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Reaching nirvana with a defaultable asset?

Published: 01 June 2017

Volume 40, pages 31–52, (2017) [Cite this article](#)



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Notes

1. Cox and Huang ([1989](#)) require the global Lipschitz continuity of the diffusive

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approach to the standard Kim and Omberg ([1996](#)) portfolio problem with a non-defaultable risky asset.

6. There are parameter values that make the investor with $(\phi > 1)$ take a net short position in the risky defaultable asset.
7. Similar investment-horizon effects have been found in the literature on dynamic portfolio choice with a risky non-defaultable asset characterized by a mean-reverting drift and a constant volatility [see, for example, Koijen et al. ([2009](#))].
8. The functions U and V are conjugate if and only if $(U(w) = \inf_{y > 0} (V(y) + wy))$ and $(V(y) = \sup_{w > 0} (U(w) - wy))$.

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1.1 A.1 Proof of proposition 3.1

The problem of utility maximization can be written as $\max_{w \in W} \left(e^{rT} u(w) \right)$ where u is defined as

$$u(w) = \sup_{\tilde{W} \in \mathcal{W}} E[U(\tilde{W}_T)].$$

(A.1)

We apply to problem (A.1) the duality approach developed by Kramkov and Schachermayer (1999, 2003). To this aim, we observe that the utility function U satisfies Inada conditions [equation (2.4) in Kramkov and Schachermayer (1999)]

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$$\begin{aligned} \{\tilde{W}\}^* &= -V^{\prime}(y\eta) = \left(\left(\frac{w}{E\left[\eta^{-\frac{1-\phi}{\phi}}\right]} \right) \right)^{-\phi} \eta \left(\frac{1}{\phi} \right) = w \frac{\eta^{-\frac{1}{\phi}}}{E\left[\eta^{-\frac{1-\phi}{\phi}}\right]}. \end{aligned}$$

The value function is then

$$\begin{aligned} J(w) &= \left(e^{rT} \right)^{1-\phi} E\left[U(\{\tilde{W}\}^*) \right] = U(w e^{rT}) E\left[\left(\frac{\eta^{-\frac{1}{\phi}}}{E\left[\eta^{-\frac{1-\phi}{\phi}}\right]} \right) \right]^{1-\phi} \\ &= U(w e^{rT}) \left(E\left[\eta^{-\frac{1-\phi}{\phi}}\right] \right)^{\phi} \\ &= U(w e^{rT}) \left(E\left[\exp \left(\frac{1-\phi}{\phi} \int_0^T \sqrt{Y_t} dZ_t + \frac{1-\phi}{2\phi} \int_0^T Y_t dt \right) \right] \right)^{\phi} \\ &= U(w e^{rT}) F(T, y). \end{aligned}$$

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(A.2)

The random variable $(L_{\cdot T})$ in (A.2) is the Radon-Nikodym density of a probability measure equivalent to (\mathbb{P}) . In fact, Theorem⁹ 2.3 in Delbaen and Shirakawa (2002) applied to $(S^{DS}=Y, \rho^{DS}=0.5, \sigma^{DS}=b>0, \mu^{DS}=2\sqrt{c\phi}, \theta^{DS}=a)$ implies that $(\eta_{\cdot T}^{DS}=L_{\cdot T})$ is the Radon-Nikodym density of an equivalent probability measure $(\hat{\mathbb{Q}})$ equivalent to (\mathbb{P}) . Girsanov's theorem implies then that

$$\begin{aligned} \hat{Z}_t &= Z_t - \int_0^t a \sqrt{Y_s} ds \\ \end{aligned}$$

(A.3)

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$$M_{\{t\}} = \exp \left(\frac{a^{\{2\}} + a^{\{2\}}}{2} \int_0^t Y_{\{s\}} ds \right) G(T-t, Y_{\{t\}})$$

(A.6)

where $G(t, y)$ is a $(\mathcal{C}^{\{1,2\}})$ function to be determined in such a way that $(G(0, y) = 1)$ and M is a $(\hat{\mathbb{Q}})$ -martingale. In particular, Eq. (A.6) implies for $(t = 0)$ that $(M_0 = G(T, y))$ and for $(t = T)$

$$M_{\{T\}} = \exp \left(\frac{a^{\{2\}} + a^{\{2\}}}{2} \int_0^T Y_{\{t\}} dt \right) G(0, Y_{\{T\}}) = \exp \left(\frac{a^{\{2\}} + a^{\{2\}}}{2} \int_0^T Y_{\{t\}} dt \right),$$

since $(G(0, \cdot) = 1)$. The martingality condition $(M_0 = E^{\{\hat{\mathbb{Q}}\}}[M_{\{T\}}])$ yields then

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(A.8)

Equation (A.8) is a Riccati equation whose solution is

$$\begin{aligned} g(t) &= \frac{(a^2 + a)(e^{\sqrt{q}t} - 1)}{\sqrt{q} + b + e^{\sqrt{q}t}(\sqrt{q} - b)}. \end{aligned}$$

Since (M_t) has 0 drift in the Ito decomposition under $(\hat{\mathbb{Q}})$, (M_t) is a $(\hat{\mathbb{Q}})$ local martingale. To conclude that (M_t) is a martingale we define

$$\mathbb{z}_t = \frac{M_t}{M_0},$$

which is a $(\hat{\mathbb{Q}})$ local martingale as well, and show that (\mathbb{z}_t) is a $(\hat{\mathbb{Q}})$ martingale. To this aim, we first

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Therefore,

$$\begin{aligned} \frac{z}{t} &= 1 + \int_0^t \frac{z}{s} dm_s \\ \end{aligned}$$

with

$$\begin{aligned} m_t &= \int_0^t 2\sqrt{c\phi} g(T- \\ s)\sqrt{Y_s} d\hat{Z}_s. \end{aligned}$$

We apply Theorem 4.1 in Klebaner and Lipster ([2014](#)) to conclude that $(\frac{z}{t})$ is a true martingale. In particular, with Klebaner and Lipster notations (4.2) at page 44

$$\begin{aligned} a_s(y) &= b_s(y) = 2\sqrt{c\phi} \sqrt{y} \end{aligned}$$

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since

$$\begin{aligned} \phi(a^2+a)=a. \end{aligned}$$

\square

1.3 A.3 Proof of proposition [3.3](#)

In what follows, we will mainly work under the martingale measure (\mathbb{P}, \mathbb{Q}) whose density with respect to (\mathbb{P}) is (η) in Eq. [\(2.3\)](#). We denote with $(Z_t^\mathbb{Q})$ the (\mathbb{Q}) -Brownian motion

$$\begin{aligned} Z_t^\mathbb{Q} &= Z_t + \int_0^t \sqrt{Y_s} ds. \end{aligned}$$

(A.10)

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$$L^{\ast}=\frac{L_{\mathrm{T}}}{\eta}=\frac{\frac{d\hat{\mathbb{L}}}{d\mathbb{P}}}{\frac{d\mathbb{Q}}{d\mathbb{P}}}=\frac{d\hat{\mathbb{L}}}{d\mathbb{Q}}, \quad \text{\texttt{\textbackslash end{aligned}}}$$

$$\begin{aligned} L_{\{T\}}^* &= \frac{L_{\{T\}}}{\eta} = \exp \left(a \int_{\{0\}}^{\{T\}} \sqrt{Y_{\{s\}}} dZ_{\{s\}} - \frac{a^2}{2} \int_{\{0\}}^{\{T\}} Y_{\{s\}} ds + \int_{\{0\}}^{\{T\}} \sqrt{Y_{\{s\}}} dZ_{\{s\}} + \frac{1}{2} \int_{\{0\}}^{\{T\}} Y_{\{s\}} ds \right) \\ &= \exp \left(\left(a+1 \right) \int_{\{0\}}^{\{T\}} \sqrt{Y_{\{s\}}} dZ_{\{s\}} + \frac{1-a^2}{2} \int_{\{0\}}^{\{T\}} Y_{\{s\}} ds \right) \end{aligned}$$

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$$\int_0^t \sqrt{Y_s} ds \quad \text{quad} \quad \left(\text{hbox {with } } a+1=\frac{1}{\phi} \right) ,$$

$$\end{aligned} \} \}$$

that proves the lemma. \square

Lemma A.2

Let (M_t) be the $(\hat{\mathbb{Q}})$ -martingale defined in (A.6), namely

$$\begin{aligned} M_t &= e^{\frac{a^2+a}{2} \int_0^t Y_s ds} e^{Y_t g(T-t)}. \end{aligned}$$

Then we have

$$\begin{aligned} dM_t &= 2\sqrt{c\phi Y_t} M_t g(T-t) d\hat{Z}_t \\ &= 2\sqrt{c\phi Y_t} M_t g(T-t) \left(dZ_t + \hat{\mathbb{Q}}_t \right). \end{aligned}$$

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is the value at time T of a self-financing discounted portfolio, which admits the following representation under (\mathbb{Q})

$$\begin{aligned} \tilde{W}^* &= w + \int_0^T \psi_t^* \frac{d\tilde{P}_t}{\tilde{P}_t} = w + \int_0^T \frac{\xi_t \psi_t^*}{\sqrt{Y_t}} dZ_t^{\mathbb{Q}} \end{aligned}$$

(A.13)

since $(d\tilde{P}_t = \tilde{P}_t \sqrt{Y_t} \sigma_t dt + \tilde{P}_t \sigma_t dZ_t = \tilde{P}_t \frac{\xi_t}{\sqrt{Y_t}} dZ_t^{\mathbb{Q}})$ from (2.1) and (A.10).

Therefore, we look for the Ito representation of $(\tilde{W}^*(t) = E^{\mathbb{Q}}[\tilde{W}^*(T) | \mathcal{F}_t])$ to derive $(\psi^*(t))$

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$$\begin{aligned} \{\tilde{W}\}_t^* &= E^{\mathbb{Q}} \left[\left. \frac{\eta}{\phi} \right| \mathcal{F}_t \right] \\ &= \frac{w}{E \left[\left. \eta^{\frac{1-\phi}{\phi}} \right| \mathcal{F}_t \right]} E^{\mathbb{Q}} \left[\left. \eta^{\frac{1-\phi}{\phi}} \right| \mathcal{F}_t \right] \\ &= \frac{w}{G(T,y)} L_t^* M_t \end{aligned}$$

because $(G(T,y)=\left(F(T,y)\right) ^{\frac{1}{\phi }}=\{E\left[\eta ^{-\frac{1-\phi }{\phi }}\right] .\})$ It follows that the differential of the (\mathbb{Q}) -martingale $(\{\tilde{W}\}_t^*)$ is given by

$$\begin{aligned} d\{\tilde{W}\}_t^* &= \frac{w}{G(T,y)} d\left(L_t^* M_t \right) \\ &= \frac{w}{G(T,y)} L_t^* M_t \left[\frac{1}{\phi } \left(\frac{1}{\phi } \right) \right] \end{aligned}$$

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Cite this article

Battauz, A., De Donno, M. & Sbuelz, A. Reaching nirvana with a defaultable asset?. *Decisions Econ Finan* **40**, 31–52 (2017). <https://doi.org/10.1007/s10203-017-0192-x>

Received

07 October 2016

Issue Date

November 2017

DOI

Accepted

18 May 2017

Published

01 June 2017

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