OA Online Appendix

OA1 Risk-adjusted and risk-free discount rates

The risk-adjusted discount rate (23) reads $r = \rho + \eta g - \frac{1}{2}\eta(1+\eta)\sigma^2 + \beta\eta\sigma^2$, where $g \equiv \ln[\mathbb{E}_0[C_1]/C_0]$ defines expected growth of consumption[1], and the difference between the deterministic discount rate $\rho + \eta g$ and the risk-adjusted discount rate r is the climate risk premium Π given in (22).

The first two terms of equation (23) correspond to the deterministic Keynes-Ramsey rule. The first term ρ is the time impatience effect, which indicates that with more impatience investors demand higher returns and thus the SCC is lower. The second term ηg is the affluence effect, which indicates that with higher growth and more intertemporal inequality aversion (i.e., lower elasticity of intertemporal substitution) investors require higher returns and this implies a lower SCC. Effectively, if society is richer in the future, it will do less today to combat climate change. The third term on the right-hand side of equation (23) is the prudence term. This term always depresses the discount rate and pushes up the SCC. This prudence effect increases in the coefficient of relative risk aversion η, the coefficient of relative prudence $1+\eta$, and the variance of consumption growth. The fourth term in (23) is the insurance term. If future marginal damages are positively correlated with future consumption, i.e., $\beta > 0$, there is potential for self-insurance so that the return and the discount rate are higher, and thus the SCC is lower. If the climate beta is negative, $\beta < 0$, the SCC will be higher and climate policy must be more ambitious.

Finally, we can write equation (23) in the standard CCAPM form as

$$r = r_f + \beta\eta\sigma^2,$$

where $r_f \equiv \rho + \eta g - \frac{1}{2}\eta(1+\eta)\sigma^2$ is the risk-free discount rate and $\beta\eta\sigma^2$ the risk premium. The prudence effect depresses the risk-free rate as the additional precautionary saving resulting from macroeconomic uncertainty implies lower returns.

OA2 Computing the climate risk premium

We derive in this appendix the one-period-ahead risk-adjusted discount rate and climate risk premium in an infinite-horizon model. With power utility, the SCC at time t is given

[1]Recall from Section 2.5 that consumption growth $\ln(C_1/C_0)$ is normally distributed with mean μ and standard deviation σ. Hence, $\mathbb{E}_0[C_1/C_0] = e^{\mu+\sigma^2/2}$ and $\mathrm{Var}_0[C_1/C_0] = e^{2\mu+\sigma^2}(e^{\sigma^2}-1)$.

by

$$
\begin{aligned}
SCC_t &= \mathbb{E}_t\left[\sum_{s=t}^{\infty} e^{-\rho(s-t)}\frac{D_s u'(C_s)}{u'(C_t)}\right] = \sum_{s=t}^{\infty} e^{-\rho(s-t)}\mathbb{E}_t\left[\frac{D_s u'(C_s)}{u'(C_t)}\right] \\
&= \sum_{s=t}^{\infty} e^{-\rho(s-t)+\ln(1+\pi_{t,s})}\frac{\mathbb{E}_t(D_s)u'(\mathbb{E}_t(C_s))}{u'(C_t)} \\
&= \sum_{s=t}^{\infty} e^{-(\rho(s-t)+\eta g_{t,s}-\ln(1+\pi_{t,s}))}\mathbb{E}_t(D_s) \\
&= \sum_{s=t}^{\infty} e^{-r_{t,s}}\mathbb{E}_t(D_s),
\end{aligned}
\tag{OA.1}
$$

where

$$
\pi_{t,s} \equiv \frac{\mathbb{E}_t\left(D_s u'(C_s)\right)}{\mathbb{E}_t(D_s)u'(\mathbb{E}_t(C_s))} - 1 \approx \frac{1}{2}\eta(1+\eta)\frac{Var_t(C_s)}{(\mathbb{E}_t(C_s))^2} - \eta\beta_{t,s}\frac{Var_t(C_s)}{(\mathbb{E}_t(C_s))^2} \tag{OA.2}
$$

$$
\beta_{t,s} = \frac{Cov_t(C_s, D_s)}{Var_t(C_s)}\frac{\mathbb{E}_t(C_s)}{\mathbb{E}_t(D_s)} \tag{OA.3}
$$

$$
g_{t,s} = \ln\left(\frac{\mathbb{E}_t(C_s)}{C_t}\right) \tag{OA.4}
$$

$$
r_{t,s} = \rho(s-t) + \eta g_{t,s} - \ln(1+\pi_{t,s}) \approx \rho(s-t) + \eta g_{t,s} - \pi_{t,s}. \tag{OA.5}
$$

That is, $\pi_{t,s}$ is the cumulative climate risk premium from period t to period s, $\beta_{t,s}$ is the elasticity of a marginal damage in period s w.r.t. a unit increase of consumption in period t, $g_{t,s}$ is the growth rate of consumption in period s relative to period t, and $r_{t,s}$ is the risk-adjusted discount rate for damage in period s to period t.

To decompose the cumulative risk-adjusted discount rate to one-period-ahead discount rate, note that

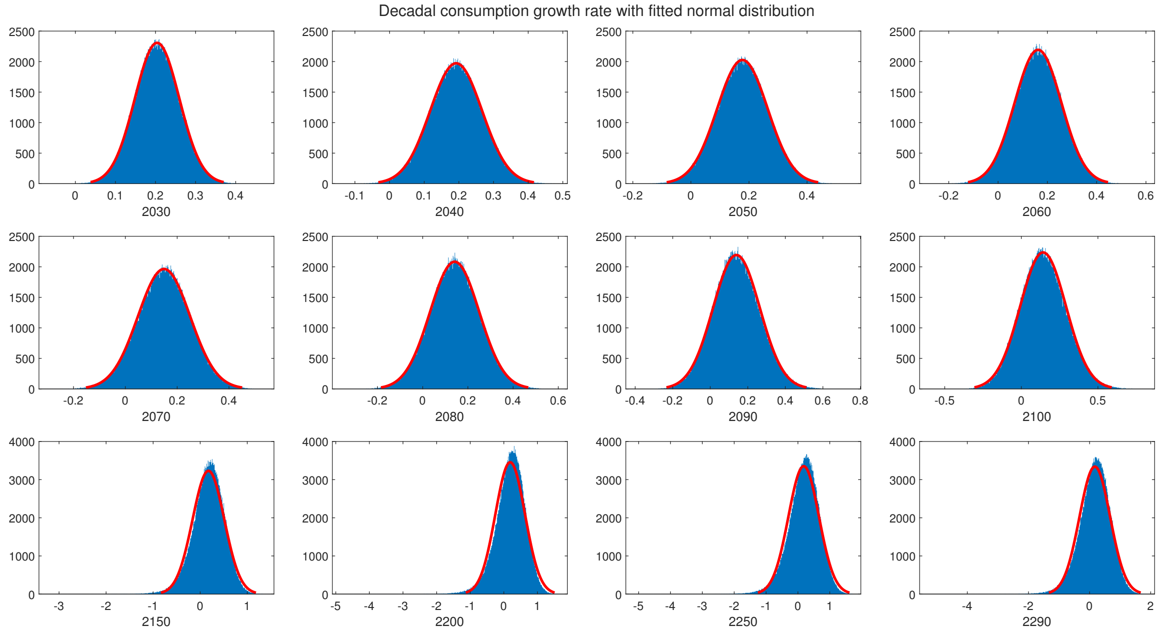
$$
SCC_t = D_t + e^{-r_{t,t+1}}\sum_{s=t+1}^{\infty} e^{-r_{t+1,s}}\mathbb{E}_t(D_s) = D_t + e^{-r_{t,t+1}}\mathbb{E}_t(SCC_{t+1}) \tag{OA.6}
$$

Continuing this process we find

$$
SCC_t = D_t + \sum_{s=t+1}^{\infty} e^{-\sum_{v=t}^{s} r_{v,v+1}}\mathbb{E}(D_s). \tag{OA.7}
$$

Equating (OA.7) and (18) allows us to find $r_{s,s+1}$ for each period s: $r_{s,s+1} = r_{t,s+1} - r_{t,s}$, which is the one-period-ahead risk-adjusted discount rate conditional on information at t. Since

$$
r_{s,s+1} = r_{t,s+1} - r_{t,s} = \rho + \eta\ln\left[\frac{\mathbb{E}_t(C_{s+1})}{\mathbb{E}_t(C_s)}\right] - (\pi_{t,s+1} - \pi_{t,s}), \tag{OA.8}
$$



Parameters: $\epsilon = 3$, $\rho_{c,d} = 0$, $\sigma_c/\sigma_d = 1$

Figure OA.1: Distribution of decadal consumption growth rate with $\rho_{c,d} = 0$

the one-period-ahead climate risk premium (conditional on information at t) can be computed either as $\pi_{s,s+1} = \rho + \eta \ln(\mathbb{E}_t(C_{s+1})/\mathbb{E}_t(C_s)) - r_{s,s+1}$ or $\pi_{s,s+1} = \pi_{t,s+1} - \pi_{t,s}$.

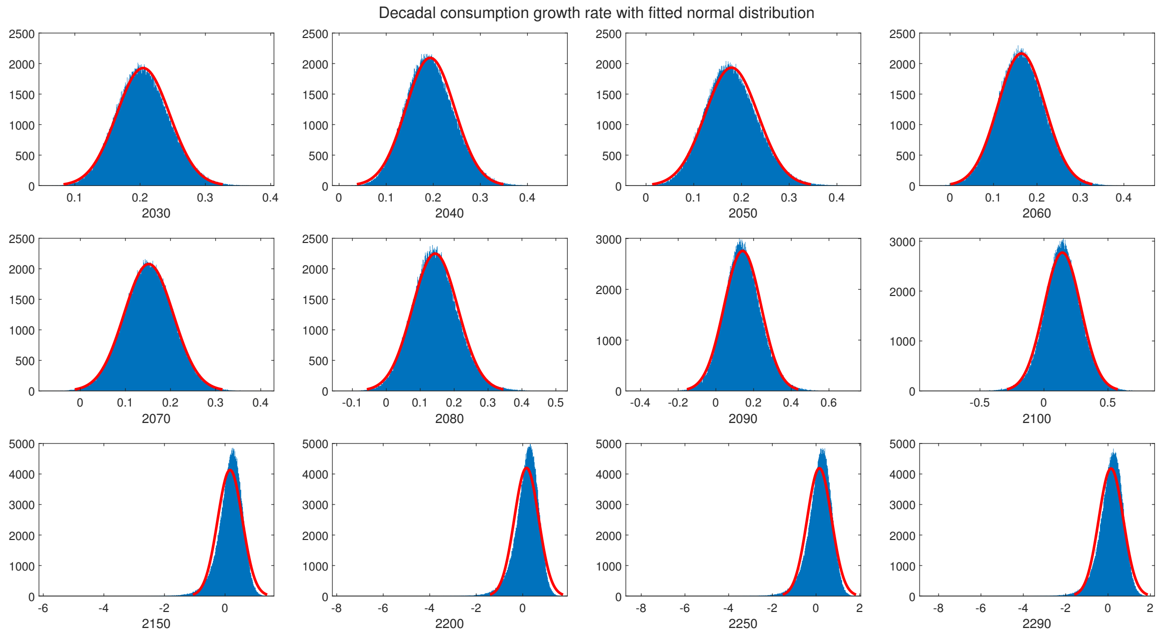
We next decompose the climate risk premium into the prudence and insurance term using

$$\pi_{s,s+1} = \frac{1}{2}(1+\eta)\sigma^2_{s,s+1} - \beta_{s,s+1}\eta\sigma^2_{s,s+1} \tag{OA.9}$$

where $\sigma^2_{s,s+1} = \frac{Var_s(C_{s+1})}{(\mathbb{E}_s(C_{s+1}))^2}$. Since consumption can be very well approximated by a log-normal distribution (see Appendix OA3) and since consumption volatility is small, we can approximate $\sigma^2_{s,s+1}$ by $\sigma^2_{s,s+1} \approx Var_t(\ln(C_{s+1}/C_s))$. We derive the one-period-ahead climate beta as a residual from (OA.9), and compute the prudence and insurance terms accordingly.

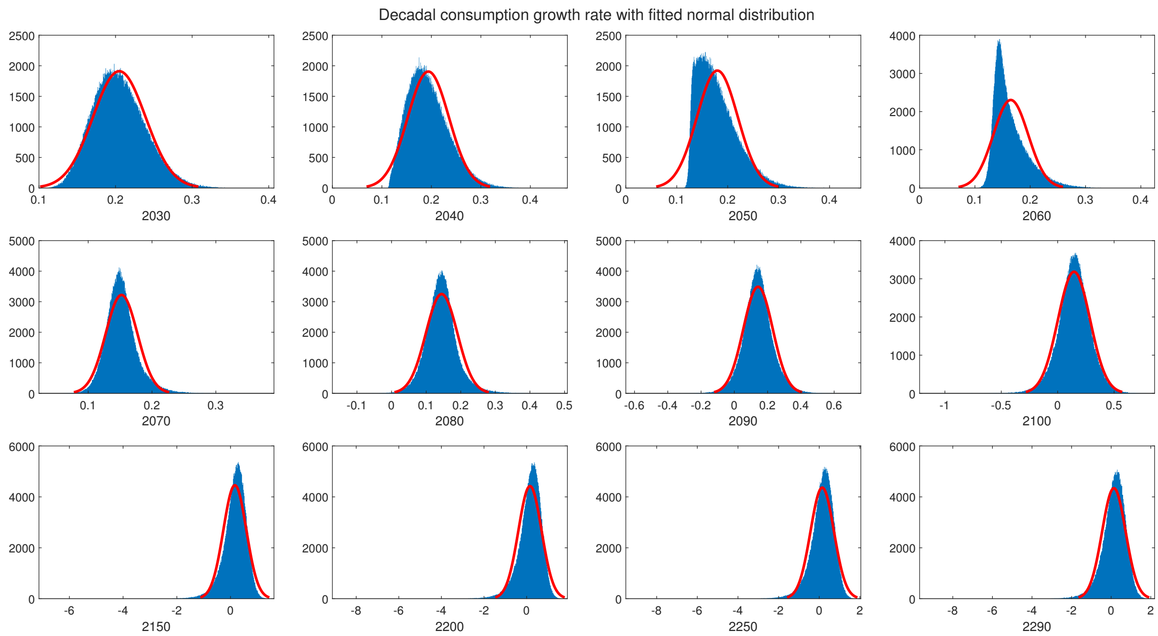
OA3 Distribution of consumption growth rate

Figures OA.1-OA.4 illustrated the histograms (in blue) and fitted normal distributions (in red) for the decadal consumption growth rates from the simulated data used in the quantitative assessment. The distribution of consumption growth rates can be very well approximated by a normal distribution for almost all correlation coefficients and for almost all periods.



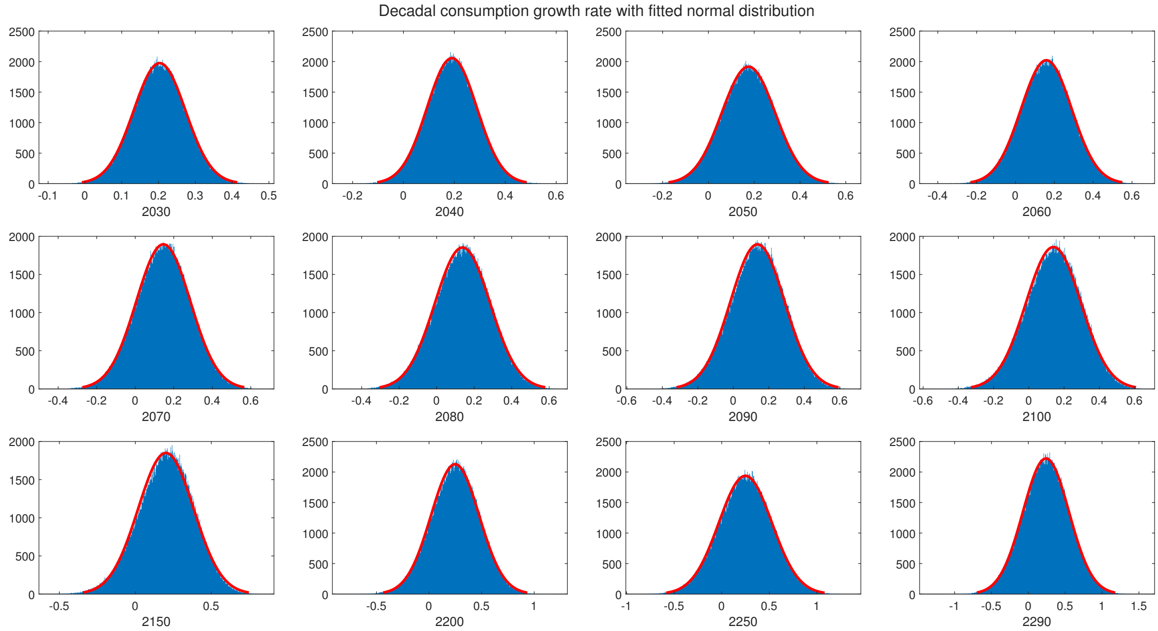
Parameters: $\epsilon = 3$, $\rho_{c,d} = -0.75$, $\sigma_c/\sigma_d = 1$

Figure OA.2: Distribution of decadal consumption growth rate with $\rho_{c,d} = -0.75$



Parameters: $\epsilon = 3$, $\rho_{c,d} = -1$, $\sigma_c/\sigma_d = 1$

Figure OA.3: Distribution of decadal consumption growth rate with $\rho_{c,d} = -1$

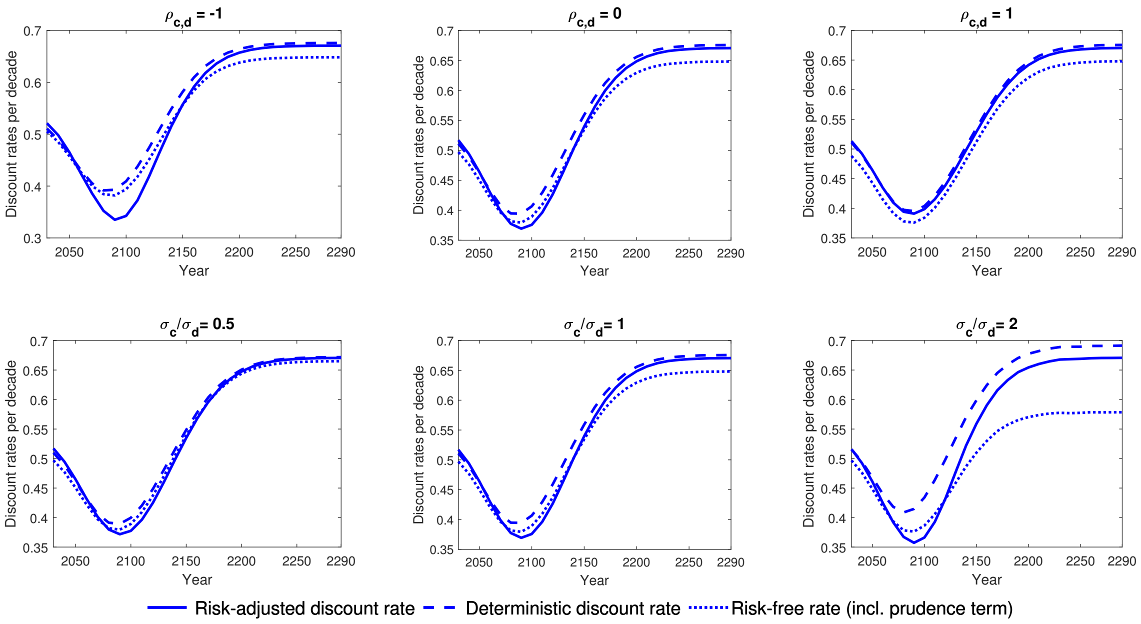


Parameters: $\epsilon = 3$, $\rho_{c,d} = 1$, $\sigma_c/\sigma_d = 1$

Figure OA.4: Distribution of decadal consumption growth rate with $\rho_{c,d} = 1$

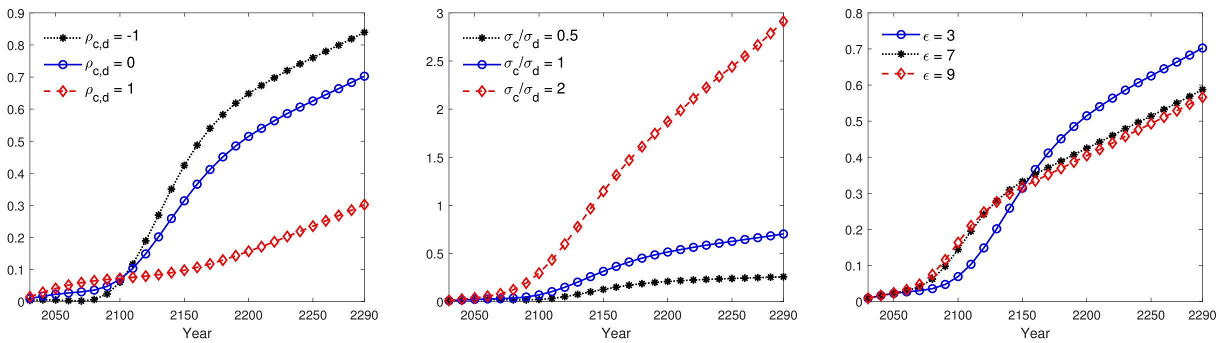
OA4 Additional graphs

Figure OA.5 illustrates the deterministic rate $(\rho + \eta g)$, the risk-free rate, and the risk-adjusted discount rate over time. The gap between the risk-free and the deterministic rate is the prudence term and the gap between the risk-adjusted discount rate and the risk-free rate is the insurance term. The dashed lines illustrated the deterministic discount rate, which is proportional to expected consumption growth. The dashed lines are always above the dotted lines, suggesting that the prudence term always lowers the discount rate. Comparing the dashed and solid lines, we see that the insurance value is positive in the mid phase of the transition. Figures OA.6 and OA.7 illustrate the cumulative prudence and insurance terms. The sum of the two correspond to the cumulative climate risk premium $\pi_{t,s}$ in (OA.2). Time-differencing the cumulative prudence and insurance terms will give us the one-period-ahead prudence and insurance terms in Figures 7 and 8.



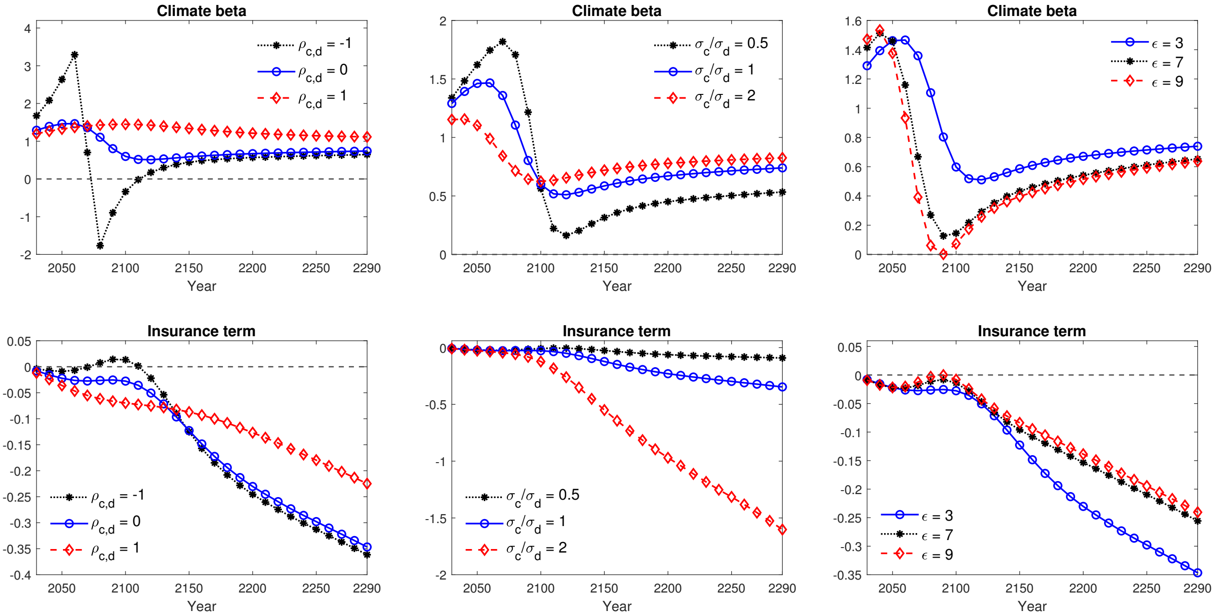
Baseline parameters: $\epsilon = 3$, $\rho_{c,d} = 0$, $\sigma_c/\sigma_d = 1$

Figure OA.5: Decomposition of discount rates for different correlation coefficients and different sizes of correlation and relative shocks



Baseline parameters: $\epsilon = 3$, $\rho_{c,d} = 0$, $\sigma_c/\sigma_d = 1$

Figure OA.6: The cumulative prudence term



Baseline parameters: $\epsilon = 3$, $\rho_{c,d} = 0$, $\sigma_c/\sigma_d = 1$

Figure OA.7: The cumulative insurance term