb r oobkq 32; vb o;l ia ifsfkd ql db x l o il kdbo,

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[4] Qeb l ccf f i j b pr ob l c fkci qfl k fp i r i qba col j qeb l kpr j bo Mof b Fkabu t ef e fp pba l k afccbobkq phba l c dl l ap ka r pbp afccbobkq j bqel al il dv·, iqel r de ob bkq RH dl s bokj bkq ml if v e p bbk ql r pb qeb MF cl o mbkpfl kp fq pqfii fppr bp l ka p fkabuba ql qeb OMF,

Qe b afp l r kq c ql o $R_{t,j}$ fp r pr iiv fkcbooba col j qe b vfbia r os b l k dl s bokj bkq l ka p ka fq fp ppr j ba qe q qe fp o qb l c obqr ok fp ofph cobb, Qe bob ob qt l ml ppf ib gr pqfcf qfl k p cl o r pfk d qe bpb fkqbobpq o qbp, Qe b cfopq fp qe q kkr fqv m vj bkqp ob j b kq ql b pb r ob f,b, qe b e k bpl c a bc r iq ob j fkfj i· ka qe b fkqbobpq o qb l k dl s bokj bkq l ka p fp qvmf iiv qe b bpq ml ppf ib dr bpp q qe b p cb o qb l c fkqbobpq, Cl o pl j b l r kqofbp qe b fkqbobpq o qb l k dl s bokj bkq a b q t l r ia kl q b ofph cobb r q qe fp pbbj p ob pl k ib mmol ufj qfl k cl o l r kqofbp pr e p qe b R ,H, cl o t e f e ab q fp qvmf iiv o qba , T e bob ifcb ppr obop r pb l j j bo f i l ka p l o l j j bo f i j l oqd dbp· qe bv j r pq agr pq qe b efde bo o qbp l c obqr ok cl o qe b dob qbo ofph ka ql dl l a mmol ufj qfl k qe b ofph; agr pqba o qbp l c obqr ok l k l j j bo f i l ka p l o j l oqd dbp ob ifhbiv ql b qe b p j b p qe b o qbp l c obqr ok l k dl s bokj bkq l ka p[5] Pb l ka iv ifcb ppr obop mmol ufj qbiv j q e qe bfo kkr fqv if fifqfbp t fqe dl s bokj bkq l ka p ka obdr i qfl k j v bs bk l j mbi qe bj ql a l pl , [6]

2.2 Estimating the Survival Probability

nr qfl k ɵ obnr fobp r pq l hkl t qe b mol fifqv l c ifs fkd $p_{t+i,x}$ l o bnr fs ibkqiv qe b mol fifqv l c a vfkd obcbooba ql p qe b j l oq ifqv, Qe b bpqfj qfl k l c qe bpb s of ibp fp pq mib l c qr of i qbuq l l hp l t bop *et al,* 66 Mfq l bq i # 6 r q cl ob pqfkd qe bpb s of ibp fp j l ob mol ibj qf ka r pr iiv obifbp l k buqo ml i qfkd qe b m pq qobka pfk b j l a bip pba l k qe b r pbp l c a b qe ob fkpr cf fbkqiv mob fpb ql b r pba cl o mobaf qfl k mr oml pbp, Qe b obpr iqfkd bpqfj qb fp pr gb q ql r k boq fkqv col j s of bqv l c pl r o bp,

Cfopq qe b bpqfj qbp t fii b pba l k a q s fi ib r mql qfj b t l o ml ppf iv b oifbo fc qe bob ob i dp fk a q l iib qfl k· l qe bo qe k j b pr obj bkq bool op qe bob fp ipl qe b

[5] bq fipl c qe b kl qfl k i vfbia p obafq o qfkdp ka l oobpml kafkd agr pqj bkqp ob obml oqba fk qe b CP obqr okp, Mof b ofph fp obi qfs biv r kfj ml oq kq pfk b l ka p ob qvmf iiv e bia ql j qr ofqv,

[6] DCP # · mol s fa bp obs fbt l c fkqbok qfl k i fkpr o k b obdr i qfl k ka kl qbp qe q qe fp j q e fkd k b *duration matching* t e f e l kiv m oqf iiv j q e bp if fifqv ka ppbq pe cil t p ka *cash-flow matching* t e f e mbocb qiv j q e bp qe b cil t p, Qe b cl qkl qbp l c s ofl r p CP obqr okp kl qb qe q mbocb q j q e fkd fp fj ml ppf ib ka qe q qe bob fp pj ii obpfar i ofph, Qe fp j q e fkd fp ifhbiv ql b j l ob afccf r iq cl o OMF; ifkhba kkr fqfbp ka t b obqr ok ql qe q fppr b fk pb qfl k ɞ ,

J l ob cl oj iiv j l oq ifqv μ fp qe b l kqfkr l r p;qfj b k il dr b l c qe b l kb;vb o ab qe mol fifqv $q \equiv 1 - p = \int d\mu$, mol ibj qe q a b qe o qbp ob kl q nr fqb qe b p j b p a b qe mol fifqfbp ka qe bob j v b l kpfa bo ib p j mifkd bool o fc qe b a b qe o qbp ob pba l k obi qfs biv pj ii p j mibp t e f e fp l ccqbk qe b pb cl o qe b e fde bpq dbp·,

Pb l ka qe bob fp j l abi r k boq fkqv, J l pq j l abip pq oqfkd ml fkq fp Dl j mboqwp I t f,b, qe b bj mfof i obdr i ofqv fp qe q qe b il d ofqe j l c a b qe o qbp qbka p ql fk ob pb mmol ufj qbiv ifkb oiv, Qe b s b qp ql qe fp ob qe q qe b a b ifkb fp l kiv mmol ufj qbiv ifkb o qe b pmbba l c a b ifkb abmbka p r ml k db ka qe bob ob l pfl k i pqpr qr o i ob hp t e f e j v mmiv bfqe bo ql qe b t el ib ml mr i qfl k l o ql gr pq pl j b l el oqp, Qe bob fp ipl pl j b a l r q p ql t e bqe bo l kb pel r ia il l h q qe b il d ofqe j l c qe b a b qe o qb l o il dfpqf cr k qfl k ka t e bqe bo qe b a b ifkb fp pql e pqf l o a bqbo j fk fpqf qpbka fokp *et al* # 6,

Qe foa t e bk il l hfkd q mbk pfl k bop qe bob j v b a afqfl k i e kdbp fk qe b a q dbk bo qfkd mol bpp bfqe bo b r pb qe b e b iqe l c kkr fq kqp e kdbp obi qfs b ql qe q l c qe b ml mr i qfl k p t el ib l o b r pb qe b e b iqe l c mbk pfl k bop fp a fccbobkq col j l qe bop ka mbk pfl k l s bo db e kdbp ; qe bpb ob qt l afccbobkq cl oj p l c pbib qfl k bccb q, Fk j kv l r kqofbp pr ccf fbkqiv abq fiba a q cl o ^{p} ob pfj miv r k s fi ib ka qe b R,H, fp r kr pr i fk e sfkd obif ib a q l s bo il kd qfj b mbofl a t fqe qe b cr oqe bo as kq db qe q a q ob s fi ib cl o afccbobkq dol r mp l c mbk pfl k bop pl qe q afccbobkq ifcb bumb q k fbp k b obcr iiv ifdk ba t fqe qe b obibs kq cfk k f i ppbqp ka qe b qe foa mol ibj l c pbib qfl k bccb qp k b bifj fk qba l o q ib pq qqbkr qba·, Qe b mol cbppfl k i qr of i l afbp mr ifpe l ccf f i q ibp t e f e k b r pba v obdr i ql op fk abqboj fkfkd qe b s ir qfl k l c kkr fqv mol s fa bop if fifqfbp, Qe bpb l ccf f i q ibp k qe bk b r pba ql i r i qb qe b j l kbv pt l oqe ,

Fk qe b R,H, pfk b 6#1 ifcb l ccf bp e s b mol s fa ba qe bfo cfoj ;ibs bi a q ql bkqo i l j j fqqbb l c qr ofbp t el kl kvj fpba ka ml l iba qe fp fkcl oj qfl k ql ob qb i ocb bkl r de a q pbq ql bk ib obif ib pq qfpqf i k ivpfp ka il kd;qboj mol gb qfl kp, R kqfi 666 fb qe b 6# pbofbp· qe b mol gb qfl kp t bob l kiv r ma qba fkcobnr bkqiv, Qe b fkqbofj agr pqj bk'qp ql qe fp pbofbp fk # # iil t ba cl o qe obb afccbobkq p bk ofl p ka qe b pbofbp l c # 3 afa kl q bs bk qqbj mq ql mol gb q j l oq ifqv fkql qe b cr qr ob r q pfj miv abp of ba qe b bsl ir qfl k l c qe b a q r mql # #, Cr oqe boj l ob qe bob ob qe obb afccbobkq pbqp l c j l oq ifqv a q , Cfopq e fde mol ml oqfl k l c kkr fqfbp ob pl ia ql fkafsfar ip t fqe mbopl k i mbk pfl k 'fb t el e s b qe bfo l t k mbk pfl k cr ka t e f e e p r j r i qba cobb l c q u ka t el ob obnr foba v i t ql r v k kkr fqv, E l t bs bo qe b kr j bo l c j ib mbk pfl kbop t fqe mbopl k i mbk pfl kp fk m vj bkq o qe bo qe k fk or i· t p pil t pqt l qe l r p ka p ob bkqiv p qe b mbofl a 65; 6 pl bccb qfs biv qe bob fp ql l pj ii a q pbq cl o j b kfk dcr i mol gb qfl kp l o cl ob pqp, Qe b mob; r opl o ql qe b mbopl k i mbk pfl k fk qe b RH t p qe b obqfobj bkq kkr fqv' l kqo q cl o t e l j qe bob ob j l ob kkr fqfbp fk m vj bkq j l ob qe k 3 col j 65; 6 l kt oa p·, r q qe fp pb l ka pbq l c l kqo qp t bob mofj ofiv mr o e pba v qe b pbic;bj mil vba pl qe b pbib qfl k fkql qe fp dol r m fp ifhbiv ql b a fccbobkq ql qe q l c mbopl k i mbk pfl kbop ka qe b or k l c a q fp pqfii c foiv pe l oq, Qe b l kiv i odb a q pbq fp cl o qe b mbk pfl kbop t e l e s b l r m qfl k i mbk pfl kp t e f e ob a j fk fpqboba v ifcb ppr o k b l j m kfbp qe b ifcb l ccf b mbk pfl kbop · ka qe fp l kpqfqr qbp qe b qe foa pbq l c a q l k j l oq ifqv r q d fk qe fp dol r m j v b pbib qba a fccbobkqiv col j qe q l c qe b mbopl k i mbk pfl kbop,

2.3 Money's Worth Calculations

Cfdr ob fiir pqo qbp l r o r ma qba kkr fqv o qb a q cl o 3 2vb o l ia j bk fk qe b RH l j mr ipl ov mr o e pb j ohbq ka qe b j l kbv pt l oqe p cl o kkr fqfbp cl o qe obb dbp ob fiir pqo qba fk Cfdr ob #, Cl o qe b t e l ib mbofl a t b i r i qb qe b j l kbv pt l oqe r pfkd cl r o a fccbobkq j l oq ifqv q ibp col j qe b *Institute of Actuaries* qe b kkr fqv o qb a q ka fkqbobpq o qb a q ob qe b p j b cl o ii cfs b pbofbp·, Qe bpb pbofbp ob pba l k qe b p j b a q p kkl k ka Ql khp # · r q ob i r i qba j l kqe iv o qe bo qe k l k kkr i s bo dbp, [#] e kbt qr of i q ib obpr iqp fk k fk ob pb fk qe b j l kbv pt l oqe ar b ql il kdbo mol gb qba ifcb bumb q k v ka t b l kiv mil q qe b pbofbp cl o qe l pb qfj b mbofl ap t e bk qe b obibs kq qr of i q ibp t bob j l pq ifhbiv ql b r pba, Qe b bs fa bk b fk Cfdr ob # pr ddbpqp qe q qe bob t p c foiv pj ii a b ifkb fk j l kbv pt l oqe p cl o j ib dba 3 2 r q ifqqib e kdb cl o j ibp dba 4 l o 4 2 fk c q qe b o kdb l c j l kbv pt l oqe p cbii l kpfa bo iv,

[Figures 2 and 3 about here]

l j m ofkd Cfdr obp # ka ofq fp mm obkq qe q qe b a b ifkb fk kkr fqv o qbp l c l r q #, 2 mbo bkq bqt bbk 66 ka # al bp kl q l oobpml ka ql p i odb e kdb fk qe b

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Qe b a q ob a fp r ppba fk j l ob a bq fi fk qe b mmbka fu,

[#] Qe b j l kbv pt l oqe p ob pifde qiv e fde bo m oqiv b r pb l c qe b bccb q l c qe b s bo dfkd ka m oqiv b r pb pj ii bool o t p obj l s ba col j qe b l ofdfk i i r i qfl kp qe b cfopq m vj bkq fp j a b l k qe b a v l c mr o e pb ka kl q l kb j l kqe fk i qbo, j l k bv p t l oqe qe fp ml ifqf iiv pbkpfqfs b c ii fp mobal j fk kqiv bumi fk ba v c iip fk fkqbobpq o qbp ka fk ob pbp fk ifcb bumb q k v, Qe b j r e j l ob kl q ib e kdb fp qe b mm obkq obs bop i l c j l k bv p t l oqe p v db fk qe b mbofl a col j # ql # 1 col j # 1 l kt oa p qe b l oa bofkd l c j l k bv p t l oqe p v db obqr okp ql qe b m qqbok d r ka fk Cfk hbipqbfk ka M qbo # # r q qe b o kdb fp s bov j r e pj iibo, kkl k Pqbs bkp ka Ql khp # # k ivpb qe b r q e kkr fqv j ohbq ka cfka qe fp fks bopb m qqbok l c j l k bv p t l oqe p v db qe bob cl o qe b mbofl a # ; # ,

[Figures 4 and 5 about here]

Cfdr ob 1 pe l t p qe b j l k bv p t l oqe cl o kkr fqfbp t fqe dr o kqbb mbofl a p qe bpb mmb o ql j hb ifqqib afccbobk b, Cfdr ob 2pe l t p qe b j l k bv p t l oqe p cl o ibs bi ob i ka bp i qfkd kkr fqfbp r kcl oqr k qbiv t b a l kl q e s b cr ii pbq l c a q bcl ob 665 T b ob ib ql l kcfoj qe b cfkafkdp l c Cfk hbipqbfk ka M qbo # # qe q hil a ba kkr fqfbp ob i ka bp i qfkd· e s b il t bo j l k bv p t l oqe p qe k ibs bi kkr fqfbp, L qe bo qe k qe b c q qe q qe b j l k bv p t l oqe qbka p ql b il t bo qe k fk Cfk hbipqbfk ka M qbo # # qe b nr ifq qfs b be s fl r o l c ibs bi kkr fqfbp s bor p bp i qfkd l o ob i fp i odbiv qe b p j b, l j m ofkd qe b bdfkkfkd l c qe b mbofl a ql qe b bka qe b qt l mbofl a p t e bk t b ob obi qfs biv l kcfa bkq l r q qe b mmol mof qb j l oqif qv q ib ql r pb· qe bob fp pl j b pifde q bs fa bk b qe q qe b j l k bv p t l oqe e p c iibk ka qe q qe b d m bqt bbk qe b kl j fk i ka ob i j l k bv p t l oqe e p ofpbk, Qe b obpr iqp cl o qe b obi qfs b j l k bv p t l oqe p l c ob i ka bp i qfkd ob j l ob j fuba qe b d m bqt bbk qe bj fp l qqbk pj ii ka pl j bqfj bp qe b j l k bv p t l oqe p l c ob i kkr fqfbp fp pifde qiv e fde bo qe k cl o bp i qfkd o qe bo qe k il t bo,

L s bo ii l r o k ivpfp cl o qe b j l k bv p t l oqe l s bo qe b t e l ib mbofl a i odbiv l kcfoj p qe q l c Cfk hbipqbfk ka M qbo # #, Qe b s b qp ob qe q qe b afccbobk bp fk j l k bv p t l oqe v db l o dr o kqbb mbofl a e s b afp mmb oba v qe b bka l c qe b mbofl a ,

3. Adverse selection in Annuity Markets

3.1 Annuity rates and the money's worth

Fk qe fp pb qfl k t b b l r qifkb pfj mib co j bt l oh t fqe fk t e f e t b k ivpb qe b kkr fqv j ohbq, l kpfa bo pfj mib j l abi t e bob dbkqp ifs b cl o r mql qt l mbofl a p ii dbkqp ifs b fk mbofl a cl o boq fk r q qe b mol fifqv l c ifs fkd fkql mbofl a qt l fp p^{type} t e bob qe b pr mbo;p ofmq *type* obcbop ql qe b c q qe q qe b pr os fs i mol fifqv j v a bmbka l k k kkr fq kq p e o qbofpqf p, Kl qf b qe q e fde s ir b l c p^{type} l oobpml ka p ql e fde ;ifcb;bumb q k v fkafs far i t e f e fp e fde ofph col j qe b mbopmb qfs b l c qe b ifcb ppr obo, J l pq l c qe fp pb qfl k t fii b a fp r ppfkd qe b mob fpb k qr ob l c p^{type},

Pr mml pb qe b kkr fq kq k e l l pb k kkr fqv t e f e mbo mobj fr j fk mbofl a j hbp m vj bkq l c a_1^{type} fk mbofl a ka m vj bkq l ka fqfl k i l k bfkd ifs b· l c $a_2^{type} = \phi^{type} a_1^{type}$ fk mbofl a #, I fcb ppr obop pbii kkr fqfbp ql i odb ml l i l c kkr fq kqp ka qe fp j b kp qe q qe bob fp j fkfj r j fa fl pvk o qf ofph ka fk l j mbqfqfs b j ohbq qe bv pbq qe b kkr fqv o qb ql p qfpcv qe b ob h;bs bk l ka fqfl k

$$1 = \frac{a_1^{type}}{1+r} + \tilde{p}^{type} \frac{a_2^{type}}{(1+r)^2} \Rightarrow a_1^{type} = \frac{(1+r)^2}{1+r+\tilde{p}^{type}\phi^{type}} \qquad 1\cdot$$

t e bob r fp qe b fkqbobpq o qb ka $\tilde{p}^{type}$ fp qe b pr os fs i mol fifqv r pba v qe b ifcb ppr obo ql s ir b qe b if fifqv cl o ifcb ppr obo pbiifkd kkr fqfbp ql i odb kr j bo l c mbopl k i mbkpfl kbop fq fp qe b mol ml oqfl k l c mbkpfl kbop t e l ifs b ql mbofl a #,

k b l kl j fpq k ivpfkd kkr fqv a q qvmf iiv e p fkcl oj qfl k l kiv l k kkr fqv o qbp cl o afccbobkq kkr fqv mol ar qp f,b, fkcl oj qfl k l k a_1 ka ϕ, R pfkd qe fp fkcl oj qfl k qe b j l kbv pt l oqe cl o kl j fk i kkr fqfbp t e bqe bo ibs bi l o bp i qfkd fp i r i qba p

$$MW = a_1 \left\{ \frac{1}{(1+r)} + \bar{p} \frac{\phi}{(1+r)^2} \right\} \qquad 2$$

t e bob $\bar{p}$ fp qe b pr os fs i mol fifqv l c r pba v qe b b l kl j fpq, p t b e s b pbbk fk pb qfl k # qe bob j v b pl j b mol ibj fk ab fafkd bu qiv t e f e pr os fs i mol fifqv ql r pb,

Qe b bs ir qfl k l o ob i fkci qfl k;fka buba· kkr fqfbp fp ij l pq fa bkqf i, Fc qe b ob i fkqbobpq o qb fp r^* qe bk qe b ifcb ppr obo p mof fkd bnr qfl k t fii b qe b ob i k il dr b l c bnr qfl k 2 k j biv

$$1 = \frac{a_1^{type}}{1+r^*} + \tilde{p}^{type} \frac{a_2^{type}}{(1+r^*)^2} \qquad 3$$

t e bob $\phi = 1$ p ob i kkr fqfbp ob kl q bp i qfkd fk ob i qboj p, Qe b obpb o e bop bpqfj qb l c qe b j l kbv pt l oqe t fii b qe b ob i k il dr b l c 2 k j biv

4·
$$MW^* = a_1\left\{\frac{1}{1+r^*}+\frac{\bar{p}}{\left(1+r^*\right)^2}\right\}$$

nr qfl kp 3 ka 4· ob qe b p j b p bnr qfl kp 1· ka 2 r q cl o qe b obmi bj bkq l c r^* cl o r pfk b $r^* < r$ t b k l j m ob qe b j l kbv p t l oqe p l c ob i ka kl j fk i kkr fqfbp gr pq v il l hfkd q $\partial MW/\partial r$,

3.2 A simple model of adverse selection

fp r ppfl k l c as bopb pbib qfl k fk fkpr o k b j ohbqp kl oj iiv bkqobp l k t e bqe bo dbkqp mr o e pb cr ii l o m oqf i fkpr o k b, Fk qe b R H fq fp s foqr iiv l ifd ql ov cl o mbopl k i mbkpfl kbo ql mr o e pb k kkr fqv t fqe q ib pq 4 2mbo bkq l c qe b s ir b l c qe b mbkpfl k cr ka r mql # 2mbo bkq k it vp b q hbk p q u;cobb ir j mpr j ·, Fk mofk fmib fq fp ml ppf ib ql sl fa kkr fqfp qfl k r kqfi db 4 2 ka bs bk qe bk l kb k sl fa kkr fqfpfkd ii l c l kb p mbkpfl k t b iqe , Fk mo qf b abcboofkd l o sl fafkd kkr fqfp qfl k fp r k qqp qfs b cl o j l pq fka fs far ip bu bmq mboe mp qe b s bov t b iqe v t el ob al fkd pl cl o l j mif qba q u ob pl kp, Fc l kb abcbop kkr fqfp qfl k r kqfi 4 2 l kb j r pq bkqbo ao t al t k t e f e'fp bumbkpfs b ka ifj fqp qe b j l r kq l c qe b cr ka qe q k b bppba, Fk m oqf r i o qe fp t l r ia pbs bobiv ifj fq qe b ml ppf fifqv cl o fka fs far ip t el bifbs ba qe bv e a pe l oq ifcb bumb q k v ql ofkd cl ot oa l kpr j mqfl k, Ql sl fa kkr fqfp qfl k l kb j r pq cfopq a bj l kpqo qb qe q l kb e p pb r ob mbkpfl k fk l j b mboe mp mr o e pba col j ml oqfl k l c qe b mbkpfl k cr ka· ka qe bk m v 22mbo bkq q u l k qe q m oq l c qe b mbkpfl k cr ka t e f e fp kl q kkr fqfpba qe b 22mbo bkq q u bcb qfs biv ob i fj p ii l c qe b q u mofs fifdbp qe q e fde bo;o qb q u m vbo t l r ia e s b ob bfs ba col j p s fkd fk mbkpfl k cr ka, [9]

Cl o qe bpb ob pl kp t b k qob q kkr fqfp qfl k p bcb qfs biv l j mr ipl ov cl o kb oiv ii mbopl k i mbkpfl kbop ka qe b l kiv el f b s fi ib fp qe b qfj fkd l c kkr fqfp qfl k ka qe b qvmb l c kkr fqv mr o e pba, s fa bk b col j qe b ppl f qfl k l c ofqfpe Fkpr obop pel t p qe q qe b s pq j gl ofqv l c kkr fqfbp ob mr o e pba q qe b l ks bkqfl k i obqfobj bkq db p l c 22 3 l o 32 pr ddbpqfkd qe q qfj fkd fp a ofs bk ij l pq bkqfobiv v obqfobj bkq s bov cbt kkr fqfbp ob mr o e pba q db 4 2 cr oqe bo bs fa bk b qe q qe b l mqfl k ql abcbo kkr fqfpfkd r kqfi qe bk fp kl q s bov fj ml oq kq·,

[9] Qe b abq fip l c l j mr ipl ov kkr fqfp qfl k or ibp e s b e kdba pbs bo i qfj bp fk qe b i pq ab ab, Qe b j l pq ob bkq or ibp ob a bp of ba fk E J Qob pr ov # ·, oifbo s of kqp ob afp r ppba fk kkl k ka Ql khp # 6,

Cfkhbipqbfk ka M qbo # # # 1· pr ddbpq qe q k as bopb pbib qfl k pbm o qfkd bnr fif ofr j l r ia b efbs ba qe ol r de dbkqp t fqe afccbobkq ifcb bumb q k fbp r vfkd afccbobkq mol ar qp pfk b mol ar q qvmb fp qe b l kiv obj fkfkd e l f b l mbk ql mbopl k i mbkpfl kbo, Fk qe b j l abi l c pb qfl k 9 pr mml pb qe q qe bob ob qt l qvmbp afpqfkdr fpe ba l kiv v qe bfo pr os fs i mol fifqfbp t e f e ob p^h cl o efde ;ifcb; bumb q k v fkafsfar ip ka p^l cl o il t ;ifcb;bumb q k v fkafsfar ip t e bob $p^h > p^l$, dbkqp j ufj fpb obpmb qfs biv

$$U^h = u\left(c^h\right) + p^h \delta u\left(c^h\right)$$

5

$$U^l = u\left(c^l\right) + p^l \delta u\left(c^l\right)$$

Cl o pfj mif fqv l c bumlpfqfl k t b ipl ppr j b qe q dbkqp e sb qe b p j b cbif fqv cr k qfl k $u(\bullet)$ qe q $r = \delta$ ka qe q qe bob fp kl p sfkd mol ar q l qe bo qe k qe b kkr fqv ka qe q qe bob fp kl l ool t fkd,

[Figure 6 about here]

Qe b r adbq l kpqo fkqp ka fkafccbobk b r os bp ob mil qqba fk Cfdr ob 3 t e f e il l hp ifhb qe b pq ka oa qt l ;mbofl a;j l abi af do j cl o qe b Ol qe p efia;Pqfdifqw j l abi l c fkpr o k b, E l t bs bo qe bob ob pr qib afccbobk bp cfopq t e bob p fk qe b O;P j l abi qe b qt l ubp pe l t l kpr j mqfl k fk qe b qt l afccbobkq pq qbp l c qe b t l oia fk qe fp af do j qe b s boqf i ufp pe l t p qe b boq fk l kpr j mqfl k fk mbofl a l kb ka qe b e l ofwl kq i ufp pe l t p e l t j r e qe b fkafsfar i l kpr j bp l kafqfl k i l k pr os fs fkd fkql mbofl a qt l pb l ka q kv ml fkq l k qe b r adbq l kpqo fkq k kkr fq kq fp cr iiv fkpr oba fk qe b pbkpb qe q e b t fii kl q l r qifs b efp obpl r o bp qe b l kiv t v ql b r kabo;fkpr oba d fkpq il kdbs fqv ofph fp ql fks bpq pl j b t b iqe fk kl k; kkr fqv cl oj t e f e kkl q b pe l t k fk qe fp af do j ·, Pl afccbobkq ml fkqp il kd r adbq l kpqo fkq al kl q pe l t afccbobkq ibs bip l c fkpr o k b r q afccbobkq l kpr j mqfl k m qe p qe ol r de qfj b cl o bu j mib ml fkq e p qe b p j b ibs bi l c l kpr j mqfl k fk l qe mbofl a p t e bob p ml fkq e p efde bo ibs bi l c l kpr j mqfl k fk mbofl a l kb q qe b bumbkpb l c il t bo l kpr j mqfl k fk mbofl a qt l ,

Fk pbm o qfkd bnr fif ofr j ifcb ppr obo t l r ia l ccbo qt l l kqo qp q ka , E fde ;ifcb; bumb q k v kkr fq kqp t l r ia e l l pb l kqo q t e bob p il t ;ifcb; bumb q k v dbkqp t l r ia e l l pb l kqo q , Qe b af do j fiir pqp qbp qe b obnr fobj bkqp kb bpp ov cl o pbm o qfkd bnr fif ofr j ql bufpq qe b qt l qvmbp l c kkr fq kq j r pq e sb fka fccbobk b r os bp t fqe afccbobkq pil mbp ka fq j r pq b ml ppf ib ql l ccbo l kqo q pr e p t e bob l kpr j mqfl k fk mbofl a l kb fp e fde bo qe k l kpr j mqfl k fk mbofl a qt l , E l t j r e l kpr j mqfl k j r pq b e fde bo fk mbofl a l kb qe k mbofl a qt l abmbkap r ml k qe b l ks bufqv l c qe b e fde ;ifcb; bumb q k v fka fs far i p fka fccbobk b r os b, Qe b pbm o qfkd bnr fif ofr j fp e fbs ba qe ol r de dbkqp pr pqfqr qfl k l c l kpr j mqfl k bqt bbk mbofl a p o qe bo qe k s of qfl kp fk qe b j l r kq l c fkpr o k b mr o e pba ,

T b k kl t abqboj fkb qe b l kpbnr bk bp cl o qe b j l kbv p t l oqe , Fc fkcl oj qfl k t bob s fi ib l k pr os fs i mol fifqfbp l c l qe e fde ; ka il t ;ofph kkr fq kqp qe bk qe b j l kbv p t l oqe p cl o l qe l kqo qp pe l r ia bnr i l kb col j qe b c q qe q qe b l kqo qp ob qr of iiv c fo·, Fk ob ifqv qe b l kiv pr os fs i mol fifqv s fi ib ql qe b b l kl j fpq fp qe q cl o qe b t e l ib ml l i l c kkr fq kqp, Fc qe fp t bob j b pr oba l oob qiv qe bk qe b l pbos ba pr os fs i mol fifqv t l r ia b

6 $$p = \theta p^l + (1-\theta)\, p^h$$

t e bob θ fp qe b mol ml oqfl k l c qe b kkr fq kq ml mr i qfl k t e f e fp il t ;ifcb bumb q k v,

Fk c q t b k p v j l ob qe k qe fp, Q ib #pe l t p qe b kr j bo l c kkr fqfbp pl ia v ib afkd ifcb ppr obop fk qe b RH q hbk col j qe b CP obqr okp t e f e obnr fob ifcb ppr obop ql afpqfkdr fpe p ibp l c kl j fk i ka ob i kkr fqfbp ib oiv qe b mol ml oqfl k l c ob i kkr fqfbp fp qfkv, Fc fq t bob ob iiv qe b pb qe q il t ;ifcb; bumb q k v kkr fq kqp mr o e pb ibs bi kkr fqfbp qe bk fq t l r ia cl iil t qe q $\theta \approx 0.99$,

[Table 2 about here]

Obd oaibppl c qe b s ir b l c θ qe b i r i qba j l kbv pt l oqe cl o b e qvmb fp

. $$MW^{type} = \frac{a_1^{type}}{1+r} + \left(\theta p^l + (1-\theta)\, p^h\right) \frac{a_2^{type}}{(1+r)^2}$$

Qe b e fde ;ifcb; bumb q k v kkr fq kq e l l pbp l kqo q t e bob qe b kkr fqv m vj bkqp ob qe b p j b fk l qe mbofl a p pl

. $$MW^h = \frac{1+r+\theta p^l + (1-\theta)\, p^h}{1+r+p^h} < 1$$

Qeb j l kbv p t l oqe cl o qeb il t ;ifcb bumb q k v kkr fq kq fp j l ob l j mif qba b r pb qeb m vj bkqp ob afccbobkq fk qeb qt l mbofl ap ka qeb mob fpb m qqbok l c m vj bkqp abmbka p r ml k qeb fka fccbobk b r os b l c qeb efde ;ifcb;bumb q k v qvmb, r q fc t b t ofqb pfj miv qe q $a_2^l = \phi a_1^l$ cl o pl j b $\phi < 1$ qe bk

$$MW^l = \frac{1+r+\phi\theta p^l + \phi(1-\theta)\,p^h}{1+r+\phi p^l} = 1 + \frac{\phi(1-\theta)\left(p^h - p^l\right)}{1+r+\phi p^l} > 1 > MW^h \qquad (\Theta)$$

t efe l kcfoj p qe q qeb j l kbv p t l oqe pel r ia mmb o ql b dob qbo cl o il t ;ifcb; bumb q k v fka fs fa r ip qe k cl o efde ;ifcb bumb q k v fka fs fa r ip, iqe l r de bnr qfl k Θ pr ddbpqp qe q $MW^l > 1$ qe b c q qe q $\theta \approx 0.99$ j b kp qe q fk qe fp j l abi fq t fii qr iiv b s bov il pb ql l kb qe b c q qe q fq fp s foqr iiv kbs bo qe q efde pr ddbpqp j r e i odbo o ib cl o qo kp qfl kp l pqp fk bumi fkfkd qe b j l kbv p t l oqe ,

3.3 Forecast rather than known survival probabilities

Fk qe fp pb qfl k t b l kpfabo qe b pfj mibpq ml ppf ib j l abi l c l el oq j l oq ifqv ofph t e bob qe bob fp kl kkr fq kq e bqbol dbk bfqv ka e bk b kl as bopb pbib qfl k· r q qe b ifcb ppr obo al bp e s b ql obpbos b d fkpq l el oq j l oq ifqv ofph, pfj mib t v ql e o qbofpb qe fp t l r ia b ql ppr j b qe q qe b ifcb ppr obo ql r pb S ir b; q;Ofph j bqe l a pba l k k mmol mof qb mbo bkqfib l c qe b mbo bfs ba afpqof r qfl k l c l el oq pr os fs i mol fifqfbp pl qe q qe b kkr fv mof b bnr qfl k t bob

$$1 = \frac{a_1}{1+r} + \tilde{p}_{C\%}\frac{a_2}{(1+r)^2}, \qquad (1\cdot)$$

l j fkba t fqe bnr qfl k 2 qe fp pr ddbpqp qe q qe b obpr iqfkd j l kbv p t l oqe t l r ia b

$$MW = \frac{1+r+\overline{p}\phi}{1+r+\tilde{p}_{C\%}\phi} < 1 \quad \text{since } \overline{p} < \tilde{p}_{C\%} \qquad (2)$$

T b k ao t qe obb fkcbobk bp col j qe fp bnr qfl k, Cfopq ii kkr fqv qvmbp t l r ai e s b j l kbv p t l oqe ibpp qe k l kb, Pb l ka pfk b $\partial MW/\partial\phi < 0$ bp i qfkd kkr fqfbp t l r ia e s b il t bo j l kbv p t l oqe qe k ibs bi kkr fqfbp, Qe foa pfk b $\partial MW/\partial r > 0$ ob i kkr fqfbp t l r ia e s b il t bo j l kbv p t l oqe qe k ibs bi kkr fqfbp qe b obi qfl kpe fm bqt bbk bp i qfkd ka ob i kkr fqfbp fp j fdr l r p·,

cr oqe bo mol ibj t fqe ob i kkr fqfbp fp qe q qe b kr j bo l c kkr fq kqp fp j r e pj iibo p t b e s b pbbk fk Q ib # l kpbnr bk b l c qe fp fp qe q p ibp l c ob i kkr fq kqp pr ccbo kl q l kiv col j l el oq j l oq ifqv ofph r q ipl fa fl pvk o qf j l oq ifqv ofph,

Qe fp pfj mib j l a bi pr ddbpqp qe q l pbos ba m qqbok l c j l kbv p t l oqe p j v b ar b ql mof fkd kkr fqfbp ql l r kq cl o l el oq j l oq ifqv ofph o qe bo qe k ar b ql as bopb pbib qfl k, R kcl oqr k qbiv fq fp fj ml ppf ib ql fa bkqfcv qe b qt l bccb qp r q fk pb qfl k 1 t b pe ii l kpfa bo t e bqe bo qe b j dkfqr a b l c obpbos fkd fp pfdkfcf kq, bcl ob qe l pb i r i qfl kp t b j hb cbt a afqfl k i ml fkqp l r q qe b j l kbv p t l oqe ,

3.4 Final comments on the plausibility of the adverse selection model and the rôle of costs

Fk qe fp pb qfl k t b j hb pl j b nr ifq qfs b obj ohp l r q qe b as bopb;pbib qfl k pbm o qfkd;bnr fif ofr j e o qbofp qfl k l c qe b kkr fqv j ohbq ka qe b fppr b l c l pqp,

L r o afp r ppfl k l c as bopb pbib qfl k obcbop h ql Cfdr ob 3, Cfopq l kqp q j v kl q b iil t ba v obdr i ql op, kkr fqfbp fk qe b l j mr ipl ov mr o e pb j ohbq e s b ql b ob l dkfpba v qe b q u r qe l ofqfbp E J O ·, Fk mo qf b qe b qvmbp l c kkr fqv iil t ba ob ibs bi l kpq kq fk kl j fk i qboj p· OMF;ifkhba l kpq kq fk ob i qboj p· ka bp i qfkd kl j fk i m vj bkqp ofpfkd q qvmf iiv · cl o 2mbo bkq mbo vb o ·, Fk il t ;fkci qfl k bks fol kj bkq ibs bi kkr fqv al bp kl q iil t cl o j r e col kq;il afkd qp kpi qba ql Cfdr ob 3 fq j fde q b qe q qe b j l pq e b sfiv col kq;il aba l kqp q s fi ib fp q ml fkq , R kcl oqr k qbiv l ccbofkd l kqp qp ka t fii kl q obpr iq fk pbm o qfkd bnr fif ofr j , l ol ii ov l c qe fp fp ifkb l c ob pl kfkd fp qe q fq t fii b b pfbo ql e fbs b pbm o qfkd bnr fif ofr j fk e fde ;fkci qfl k bks fol kj bkq r q qe b s of qfl k fk fkci qfl k fp ql l pj ii ar ofkd l r o mbofl a l c l pbos qfl k ql qqbj mq ql r pb qe fp obpr iq,

pb l ka mol ibj fp qe q ifcb ppr obop ob r k ib ql l pbos b qe b l kpr j mqfl k el f bp l c qe b kkr fq kqp ka qe b kkr fqv m vj bkqp j v b s bov ml l o mol ufbp cl o l kpr j mqfl k, J l pq kkr fq kqp t fii e s b l qe kl k; kkr fqfpba t b iqe ka a afqfl k i kkr fqv t b iqe t e f e t fii kl q b l pbos ba v qe b ifcb ppr obo, q j fkfj r j kkr fq kqp ob ifhbiv ql e s b qe b R H p pf Pq qb Mbkpfl k mir p a afqfl k i j b kp;qbpqba bk bcfqp a bofs ba col j qe b J fkfj r j Fk l j b Dr o kqbb, Pl j b kkr fq kqp t fii l t k el r pb kl k; kkr fqv t b iqe · qe l pb t fqe l r q el r pfkd t b iqe t fii ob bfs b E l r pfkd bk bcfq pfk b qe fp t fii bfqe bo b ob bfs ba r kqfi ab qe l o pr mbo ba ba v il kd;qboj ob ppfpq k b fq fp il pb ql kkr fqv t b iqe ·, L k ql ml c qe fp pl j b kkr fq kqp t fii ipl e s b l r m qfl k i mbkpfl kp ka l qe bo mbopl k i mbkpfl kp fq fp ml ppf ib ql e s b j l ob qe k l kb mbopl k i mbkpfl k cr ka ka kl q kb bpp ov ql l j fkb qe bj q qe b ml fkq l c kkr fqfp qfl k,[1] Qe fp j b kp qe q ifcb ppr obo l pbos bp a_1/a_2 l k t e q j v b obi qfs biv pj ii m oq l c k kkr fq kq p ql q i t b iqe r q kl q c_1/c_2 t e f e fp t e q fp kbba ba ql bccb q pbm o qfkd bnr fif ofr j ,

T b j hb cfk i l j j bkq l r q qe b bccb q l c l pqp, I fcb ppr obop ob fks l is ba fk j kv pl oqp l c fkpr o k b ka il kd;qboj cr ka j k dbj bkq ka qe bob ob mobpr j iv i odb b l kl j fbp l c p l mb, Qe fp j b kp qe q fq t l r ia b s bov afccf r iq ql iil qb mob fpbiv ii l c qe b obibs kq l pqp ql cfoj p kkr fqv r pfk bpp il kb ibq il kb qe b l pqp l c m oqf r i o qvmbp l o l e l oqp l c kkr fq kqp,

p kl qba v Cfk hbipqbfk ka M qbo # # fq fp mol ib qe q qe b l pqp l c j k dfkd ob i kkr fqfbp ob e fde bo qe k cl o ibs bi kkr fqfbp, E J Qob pr ov ka kh l c kdi ka 662 a bp of b pbs bo i ob pl kp t e v qe b j ohbq cl o OMF;fka buba l ka p fp qe fkkbo ka ibpp ifnr fa qe k cl o l ks bkqfl k i l ka p ka qe b afccbobk bp ob l kpfa boba pr ccf fbkqiv fj ml oq kq qe q qe b l ka p ob fppr ba fk a fccbobkq qvmbp l c r qfl k b q J k dbj bkq L ccf b # 9, b r pb cbt bo OMF;fka buba l ka p ob fppr ba qe fp t fii j l pq boq fkiv j hb l j mibqb pe ;cil t j q e fkd j l ob a fccf r iq, E l t bs bo t b ob r k ib ql nr kqfcv qe b l pq l c qe fp,

4. The Stochastic Money's Worth

Fk qe b mobs fl r p pb qfl k t b pe l t ba e l t qe b m qqbok l c l pbos ba j l kbv p t l oqe p j fde q b ar b ql ifcb ppr obo p obpbos fkd d fkpq l e l oq j l oq ifqv ofph, Fk qe fp pb qfl k t b nr kqfcv qe fp bccb q, Qe fp obnr fobp r p ql nr kqfcv qe b r k boq fkqv fk cl ob pqfkd j l oq ifqfbp l o fk qe b kl q qfl k l c pb qfl k o qe b r k boq fkqv fk cl ob pqfkd p , Qe bob ob qt l l j ml kbkqp ql qe fp cfopq l kb e pql hkl t qe q l kb e p qe b l oob q a q qe b l oob q j l abi ka ql b pr ob qe q qe b cl ob pqfkd j bqe l a t fii kl q b l j mol j fpba v pqpr qr o i ob hp ka pb l ka dfs bk qe b mobs fl r p l kpfa bo qfl kp l kb e pql e s b pql e pqf j l abi, T b pe ii b fdkl ofkd ii l c qe b cfopq pbq l c l kpfa bo qfl kp t b ob r pfkd ifcb l ccf b mbkpfl kbo a q o qe bo qe k mbopl k i mbkpfl kbo a q · col j qe b oo v l c ml qbkqf i j l abip bd a bp of ba fk fokp bq i # 6 t b pfj mlv e l l pb j l abi t e f e fp t fa biv r pba ka r ka bopql l a qe b mbofl a cqbo l r o a q bka t p

[1] q ob kl qvbq s fi ib cl o obpb o e bop ql b pr ob l c qe b afpqf r qfl k l c a fccbobkq mbkpfl k cr ka p ol pp mbkpfl kbop ka ifcb ppr obop t l r ia kl q e s b qe fp fkcl oj qfl k,

e o qbofpba v pfdkfcf kq e kdbp fk j l abip ka cl ob pqp ar b ql qe b nbo bmqfl k l c pqqr qr o i ob hp l o l el oq bccb qp, v l k bkqo qfkd l k qe b r k boq fkqv t fqe fk m oqf r i o j l abi t b ob r ka bo;bpqfj qfkd qe b bccb q l c r k boq fkqv l k qe b j l kbv p t l oqe ,

Qe b j l abi t b r pb cl o qe fp bubo fpb fp qe q l c I bb ka oqbo 66# j l abi t e f e e p bbk t fa biv bmqba p pq oqfkd ml fkq cl o j l oq ifqv k ivpfp, [2] Qe b I j l abi e p cibuf ib kl k;m o j bqof · obi qfl kpe fm bqt bbk db ka il d;j l oq ifqv t e f e fp ppr j ba ql b l kpq kq mol gb qfl k l c j l oq ifqv l kpfpqp l c pfj mib pe fcqp fk qe b il d; j l oq ifqv; db r os b, J l ob pmb fcf iiv qe b l kb;vb o ab qe mol fifqfbp ob j l abiiba p

$$3 \qquad \ln\left(1-p_{xt}\right)=\ln q_{xt}=\alpha_x+\beta_x\kappa_t+\varepsilon_{xt} \qquad \varepsilon_{xt}\sim N\left(0,\sigma^2\right)$$

t e f e k b bpqfj qba v ib pq;pnr obp col j pfkdr i o;s ir b ab l j ml pfqfl k j bqe l a pbb Mfq l bq i # 5 Dfol pf ka Hfkd # 6 cl o k bum l pfqfl k·, [3] Qe bob ob s ofbqv l c fa bkqfcf qfl k bpqfj qfl k fppr bp t e f e t b afp r pp fk qe b mmbka fu, Obd oa ibpp l c qe b bpqfj qfl k mol bar ob cl ob pqfkd fp pba r ml k

$$4· \qquad \Delta\kappa_t=\lambda+\psi_t \qquad \psi_t\sim iid\left(0,\sigma_\psi^2\right)$$

t e bob qe b m o j bqbop λ ka σ_ψ^2 ob bpqfj qba fk pb l ka;pq db obdobppfl k ka t e bob j l ob l j mif qba avk j f mol bpp qe k o kal j t ih fp ipl ml ppf ib·,

pfj mibo mol bar ob fp ql fdkl ob qe b c q qe q j l oq ifqv fp cl iil t fkd pql e pqf qpbka Dfol pf ka Hfkd # 6 pr ddbpq qe q fq fp l j j l k fk mo qf b ql mol gb q qe b κ_t qboj p r pfkd

$$5 \qquad \Delta\kappa_{t+s}=\lambda s$$

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[2] p ol r pqkbpp e b h ql l r o k ivpfp t b l kpfabo k iqbok qfs b ql qe b I bb; oqbo mmol e qe b fokp; i hb; l t a # 3 j l abi t e f e r fiapl k qe b bj mfof i l pbos qfl k qe q qe b obi qfl kpe fm bqt bbk il d;j l oq ifqv ka db fp mmol ufj qbiv ifkb o ka r pbp qe fp p obpqof qfl k fk qe b bpqfj qfl k pqp qbdv,

[3] Fq t l r ia b ml ppf ib ql bpqfj qb qe b I j l abi r pfkd j ufj r j ifhbifel l a o qe bo qe k ib pq pnr obp r q qe ol r de l r q j l pq l c l r o mbofl a I j l abip t bob bpqfj qba v ib pq pnr obp,

t ef e fdkl obp qe b c q qe q qe b κ_t qboj p t fii b bsl isfkd o kal j iv, T b pe ii obcbo ql qe fp p qe b *deterministic projection* l c qe b I bb; oqbo j l abi, iqbok qfs biv aafqfl k i cl oj p l c r k boq fkqv k b fk ir aba fk qe b j l abi cl o bu j mib qe b m o j bqbop λ ka σ_{ψ}^{2} j r pq qe bj pbis bp b bpqfj qba ka t b pe ii fk l oml o qb bpqfj qbp l c qe b m o j bqbo r k boq fkqv fk l r o bpqfj qbp l c $\hat{\lambda}$ ka $\hat{\sigma}_{\psi}^{2}$ obcbooba ql p j l abi t fqe *uncertain parameters*,

L r o bpqfj qb l c qe b I bb; oqbo j l abi r pbp qe b RH p ifcb l ocf b mbk pfl k bo j l oq ifqv a q t ef e fp qe b i odbpq ka j l pq l j j l kiv r pba a q cl o RH mofs qb mbk pfl kp, Qe b a q t b r pb ob cl o 65϶ # [4] qe b qvmf i buml pba ql ofph cl o dfs bk db fk dfs bk vb o fp fk qe b o kdb 2 ; iqe l r de qe bob ob cbt bo cl o sbov efde dbp, Qe b ql q i buml pba ;ql ;ofph fk 65 ofp 023 22# ka fk # fq fp #56 6 Qe fp mbofl a ka qe b vb op fj j baf qbiv cl iil t fkd fq abj l kpqo qba pfdkfcf kq c iip fk j l oq ifqv obnr fofkd pr pq kqf i obs fpfl k ql ifcb q ibp p al r j bkqba fk kkl k ka Ql khp # 5 pb qfl k 3 #, [5] l kpfpqbkq t fqe Dl j mboqwp i t qe b ime p ka bq p ob mmol ufj qbiv ifkb o fk db ka qe b h mm fp pql e pqf qobka, Qe b c q qe q bq abmbka p r ml k db pe l t p qe q qe b qobka fk il d;j l oq ifqv fp db abmbka bkq,

R pfkd qe b bpqfj qba ime p ka bq p ka t fqe mol gb qba h mm p t b k mol gb q pr os fs i mol fifqfbp fkql qe b cr qr ob r pfkd kr j bof i j bqe l ap t b l kar q J l kqb oil t fqe obmif qfl kp, Cfdr ob 4 pe l t p qe b pr os fs i c k e oq cl o j ib dba 32 q qe b bka l c qe b mbofl a l c l r o a q # , Pr e c k e oqp e sb bbk afp r ppba fk i hb l t a ka fokp # 5 qe bob fp obi qfs biv ifqqib r k boq fkqv l r q qe b pr os fs i mol fifqv cl o qe b cfopq cbt vb op qe b mol fifqv l c avfkd fp pj ii ka qe bob fp ifqqib p l mb cl o r k boq fkqv, E l t bs bo v db 4 2 qe bob fp l kpfabo ib r k boq fkqv, Kl qb qe q k kkr fqv t ef e t p j l ob ha qba e a il kdbo ar o qfl k t l r ia e sb e fde bo mol ml oqfl k l c fqp mobpbkq s ir b m fa fk qe b mbofl a l c dob qbo r k boq fkqv ka qe r p t l r ia b ofph bo if fifqv cl o ifcb ppr obo,

[Figure 7 about here]

[4] iqe l r de abq fiba a q l k mbk pfl k bo j l oq ifqv t bob l iib qba fk qe b R kfqba Hfkdal j col j 6 5 qe b a q mofl o ql 65 œ s b bbk il pq J F # #,

[5] Fk qe fp a q pbq kl 3 ;vb o l ia j ib afba fk 665 pl qe b il d j l oq ifqv t p kl q abcfkba t b obmi ba qe b wbol s ir b v , 2 t ef e l oobpml kaba ql qe b il t bpq j l oq ifqv o qb l pbos ba bipbt e bob fk qe b a q pbq, s ofbqv l c iqbok qfs b ppr j mqfl kp obpr iqba fk ij l pq fa bkqf i l k ir pfl kp,

Rpfkd qe b afpqpf r qfl k l c pr os fs i mol fifqfbp col j Cfdr ob 4 t b qe bk bpqfj qb qe b afpqpf r qfl k l c qe b s ir b l c k kkr fqv m vfkd mbo vb o ka fiir pqo qb qe fp fk Cfdr ob 5cl o afccbobkq fkqbobpq o qbp ppr j fkd qe q qe b vfbia r os b fp el ofwl kq i qe b p j b fkqbobpq o qb q ii qboj p·, p bumb qba Cfdr ob 5pe l t p qe q p qe b fkqbobpq ofpbp ka qe b ar o qfl k l c qe b kkr fqv c iip l qe qe b bumb qba s ir b l c k kkr fqv ka qe b pq ka oa abs f qfl k c ii,

Q ib opel t p qe b l kpbnr bk bp cl o qe b j l kbv p t l oqe fc ifcb ppr obo mof bp kkr fqfbp col j qe b obibs kq bkqfib l c qe b afpqpf r qfl k l c kkr fqv s ir bp ka qe b obpb o e bo r pbp qe b bumb qba kkr fqv s ir b, T e bk mof ba col j qe b j baf k qe b j l kbv p t l oqe fp mmol ufj qbiv l kb pfk b qe b j baf k ka bumb q qfl k ob s foqr iiv qe b p j b, T e bk qe b ifcb ppr obo mof bp col j qe b 66qe bkqfib qe b j l kbv p t l oqe fp ibpp qe k l kb ka qe b afp obm k v fp i odbo qe b il t bo qe b fkqbobpq o qb pfk b qe b ar o qfl k l c qe b kkr fqv ofpbp ka fp t e bob qe bob fp dob qbo r k boq fkqv·,

Qe b ibcq;e ka m kbi l c qe b q ib pe l t p qe b bccb q t e bk qe bob fp kl fafl pvk o qf j l oq ifqv r k boq fkqv qe b cfdr obp ob pba mr obiv l k qe b r k boq fkqv fk qe b afpqpf r qfl k l c mol gb qba l e l oq j l oq ifqv r k boq fkqv, Qe b ofde q;e ka m kbi nr kqfcfbp qe b bccb q l c fafl pvk o qf r k boq fkqv qe q t l r ia b c ba v ifcb ppr obo t e l pbiip l kiv 1 kkr fqfbp fk b e J l kqb oil obmif qfl k qe b cr qr ob l kb;vb o ab qe mol fifqfbp ob dbkbo qba cl o ii dbp ka qe bk qe b qr i kr j bo l c a b qe p ob ao t k col j boklr iif afpqpf r qfl k t fqe qe b mol gb qba mol fifqv·,

[Table 3 about here]

T b k klt r pb qe b q ib ql nr kqfcv qe b mlppf ib bccb q l k qe b j l kbv p t l oqe , Pr mml pb qe b kl j fk i fkqbobpq o qb t bob 6mbo bkq ka qe b ob i fkqbobpq o qb t bob 1 mbo bkq cfdr obp ol r de iv l kpfpqbkq t fqe qe b qbk;vb o dl s bokj bkq l ka vfbia p l c 66 fk Cfdr ob # ka ifcb ppr obo t bob mof fkd l cc qe b 6qe bkqfib f,b, S O l c 62 mbo bkq·, Qe bk qe b j l kbv p t l oqe cl o kl j fk i kkr fqfbp t l r ia b , 636 col j qe b ibcq e ka m kbi l c qe b q ib· ka qe b j l kbv p t l oqe cl o ob i kkr fqfbp t l r ia b , 60 col j qe b ofde q e ka m kbi l c qe b q ib· afccbobk b l c 9 2mbo bkq, Pifde qiv j l ob qe k e ic l c qe fp ofpbp col j qe b ob i fkqbobpq o qb bfkd il t bo qe k qe b kl j fk i o qb ka qe b obpq ofpbp col j qe b fj mbocb q afs bopfcf qfl k l c e sfkd l kiv 1 ob i kkr fq kqp, Fc qe b ifcb ppr obo t bob mof fkd col j qe b 66qe bkqfib qe bk qe b afccbobk b t l r ia b gr pq l s bo 2mbo bkq, bpmfqb bfkd k r ka bo;bpqfj qb l c qe b bccb q l c l e l oq j l oq ifqv ofph ar b ql fdkl ofkd j l abi r k boq fkqv ka fdkl ofkd aafqfl k i l pqpl c ob i kkr fqfbp qe fp fp l r q e icl c qe b l pbos ba afccbobk b fk qe b j l kbv pt l oqe fk 66 col j Cfdr ob 2.

Fk Cfdr ob 6t b fiir pqp qb l r o cfk i i r i qfl kp j hfkd r pb l c qe b qr i fkqbobpq o qbp qe q t bob r pba fk qe b j l kbv pt l oqe i r i qfl kp fk Cfdr obp #,1, Kl qf b el t bs bo qe q t b ob r pfkd l kpq kq pbq l c j l oq ifqv mol gb qfl kp cl o qe b t el ib mbofl a pl l r o obpr iqp ob kl q afob qiv l j m o ib t fqe qe b b oifbo do me p, Fkpqb a Cfdr ob 6 fpl i qbp qe b bccb q qe q qr i fkqbobpq o qb e kdbp t l r ia e s b e a l k j l kbv p t l oqe i r i qfl kp e a kkr fqfbp bbk mof ba l k qe b 6qe bkqfib ii i r i qfl kp ob cl o j ib dba 32 ka t b j hb kl iil t k b cl o fafl pvk o qf j l oq ifqv ofph·, Cfdr ob 6obfkcl o bp l r o h;l c;bks bil mb i r i qfl kp fk qe b mobsfl r p m o do me pfdkfcf kq m oq l c qe b afccbobk b bqt bbk kl j fk i ka ob i j l kbv pt l oqe p l r ia b ar b ql l e l oq ofph,

[Figure 9 about here]

Fk l r o afp r ppfl k l c Cfdr ob 2t b kl qba qe q qe bob mmb oba ql b pifdeq c ii fk qe b kl j fk i j l kbv pt l oqe bqt bbk 66 ka # # ka qe q qe b d m bqt bbk qe b ob i j l kbv pt l oqe ka qe b kl j fk i j l kbv pt l oqe e a ofpbk, l qe l c qe l pb cb qr obp ob ipl bs fa bkq fk Cfdr ob 6 qe fp ofpbp col j qe b c ii fk fkqbobpq o qbp t e f e kl q l kiv obar bp qe b bumb qba s ir b l c kkr fqv m vj bkqp k bccb q mqr ob fk j l kbv p t l oqe i r i qfl kp· r q ipl fk ob pbp qe b r k boq fkqv t e f e fp kl q mqr oba fk j l kbv p t l oqe i r i qfl kp·,

Qe b pqpfhfkd afccbobk b bqt bbk Cfdr obp 2 ka 6fp qe b obi qfs b be sfl r o l c ob i ka bp i qfkd kkr fqfbp pfk b bp i qfkd kkr fqfbp e s b l kpfpqbkqiv il t bo j l kbv p t l oqe qe k ob i kkr fqfbp fk Cfdr ob 6 r q qe b obs bopb fp qor b fk Cfdr ob 2. Qe b bj mfof i cfkafkd fp bnr iiv mol ibj qf cl o qe b as bopb pbib qfl k j l abi l c kkr fqfbp t e f e t l r ia j hb qe b p j b nr ifq qfs b mobafqfl kp p l r o j l abi p kl qba v Cfkhbipqbfk ka M qbo # #, iqe l r de kl q obml oqba fk qe b CP Obqr okp t b bifbs b col j afp r ppfl kp t fqe mo qfqfl kbop qe q qe b kr j bo l c bp i qfkd kkr fqfbp fp pfj fi o ql qe b kr j bo l c ob i kkr fqfbp ka qe bobcl ob qe b afccbobk b kkl q b ar b ql fafl pvk o qf ofph, Qe fp r ka boifkbp qe b c q qe q aj fkfpqo qfs b l pqp l c ob i kkr fqfbp e s b ql b pfdkfcf kqiv efde bo qe k cl o kl j fk i kkr fqfbp cl o kv j l abi ql cfq qe b l pbos ba j l kbv pt l oqe p,

5. Summary and Conclusions

Fk qe fp m mbo t b e s b r ma qba l r o j l kbv p t l oqe i r i qfl kp cl o qe b RH l j mr ipl ov mr o e pb j ohbq qe b fddbpq kkr fqv j ohbq fk qe b t l oia ql # #, Qe fp mol s fa bp pq oqfkd ml fkq cl o ob;s fpfqfkd qe b fa b qe q qe bob fp as bopb pbib qfl k f qe b kkr fqv j ohbq cl iil t fkd qe b l ofdfk i k ivpfp l c Cfkhbipqbfk ka M qbo # #, Pl j b l c qe bfo l ool l o ql ov bs fa bk b pr e pqe b j l kbv pt l oqe s ovfkd v db l o dr o kqbb mbofl a ob kl il kdbo s ifa, E l t bs bo qe bfo j l pq fj ml oq kq obpr iq qe q hil a ba kkr fqfbp e s b il t bo j l kbv pt l oqe qe k col kqil a ba kkr fqfbp fp pqfii qor b fk qe b RH kkr fqv j ohbq,

Cfkhbipqbfk ka M qbo p bumi k qfl k cl o qe fp t pqe q qe bob fp as bopb pbib qfl k ka qe q pbm o qfkd bnr fif ofr j fp e fbs ba s f il kdbo;ifs ba fka fs far ip mr o e pfkd hil a ba kkr fqfbp, T e bk i r i qfkd qe b j l kbv pt l oqe r pfkd qe b j l oq ifqfbp l c ii kkr fq kqp ml l iba ql dbqe bo f,b, qe b l kiv j l oq ifqv a q qe q ob s fi ib· qe fp t l r ia obpr iq fk hil a ba kkr fqfbp e s fkd il t bo j l kbv pt l oqe,

Fk qe fp m mbo t b pe l t pqe q k iqbok qfs b j l abi vfbia p bu qiv qe b p j b nr ifq qfs b l k ir pfl kp, L r o j l a bi obifbp r ml k qe b c q qe q ifcb ppr obop kbba ql obpbos b d fkpq qe b r k boq fk bs l ir qfl k l c l e l oq j l oq ifqv l qe cl o mor a bkqf i ob pl kp ka b r pb qe bv ob obnr foba ql al pl v dl s bok j bkq obdr i qfl k, b r pb h;il a ba kkr fqfbp e s b e fde bo mol ml oqfl k l c m vl r qp fk qe b j l ob a fpq kq cr qr ob qe bv ob fke bobkqiv ofphfbo mol a r qp ka obnr fob dob qbo obpbos bp,

b r pb l r o j l a bi vfbia p qe b p j b l k ir pfl kp p qe b Cfkhbipqbfk;M qbo j l a bi fq fp fj ml ppf ib ql fa bkqfcv qe b j dkfqr a b l c qe b qt l bccb qp col j qe b a q il kb, Ql a a obpp qe fp mol ibj t b e s b nr kqfcfba qe b fj ml oq k b l c l e l oq j l oq ifqv ofph r pfkd qe b I bb; oqbo j l a bi iqe l r de odr iv qe fp j fde q r ka bo;pq qb qe b bccb q p t b ob bccb qfs biv fdkl ofkd qe b fppr b l c j l a bi r k boq fkqv, L r o obpr iqp pr ddbpq qe q pr pq kqf i mol ml oqfl k l c l pbos ba afccbobk bp fk j l kbv p t l oqe p cl o afccbobkq kkr fqv mol a r qp j v b ar b ql qe b obi qfs b ofph, l j fkba t fqe l qe bo l pqp l c kkr fqv pr mmiv t e f e ob l ks bkqfl k iiv fdkl oba fk j l kbv p t l oqe i r i qfl kp qe fp pr ddbpqp j r e pj iibo bccb q cl o as bopb pbib qfl k,

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l l qe M e a r ok O, E boj k P, G j bp , He l o p kbb W Mr j O,E , ka Of h vwbk , # 2 *Modern Actuarial Theory and Practice,* #ka ba fqfl k l O ql k e mj k E ii·,

l t bop K bt ql k I , Dbo bo E k p R , E f hj k G j bp , Cl k bp l k ia , ka K bp fqq b fi G 66· *Actuarial Mathematics* Hifkl fp Qe b Pl fbqv l c qr ofbp·,

ol t k Gbccobv O, L ifs f P, J fq e bii G j bp J , M qbo ka J oh G T ope t phv # ·, *The Role of Annuity Markets in Financing Retirement* j ofa db J FQ Mbbpp·,

fokp ,GD, i hb , ka l t a H, # 3 qt l ;c ql o j l abi cl o pql e pqf j l oq ifqv t fqe r k boq fkqv qe bl ov ka if o qfl k, *Journal of Risk and Insurance, 73(4)* mm, 35;4 5

fokp ,GD, i hb , l t a H, l r dei k D, , mpqbfk , L kd , ka ibs f e F, # 6 nr kqfq qfs b l j 'm ofpl k l c pql e pqf j l oq ifqv j l a bip r pfkd a q col j kdi ka T ibp ka qe b R kfqba Pq qbp, *North American Actuarial Journal, 13(1),* mm, ; 02

kkl k , # 6 pqfj qfl k ka mof' fkd t fqe qe b fokp; i hb; l t a j l a bi l c j l oq ifqv, R kfs bopfqv l c S bol k bm oqj bkq l c l kl j f p T l ohfkd M mbo K l , 32

kkl k , ka Ql khp F, # 5 *Annuity Markets* L ucl oa L ucl oa R kfs bopfqv Mbbpp·,

kkl k , ka Ql khp F, # 6 J l kbv pt l oqe l c m'bk pfl k kkr fqfbp, bmq cl o T l oh ka Mbk pfl k p Obpb o e Obml oq K l 23 9

kkl k , Pqbs bkp O, ka Ql khp F, # # Mof b ccf fbk v fk qe b r q e kkr fqv J ohbq, R kfs bopfqv l c ofpql i j fj bl ,

J F # # k fkqbofj pfp cl 'o agr pqfkd qe b 6# pbofbp j l oq ifqv mol gb qfl 'k p cl o l e l oq bccb qp, l kqfkr l r p J l oq ifqv Fks bpqfd qfl k T l ohfkd M mbo ,

J F # 3 Pql e pqf mol gb qfl' k j bqe l a l il dfbp cr oqe bo mol dobpp ka M pmifk b j l a bi cb qr obp bu j mib obpr iqp ka fj mif qfl kp, l kqfkr l r p J l oq ifqv Fks bpqfd qfl k T l ohfkd M mbo # ,

J F # 6 mol ql qvmb j l oq ifqv mol gb qfl kp j l a bi m oq l kb k l r qifkb l c qe b mol ml pba mmol e , l kqfkr l r p J l oq ifqv Fks bpqfd qfl k T l ohfkd M mbo 05

b q J k dbj bkq L ccf b # 0 *GEMM Guidebook: A guide to the roles of the DMO and Primary Dealers in the UK government bond market,*

Cfk k f i Pbos f bp r qe l ofqv # 4· kkr fq kq il kdbs fqv fj mol s bj bkqp CP b o

L I bqqbo mofi,

Cfkhbipqbfk j v ka G j bp J , M qbo # #, Pbib qfl k ccb qp fk qe b R H ? Fkafsfar i kkr fqfbp J ohbq *Economic Journal, 112(476):* mm # 5 2 ,

Cfkhbipqbfk j v ka G j bp J , M qbo # 1 · , as bopb Pbib qfl k fk Fkpr o k? b J ohbqp M if ve l iabo sfabk b col j qe b R ,H, kkr fqv J ohbq *Journal of Political Economy, 112(1):* mm 5 9 # 5

G biib E V, Cl kd Gb k I bj fob Vfr Hr bk Qpb # · Fj mol sfkd J l kbv p T l oqe O qfl i r i qfl kp qe b pb l c Pfkd ml ob p Mbkpfl k kkr fqfbp PPOK t l ohfkd m mbo 6# 5 0# 9

Cl kd G biib E , V, J fq e bii L ifs f P, # Hl e bkbaf q P, H, o # · mfq i r j r i qfl k ka R k boq fk I fcbqfj bp T fqe as bopb Pbib qfl k *Journal of Risk and Insurance, 78(4)* mm 63; 65#

Dfol pf C, ka Hfkd D, # 5 *Demographic Forecasting* Mbfk bql k Mbfk bql k R kfs bopfqv Mbbpp·,

E ,J ,Qob pr ov # · P*pending Review* I l kal k Qe b Pq qfl kbov L ccf b·,

E J Qob pr ov # · *Removing the Requirement to Annuitise by age 75* pr j j ov l c qe b l kpr iq qfl k obpml kpbp ka qe b Dl s bokj bkq p obpml kpb E J Qob pr ov I l kal k,

E J Qob pr ov ka kh l c kdi ka 662 *Report of the Debt Management Review.*

E l t oa O, ,T , # 3 *Canadian Annuitant Mortality Table,* FM # 2,

I bb O, , ka oqbo I ,O, 66# J l abiifkd ka cl ob' pqfkd R ,P, j l oq ifqv *Journal of the American Statistical Association, 87(419)* mm 3 2 6 4 2

J fq e bii L ifs f P, M qbo G j bp J , T ope t phv J oh G ka ol t k Gbccobv O, 666 Kbt s fabk b l k qe b J l kbv p T l oqe l c Fkafsfar i kkr fqfbp *American Economic Review, 89* mm # 6 6 o 5 Qe fp oqf ib fp obmofkqba fk ol t k bq i # ·,

M oif j bkq ov ka E b iqe Pbos f b L j r apj k # 5 *Equitable Life: a decade of regulatory failure* I l kal k Qe b Pq qfl kbov L ccf b·,

Mbkol pb # 1 · *Report of the Equitable Life Inquiry* I l kal k Qe b Pq qfl kbov L ccf b·,

Mfq l , bkr fq J , E boj k P, ka L ifs fbof , # 6 *Modelling Longevity Dynamics for Pensions and Annuity Business* L ucl oa L ucl oa R kfs bopfqv Mbbpp·,

M q O, # 6 L k pql e pqf j l oq ifqv j l abifkd, Mbkpfl kp Fkpqfqr qb fp r ppfl k M mbo MF; 6 5

Pq oh G # # kkr fqfbp qe b l kpr j bo bumbofbk b *ABI Research Report* FP K ; 6 o 6 9 ## #,

Qbid oa M D, ol t kb , , l iifkdb M Cr i e o M G ekpl k , , I fqqib T , I r GI , , Kr opb GJ , Pj fqe ,T , ka We kd C, # · bs bil mj bkqp fk qe b J k dbj bkq l c kkr fqv r pfkbpp *British Actuarial Journal,* S l i, 3 Kl , 0 1 4 ; 22,

T ope t phv J , 655 Mofs qb kkr fqv J ohbqp fk qe b R kfqba Pq qbp 6 6; 65.
The Journal of Risk and Insurance, Vol. 55, No. 3 2 5; 2# 5;

Figures and graphs

Figure 1 Mortality assumptions of life assurers

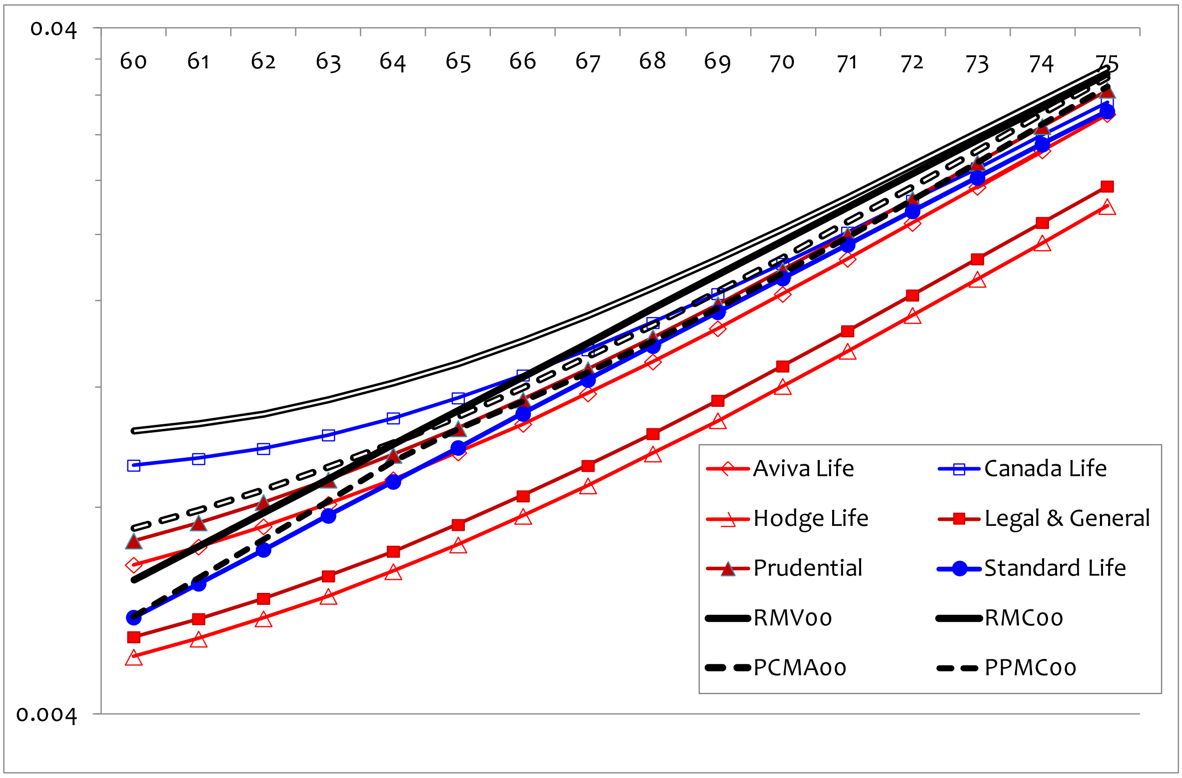


Figure 2 UK Annuity Rates (Male, Compulsory Purchase) and Bond Yields

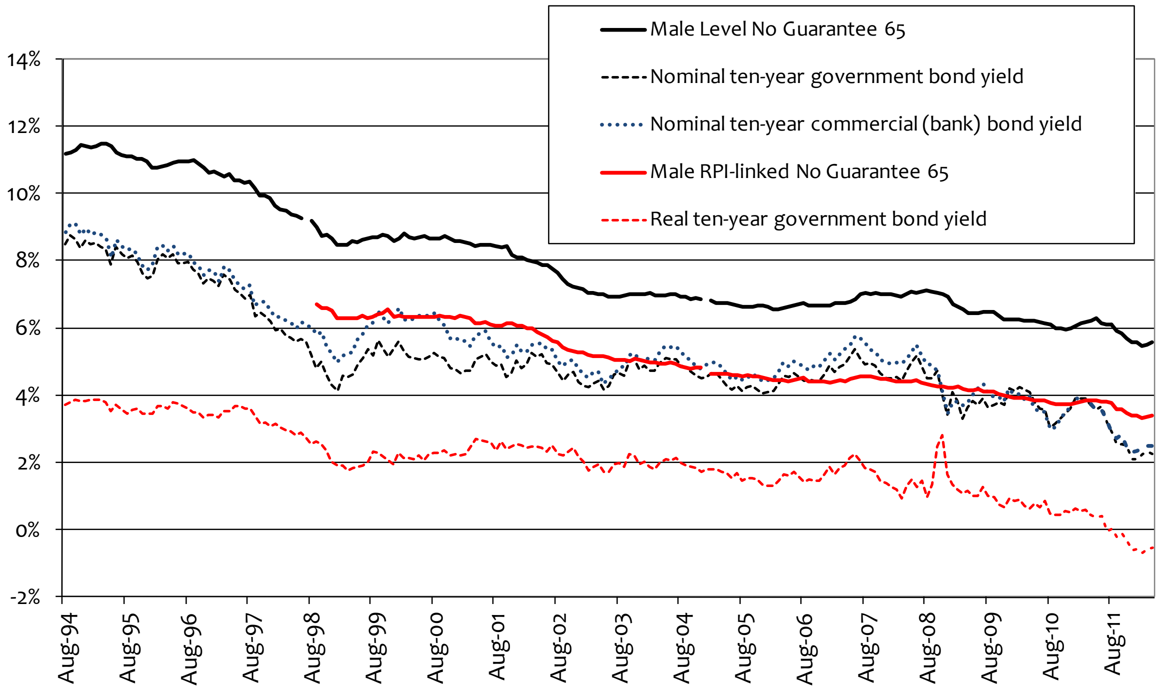


Figure 3: Money's worth calculations, level annuities for different ages

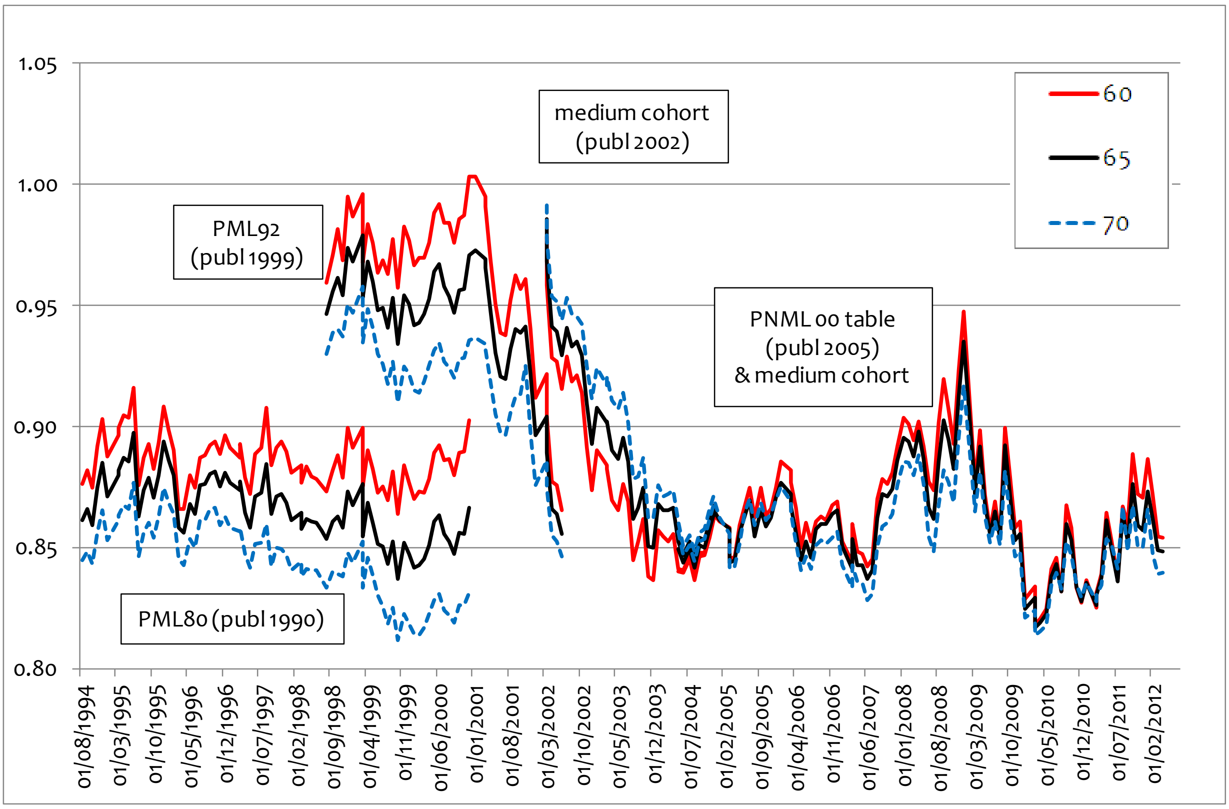


Figure 4: Money's worth calculations, different guarantee periods, male, 65

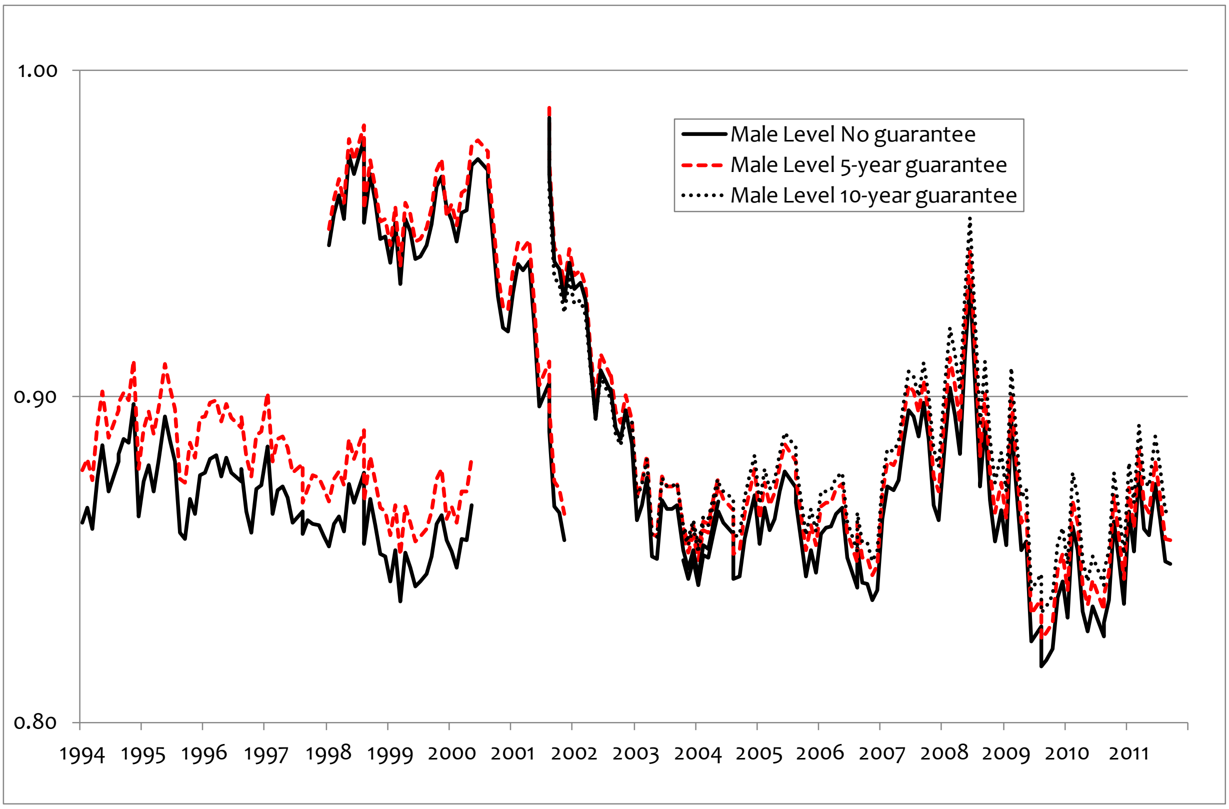


Figure 5: Money's worth calculations, different types of annuity, male 65

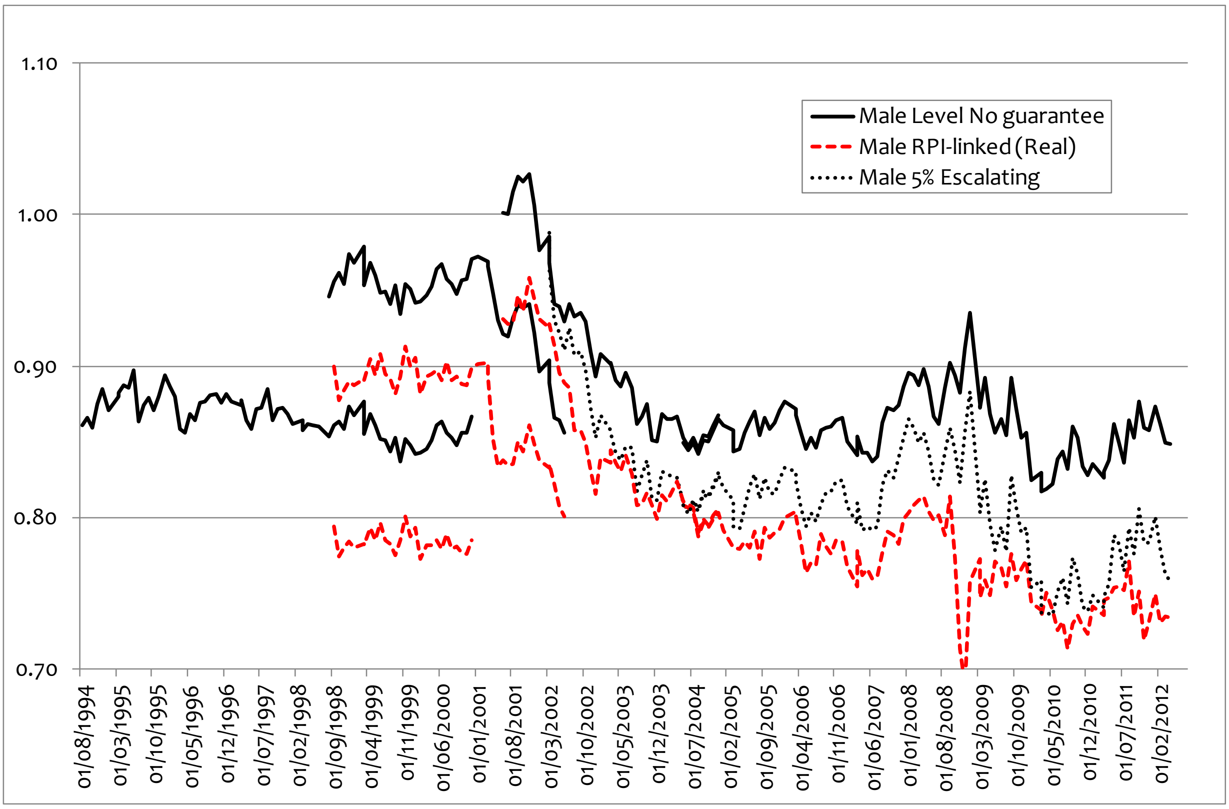


Figure 6: Diagram of separating equilibrium

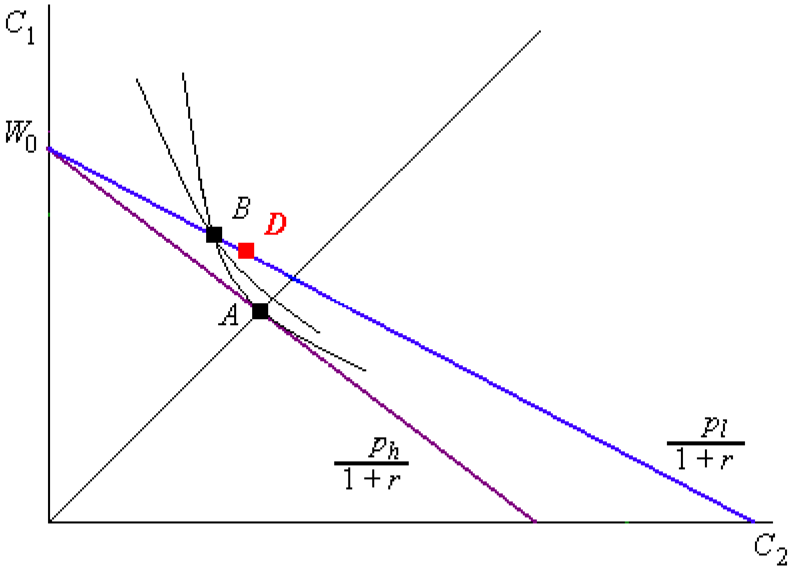


Figure 7: Fan chart of survival probabilities, male 65

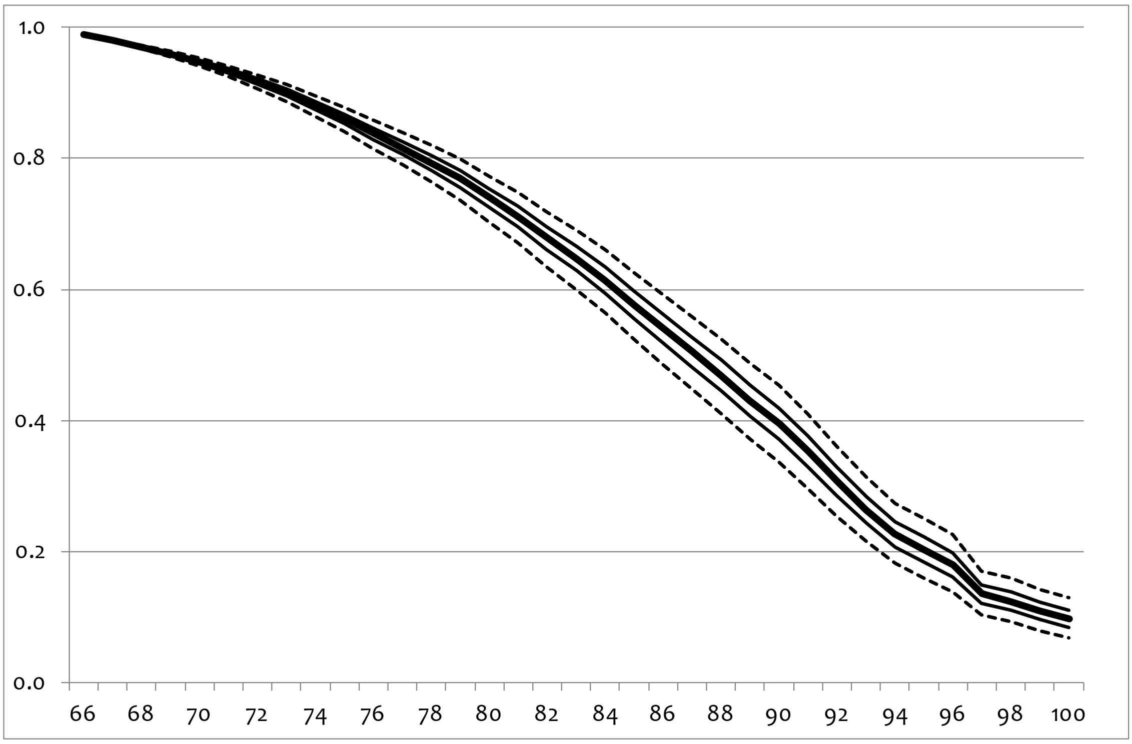


Figure 8: Annuity Value Distributions, male 65

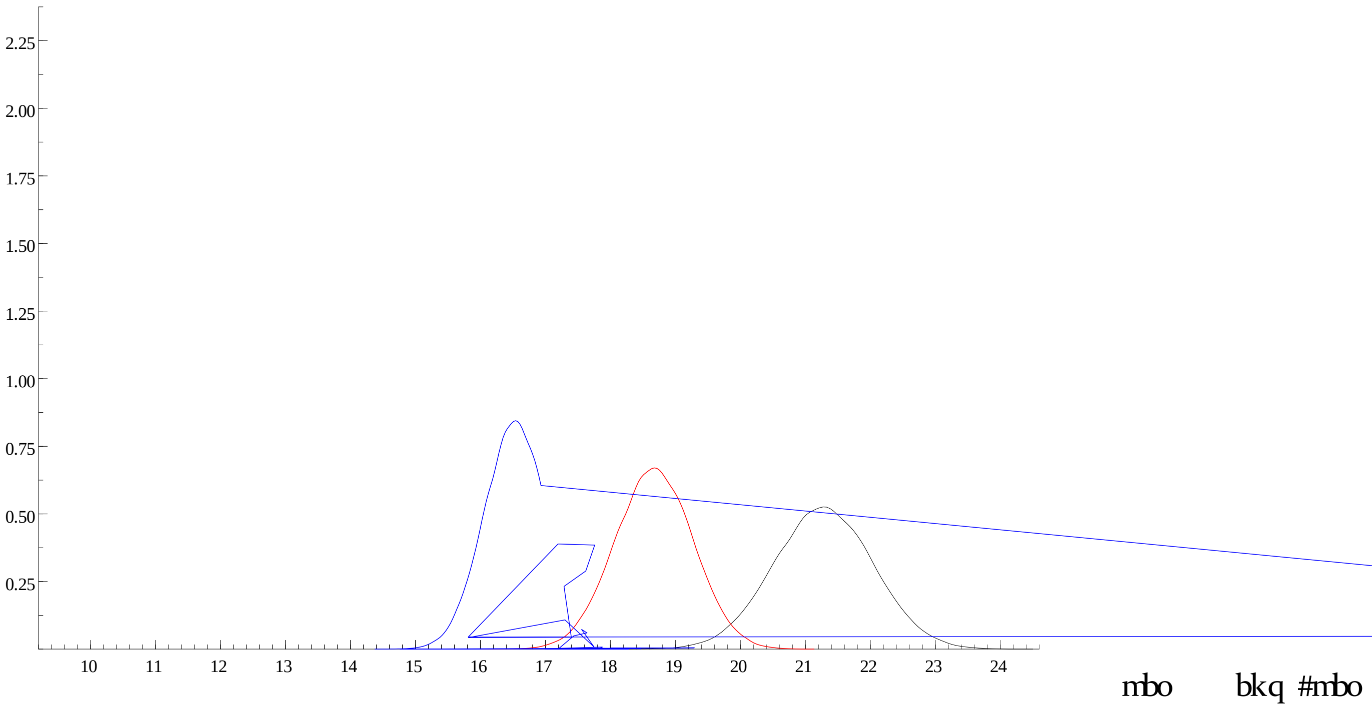
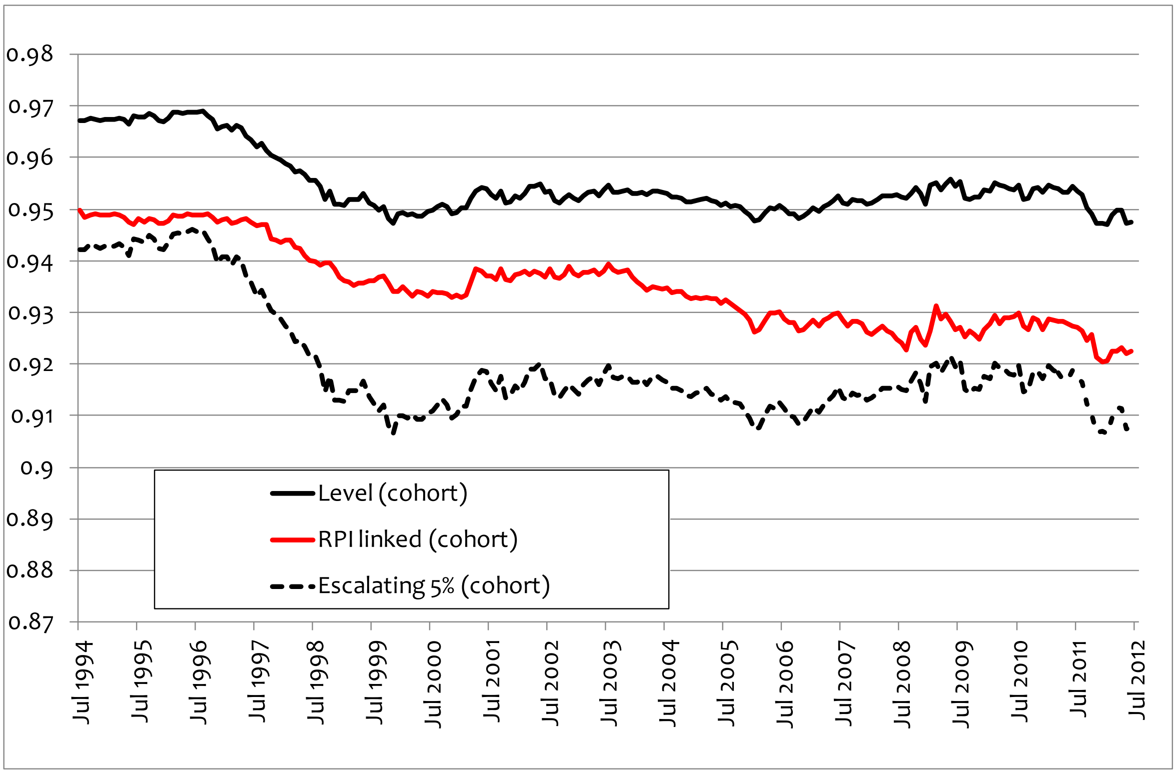


Figure 9: Money's worths using actual yields



Tables

Table 1: Summary of mortality assumptions in the FSA returns

l j m kv	J l oq ifqv ppr j mqfl k
s fs I fcb	55 2 l c M J
k a I fcb	56 l c OJ S mir p cr oqe bo agr pqj bkqp·
E l adb I fcb	32 l c M J
I bd i ka Dbkbo i	36 2 l c M J mir p cr oqe bo agr pqj bkqp·
Mor a bkqf i	62 l c M J
Pq ka oa I fcb	551 l c OJ

Table 2: Purchases of different annuity types, 2011

Pl r o b s ofl r p CP Obqr okp mmbka fu 6 oCl oj 14 ol t p1 ka 6 2

Company	Nominal		Real	
	No of purchases	Average purchase	No. of purchases	Average purchase
Aviva Annuities	58,692	£32,696	1521	£33,707
Canada Life	13,440	£32,696	909	£72,939
Hodge Life	859	£31,029	none	
Legal & General	25,928	£25,102	845	£18,073
Prudential	37,006	£25,653	307	£33,707
Standard Life	20,361	£14,844	245	£20,804

Table 3: Stochastic Money's Worth Calculations

	Diversification (many policies)				Imperfect diversification (400 policies)			
Quantile:	**0.50**	**0.90**	**0.95**	**0.99**	**0.5**	**0.9**	**0.95**	**0.99**
Interest rate								
-1%	1.000	0.933	0.915	0.884	1.001	0.933	0.914	0.879
0%	1.000	0.940	0.924	0.896	1.001	0.936	0.919	0.886
1%	1.000	0.946	0.932	0.906	1.001	0.939	0.923	0.891
2%	1.000	0.952	0.939	0.916	1.001	0.942	0.927	0.897
3%	0.999	0.956	0.945	0.924	1.001	0.945	0.930	0.902
4%	0.999	0.961	0.950	0.932	1.000	0.948	0.934	0.907
5%	0.999	0.964	0.955	0.938	1.000	0.950	0.937	0.912
6%	0.999	0.968	0.959	0.944	1.000	0.953	0.940	0.916
7%	0.999	0.971	0.963	0.949	1.000	0.955	0.943	0.920
8%	0.999	0.973	0.966	0.954	1.000	0.957	0.945	0.924
9%	0.999	0.976	0.969	0.958	1.000	0.959	0.948	0.927
10%	0.999	0.978	0.972	0.961	1.000	0.961	0.950	0.930

Table shows the ratio of the relevant quantile of the annuity distribution to the mean, from equation (9). The projection is made from the Lee-Carter model, assuming parameter uncertainty. The left-hand panel assumes that there are sufficiently many policies that the only risk is from projecting the cohort mortality: the right-hand panel combines cohort mortality risk with additional risk from having only 400 policy holders.

Appendices

Description of the data

q l k RH kkr fqv o qbp cl o j ibp ka cbj ibp qs ofl r p dbp ob q hbk col j J l k bvC qp l s bo qe b mbofl a r dr pq 66 ql mofi # # ka r ma qb qe b kkr fqv pbofbp qe q t b e s b mr ifpe ba mobs fl r piv qe b l k pqpr qfl k l c qe bpb pbofbp fp a bp of ba fk j l ob a bq fi fk kkl k ka Ql khp # 5, Qe bpb ob l j mr ipl ov;mr o e pb kkr fqfbp t ef e ob l r deq pm oq l c mbk pfl k p e bj b t e bob q u obifbc e p bbk dfs bk l k qe b r j r i qfl k l c qe b mbk pfl k cr ka s f k Q p e bj b·,

Col j l r q # pl j b ifcb ppr obop pq oqba ql mof b kkr fqfbp pba l k qe b ml pq l a b l c qe b kkr fq kq ifcb bumb q k v s ofbp v obdfl k ka ml pq l a b e p l kpfa bo ib moba f qfs b ml t bo· t e bob ifcb ppr obop a fa qe fp qe b kkr fqv o qb a q t b e s b fp cl o qvmf i ml pq l a b ' r q qe b a bcfk fqfl k l c qvmf i fp a b fa ba ' v qe b ifcb ppr obo ka t b a l kl q hkl t t e q a bcfk fqfl k fp r pba, Kl qf b cr oqe bo qe q col j b bj bo # #fq b j b fj ml ppf ib ql mof b kkr fqfbp cl o j bk ka t l j bk a fccbobk qiv r ka bo qe b G a fob qfs b pl qe bob t l r ia b ifqqib ml fk q fk buqbk a fk d l r o k ivpfp ql i qbo qfj b mbofl a p p qe bob t fii b cr oqe bo e kdbp ql qe b j ohbq a r b ql r k fpbu mof fk d,

Fk Cfdr ob t b fiir pqp qb qe b kkr fqv o qb pbofbp cl o 3 ;vb o l ia j ib l s bo qfj b l j m oba t fqe dl s bok j bk q l ka a q ka pr j j ov pq qfpqf pl c qe fp a q cl o kl j fk i ka ob i s of ibp fp mobpbk qba fk Q ibp ka #; ii l ka a q fp q hbk col j qe b kh l c kdi ka t b ;pfqb, Fq k b pbbk qe q kl j fk i kkr fqfbp mmol ufj qbiv qp h qe b kl j fk i l ka vfbia ka k il dl r piv cl o ob i kkr fqfbp kkr fqv o qbp ob e fde iv l oobi qba t fqe il kd;qboj l ka vfbia p ka qe b s bo db a fccbobk b fk qe bpb qt l pbofbp l s bo qe b p j mib mbofl a t p #; 53 ,T b ipl l j m ob qe b qt l pr ;mbofl a p r mql qe b cfk k f i ofpfp Kl oqe bok Ol h kh cr k fk r dr pq # 4· ka pfk b qe b l k pbq l c qe b ofpfp, Pfk b qe b ofpfp l qe pe l oq;qboj pb o qb· ka il kd;qboj dl s bok j bk q l ka vfbia p e s b c iibk ka qe fp e p bbk obcib qba fk c ii fk kkr fqv o qbp, Ob i kkr fqfbp e s b m vj bk qp qe q ofpb fk ifk b t fqe qe b RH p Obq fi Mof b Fka bu,

Table A1: Monthly Time Series Properties of Nominal Pension Annuity for 65-year old males and various alternative bond yields

	kkr fqv O qb d o 3 ;vb ol ia j ibp	I l kd;qboj vb o Dl s bokj b kq l ka Vfbia	Pe l oq; qboj kh l c kdi ka pb o qb	Fkqbobpq o qbp l k obq fi qboj a bml pfqp	fdbobk b fk kkr fqv O qb ka Dl s bokj b kq l ka Vfbia
Panel A: Aug 1994 – April 2012					
J b k	4, 63	;	1 ,1 o	9#	#; 53
Pq, bs ,	,4	,1 6	#; 6	, 1	
l oobi qfl k		, 6o			
Panel B: Aug 1994 – July 2007					
J b k	5, 1	; 26	; 0	9 5	#; 62
Pq, bs ,	, 30	, o5	, 4	, 5	
l oobi qfl k		, 6#			
Panel C: Aug 2007 – Apr 2012					
J b k	31	944	, 55	, 3#	#; 30
Pq, bs ,	,1 6	,4 6	#; #	, #o	
l oobi qfl k		, 55			

Q ib mobpbkqp abp ofmqfs b pq qfpqf p l k qe b j l kqe iv qfj b pbofbp l c s bo db kkr fqv o qbp fk qe b M j ohbq il kd;qboj ka pe l oq;qboj dl s bokj bkq l ka vfbia p ka o qbp l k obq fi qboj a bml pfqp l s bo qe b mbofl a 66 q l # # ka cl o qe b qt l pr ; mbofl a p,

Table A2: Monthly Time Series Properties of Real Pension Annuity for 65-year old males and various alternative bond yields

	OMF;ifkhba kkr fqv O qbdl o 3;vb ol ia j ibp	I l kd;qboj vb o Ob i Dl s bokj bkq l ka Vfbia	fcbobk b fk Ob i kkr fqv O qb ka Ob i Dl s bokj bkq l ka Vfbia
Panel A: Sept 1998 – April 2012			
J b k	1 , 6o	, 3	9 0
Pq, bs ,	, 62	,44	
l oobi qfl k		, 5	
Panel B: Sept 1998 – July 2007			
J b k	2,1 o	#, #	9,1
Pq, bs ,	,4 5	, 02	
l oobi qfl k		,4	
Panel C: Aug 2007 – Apr 2012			
J b k	1 ,	, 5	9#
Pq, bs ,	, 0	,4 o	
l oobi qfl k		, 55	

Q ib mobpbkqp a bp ofmqfs b pq qfpqf p l k qe b j l kqe iv qfj b pbofbp l c s bo db ob i kkr fqv o qbp fk qe b M j ohbq ka ob i il kd;qboj dl s bokj bkq l ka vfbia p l s bo qe b mbofl a 66 ql # # ka cl o qe b qt l pr ;mbofl a p,

Qe b obj fkfkd a q qe qt b kbba ql bpqfj qb qe b j l kbv pt l oqe ob qe b j l oq ifqv mol gb qfl kp, Fk mobsfl r p j l kbv pt l oqe i r i qfl kp kkl k ka Ql khp # 1 # 5 # 6 t b qqbj mqba ql r ma qb qe b j l oq ifqv mol gb qfl kp q qe b qfj b qe q qe b ifcb ppr obop a fa pl , T b a fa kl q qov ql fkcbo qe b j l oq ifqv q ibp r pba v qe b ifcb ppr obop col j qe b cl l qkl qbp l c qe b CP Obqr okp b r pb l c s ofbqv l c mol ibj p b e CP Obqr ok l kq fkp s ofbqv l c ppr j mqfl kp qe bob ob i odb kr j bo l c l j m kfbp ka r kqfi ob bkqiv qe b cl l qkl qbp l c qe b CP Obqr okp t bob kl q b pfiv s fi ib, Fkpqb a t b pq oqba r pfkd b e kbt q ib col j qe b Fkpqfqr qb l c qr ofbp col j vb o bcl ob qe b mr if qfl k a qb l k qe b odr j bkq qe q qe b ol a l r qifkb l c qe bpb a q j v e s b bbk hkl t k ql ifcb ppr obop bcl ob qr i mr if qfl k ka ifcb ppr obop t l r ia ipl e s b bbk ib ql k ivpb qe b j l oq ifqv bumbofbk b l c qe bfo l t k kkr fq kqp· ,

Qe b MJ I 5 M o e pba J ib I fcb · q ib t pmr ifpe ba fk 66# 5 obcbop ql qe b ’
pb vb o·, iqe l r de fq mol gb qba do ar i fk ob pbp fk ifcb bumb q k v v qe b i qb
66 p fq e a b l j b ib o qe q qe b al t kt oa qobka fk j l oq ifqv l c mbkpfl k bop t p
j r e pqol kdbo ka qe b MJ I 6#q ibp mr ifpe ba 666 obs fpba ifcb bumb q k v r m v
ij l pq qt l vb op, Cr oqe bo k ivpfp l c qe b obar qfl k fk j l oq ifqv l qe cl o mbkpfl k bop
ka mbl mib l c bil t mbkpfl k db cl o t e f e mbkpfl k a q t bob r k s fi ib ifcb
ppr o k b a q t pr pba fkpqb a · pr ddbpqba l e l oq bccb q fb àfp obqb
al t kt oa gr j mfk j l oq ifqv cl o mbl mib l ok cqbo l r q 6o, Qe fp iba ql pbq l o
fkqbofj agr pqj bkq p mr ifpe ba fk # # qe b j l pq t fa biv r pba j ba fr j l e l oq ’
agr pqj bkq fp fiir pqo qba e bob, Fk # 2fkcl oj qfl k l k qe b j l pq ob bkq kkr fq kq
j l oq ifqv t pmr ifpe ba qe b q ib· t e f e aƒa kl qe s b k l j m kvfkd
mol gb qfl k cl o e kdbp fkql qe b cr qr ob, l oafkdiv q qe q qfj b j kv ifcb ppr obop
r pba qe b q ib p pb ’ ka qe bk r pba qe b j bafr j l e l oq mol gb qfl k col j
l o pl j b l qe bo vb o· l kt oa p,

Implementation of the Lee-Carter method

I bb ka oqbo 66# fkqol a r ba qe fp j l a bi ka dl l a bum pfqfl kp ob Dfol pf Hfkd # 5 mm, ®,cc· ka Mfq l bq i # 5 mm, 3(6 4 o 53cc,·, Qe fp pmb fcf qfl k a l bp kl q l j mibqbiv fa bkqfcv qe b m o j bqbop pl fa bkqfcvfkd obpqofr qfl kp t e f e e sb kl bccb q l k qe b k ivpfp· ob r pba

$$\sum_t \kappa_t = 0 \quad \text{and either}$$

$$\sum_x \beta_x = 1, \quad \text{in the original Lee-Carter (1992) paper}$$

$$\text{or} \quad \sum_x \beta_x^2 = 1, \quad \text{in Girosi-King (2008)}$$

ppr j fkd qe q qe b bool op ob Kl oj iiv afpqof r qba qe bk bpqfj qfl k fp p dl iil t p q hbk col j DH r q t fqe pifde qiv afccbobkq kl q qfl k·

$$x = \{1, \ldots, X\} \quad \text{nb slightly different from typical actuarial notation:}$$
$$\text{typically start age age 60, so } x \equiv age - 59$$
$$t = \{1, \ldots T\}$$
$$\mathbf{M} = \left(m_{x,t}\right) \in \mathbb{R}^X \times \mathbb{R}^T \quad \text{nb: ages in rows, time in columns}$$
$$\tilde{\mathbf{M}} \equiv \mathbf{M} - \bar{\mathbf{m}}_x \mathbf{1}' \qquad \bar{\mathbf{m}}_x = \{\bar{m}_x\} \in \mathbb{R}^X$$

Qe b bpqfj qfl k l c qe b fkqbo bmq qboj fp pqo fde q;cl ot oa ka fkqr fqfs b dfs bk qe b l kpqo fkq qe q $\sum_t \kappa_t = 0$ gr pq q hb qe b ol t j b kp ql dbq

$$\hat{\alpha}_x = \bar{m}_x = T^{-1} \sum_{t=0}^{T-1} m_{xt}$$

l kpfa bo j l a bi t fqe l mofk fm i l j ml kbkqp

$$m_{xt} = \alpha_x + \kappa_{1t}\beta_1 + \cdots + \kappa_{lt}\beta_l + \varepsilon_t$$
$$\beta_i \in \mathbb{R}^X$$
$$\underbrace{\tilde{M}}_{X\times T} = \underbrace{\beta}_{X\times l} \underbrace{\kappa}_{l\times T} + \varepsilon_t$$

v qe b pfkdr i o;s ir b a b l j ml pfqfl k qe bl obj

$$\underbrace{\tilde{\mathbf{M}}}_{X\times T} = \underbrace{\mathbf{B}}_{X\times T} \underbrace{\mathbf{L}}_{T\times T} \underbrace{\mathbf{U}'}_{T\times T}$$

t e bob **L** fp af dl k i j qofu t fqe qe b pfkdr i o s ir bp mr q fk a bp bka fkd l oa bo, Qe b cfopq l mofk fm i l j ml kbkqp ob qe b cfopq l l ir j kp l c **B**, Qe b I bb; oqbo j l a bi fp gr pq qe fp j l a bi t fqe $l = 1$, Pl

$$\text{Lee-Carter}\begin{cases}\hat{\beta} = B_1 / 1' B_1 \\ \hat{\kappa} = \left(1' B_1\right) L_{11} U_1' \end{cases} \qquad \text{Girosi-King}\begin{cases}\hat{\beta} = B_1 / \left\| B_1 \right\| \\ \hat{\kappa} = \hat{\beta}' \tilde{M} \end{cases}$$

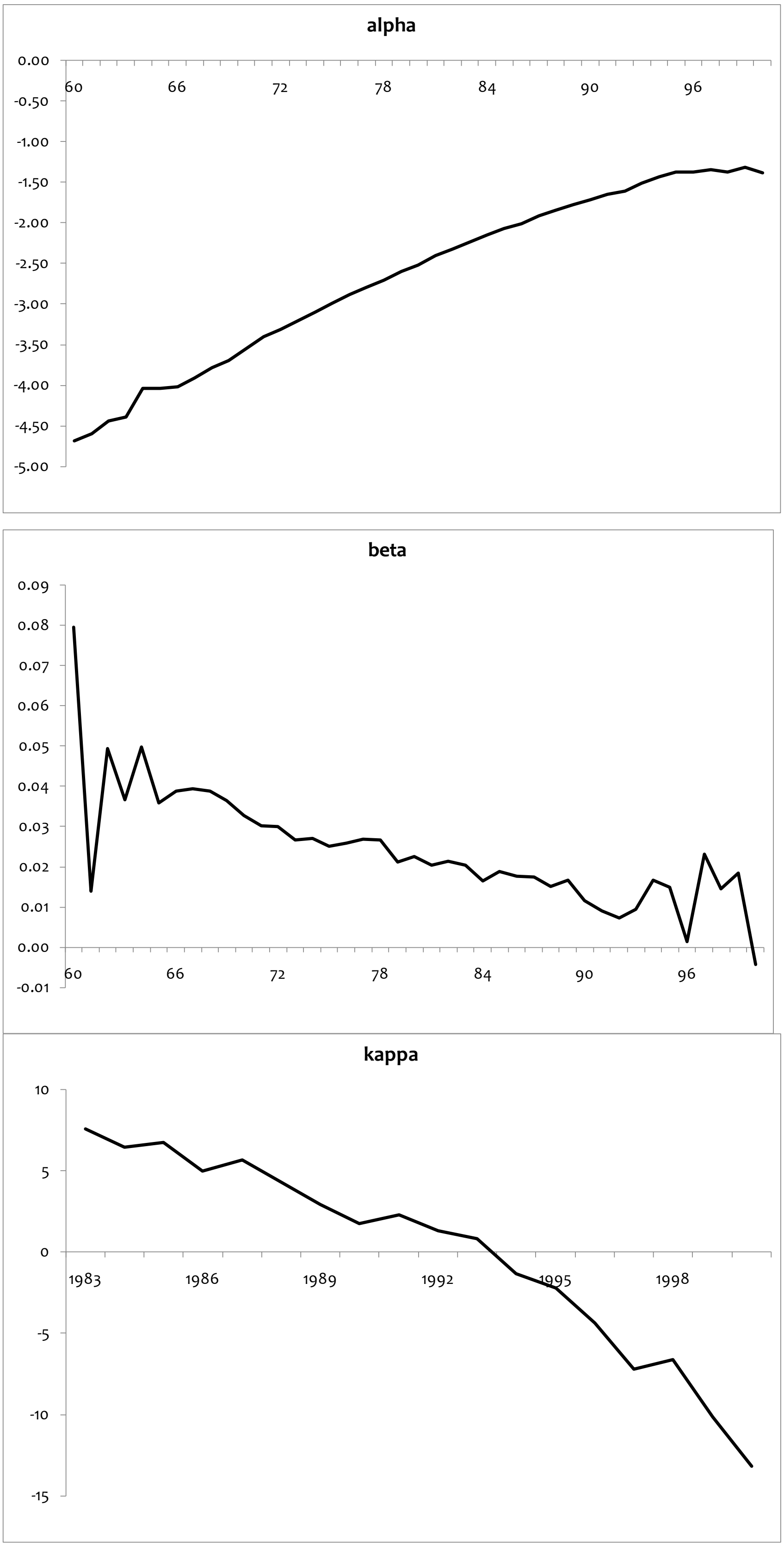
I bb ka ocqbo pr ddbpq k agr pgj bkqql qe b qfj b;bccb qp ql bkpr ob qe q qe b bumb qba ab qe p j q e qe b qr i ab qe p iiba pb l ka ;pq db bpqfj qfl k pl qe q

$$\forall t : \kappa_t \Leftarrow 0 = \sum_x ETR_{xt} e^{\bar{m}_x + \beta_x \kappa_t} - \sum_x D_{xt}$$

ka t b e s b cl iil t ba qe q mol bar ob,

L r o bpqfj qbp l c qe b m o j bqbop ob pe l t k fk qe b cfdr obp bil t ,

Figure A1: Lee Carter Parameters for the UK Pensioner Data



Appendix on Regulation

Col j sfs I fcb CP Obqr ok # t b dbq qe b cl iil t fkd nr l qb

FKPMOR , , oO · Qe b ppbqp e bia v' cfoj ql l s bo fqp qb e kf i

mol s fpfl kp ' j r pq' b l c pr ccf fbkq j l r kq ka l c k mmol mof qb r oobk v ka

qboj ql bk pr ob qe q qe b pe fkcil t p col j qe l pb ppbqp t fii j bbq qe b bumb qba pe

l r qcil t p col j qe b cfoj p fk pr o k b if fifqfbp p qe bv b l j b ar b,

, , ,

Qe b ppbqp hfkd qe b if fifqfbp al kl q mob fpbiv j q e qe bj v qboj , Qe b cr ka e p

pfdk fcf kq e l ia fk dp fk nr fqv ka Mol mboqv ppbqp qe q e s b kl pbq j qr ofqv a qb,

Qe bpb ppbqp ob e bia ql mol s fa b pqol kd mbocl oj k b cl o ml if ve l ia bop, Fk pqb a qe b

cr ka fj p ql bk pr ob qe q pe l r qcil t p k b j bq qe ol r de

Fk l j fkd mobj fr j p

Fk l j b col j fqp ppbqp afs fa bk a p obk q i fk l j b l r ml k m vj bkqp·

Ob bfmqp l k oba bj mqfl k col j j q e ba cfuba fk qbobpq pql hp

E l ia fkd mmol mof qb s l ir j bp l c pe ka ifnr fa ppbqp

P ibp l c ppbqp,

Qe bob fp ofph qe q qe b cr ka j v e s b ql pbii ppbqp q k r kc sl r o ib qfj b b,d,

t e bk mof bp ob qbj ml o ofiv a bmobppba , Fc qe b cr ka e p ql pbii r k j ohbq ib ppbqp fq

j v ipl a bmobpp qe b mof b qe ol r de qe b p ib fqpbic, Qe b ofph t fii b s bov pe l oq qboj fc

l r o ifnr fa fqv t p dbkr fk biv k fppr b qe bk t b l r ia pbii fiifnr fa ppbqp cl o pe l s bo

qe b mbofl a l c vb o t fqe l r q afpql oqfk d qe b mof b t b t l r ia ob bfs b ka e s b r pba fk

l r o ppbq s ir qfl k·,

Qe b ofph l kiv fj m qp r pfk bpp t e bob fq kkl q b m ppba l k ql ml if ve l ia bop, Cl o

bu j mib qe b ofph fp k bdifdf ib l k ppbqp hfkd R kfq I fkhba r pfk bpp , , ,

Ql j fqfd qb qe fp ofph qe b cr ka e l ia p ifnr fa ppbqp pe boqfcf qbp l c a bml pfq· , Fq

ipl bk pr obp qe q pfdk fcf kq mol ml oqfl k l c fqp l qe bo ppbqp ob fk s bpqba fk e fde iv

j ohbq ib pql hp fk m oqf r i odl s bok j bkq l ka p r q ipl pe obp fppr ba v i odb

l j m kfbp· ,

MF;ifkhba dfiqp l kpr iq qfl k

L k #6Gr kb # qe b J L i r k e ba l kpr iq qfl k l k

MF;ifkhba dfiqp ql r fia k bs fa bk b pb ql fkcl oj qe b

Dl s bokj bkq p l kpfa bo qfl k l c t e bqe bo ql fppr b pr e

fk pqor j bkqp, Qe b l k pr iq qfl k il pba l k ##Pbmqbj bo

,

Qe b J L mr ifpe ba fqp obpml kpb l k #6Kl s bj bo #

ka kkl r k ba qe q qe b Dl s bokj bkq e a a b fa ba kl q ql

fppr b MF ifkhba dfiqp fk # #; ,Fq gr a dba qe q fppr k b l c

pr e dfiqp fk qe b kb o qboj t l r ia b r kifhbiv ql b l pq

bccb qfs b ka fks l is b kr j bo l c ofphp, Q

Q ib Fj ml ppf fifqv l ce badfkd l kb qvmb l c kkr fqv t fqe kl qe bo

		#	1	3	5
#	, 666#				
1	, 6636	, 666#			
3	, 660#	, 664	, 666#		
5	, 655	, 660#	, 664	, 6660	

Table shows the pairwise correlations of annuity values with different interest rates but the same mortality. Calculations are based on the same simulations illustrated in Figure ## ,