Risk Aversion and the Labor Margin in Dynamic Equilibrium Models

Eric T. Swanson

Economic Research
Federal Reserve Bank of San Francisco

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Coefficient of Relative Risk Aversion

Suppose a household has preferences:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t),$$

$$u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \eta l_t$$

What is the household’s coefficient of relative risk aversion?
Coefficient of Relative Risk Aversion

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\[ u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \eta l_t \]

What is the household’s coefficient of relative risk aversion?

Answer: 0
Suppose the household has preferences:

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$$u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \eta \frac{l_t^{1+\chi}}{1+\chi}$$

What is the household’s coefficient of relative risk aversion?

Answer: \( \frac{1}{\frac{1}{\gamma} + \frac{1}{\chi}} \)
Outline of Presentation

- Define risk aversion rigorously in dynamic equilibrium models
- Derive closed-form expressions
- Show the labor margin has dramatic effects on risk aversion
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See the paper for:
- Epstein-Zin preferences
- internal, external habits
- asset pricing details
- numerical computations
A Household

Household preferences:

\[ E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} u(c_\tau, l_\tau), \]

Flow budget constraint:

\[ a_{\tau+1} = (1 + r_\tau) a_\tau + w_\tau l_\tau + d_\tau - c_\tau, \]

No-Ponzi condition:

\[ \lim_{T \to \infty} \prod_{\tau=t}^{T} (1 + r_{\tau+1})^{-1} a_{\tau+1} \geq 0, \]

\( \{ w_\tau, r_\tau, d_\tau \} \) are exogenous processes, governed by \( \theta_\tau \)
The Value Function

State variables of the household’s problem are \((a_t; \theta_t)\).

Let:

\[
c_t^* \equiv c^*(a_t; \theta_t),
\]
\[
l_t^* \equiv l^*(a_t; \theta_t).
\]
The Value Function

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Let:

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\begin{align*}
c_t^* & \equiv c^*(a_t; \theta_t), \\
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\end{align*}
\]

Value function, Bellman equation:

\[
V(a_t; \theta_t) = u(c_t^*, l_t^*) + \beta E_t V(a_{t+1}^*; \theta_{t+1}),
\]

where:

\[
a_{t+1}^* \equiv (1 + r_t)a_t + w_t l_t^* + d_t - c_t^*.
\]
Assumption 1. *The function* \( u(c_t, l_t) \) *is increasing in its first argument, decreasing in its second, twice-differentiable, and strictly concave.*

Assumption 2. *The value function* \( V : X \to \mathbb{R} \) *for the household’s optimization problem exists and satisfies the Bellman equation*

\[
V(a_t; \theta_t) = \max_{(c_t, l_t) \in \Gamma(a_t; \theta_t)} u(c_t, l_t) + \beta E_t V(a_{t+1}; \theta_{t+1}).
\]

Assumption 3. *For any* \((a_t; \theta_t) \in X\), *the household’s optimal choice* \((c^*_t, l^*_t)\) *lies in the interior of* \(\Gamma(a_t; \theta_t)\).

Assumption 4. *The value function* \( V(\cdot; \cdot) \) *is twice-differentiable. (It then follows that* \(c^*, l^*\) *are differentiable.*)
Assumptions about the Economic Environment

Assumption 5. *The household is atomistic.*

Assumption 6. *The household is representative.*

Assumption 7. *The model has a nonstochastic steady state, \( x_t = x_{t+k} \) for \( k = 1, 2, \ldots \), and \( x \in \{c, l, a, w, r, d, \theta\} \).
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Assumption 7′. *The model has a balanced growth path that can be renormalized to a nonstochastic steady state after a suitable change of variables.*
Compare:

\[ E \ u(c + \sigma \varepsilon) \quad \text{vs.} \quad u(c - \mu) \]
Arrow-Pratt in a Static One-Good Model (Review)

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\[ E \, u(c + \sigma \varepsilon) \, \text{ vs. } \, u(c - \mu) \]

Compute:

\[ u(c - \mu) \approx u(c) - \mu u'(c), \]
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Compute:

\[ u(c - \mu) \approx u(c) - \mu u'(c), \]

\[ E \ u(c + \sigma \varepsilon) \approx u(c) + u'(c) \sigma E[\varepsilon] + \frac{1}{2} u''(c) \sigma^2 E[\varepsilon^2], \]
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\[ \mu = \frac{-u''(c)}{u'(c)} \frac{\sigma^2}{2}. \]
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Coefficient of absolute risk aversion is defined to be:

\[ \lim_{\sigma \to 0} \frac{2 \mu(\sigma)}{\sigma^2} = \frac{-u''(c)}{u'(c)}. \]
Arrow-Pratt in a Dynamic Model

Consider a one-shot gamble in period \( t \):

\[
a_{t+1} = (1 + r_t) a_t + w_t l_t + d_t - c_t + \sigma \epsilon_{t+1},
\]

(\*)

Note we cannot easily consider gambles over:

- \( a_t \) (state variable, already known at \( t \))
- \( c_t \) (choice variable)

Note also (\*) is equivalent to gambles over income:

\[
a_{t+1} = (1 + r_t) a_t + w_t l_t + (d_t + \sigma \epsilon_{t+1}) - c_t,
\]

or asset returns:

\[
a_{t+1} = (1 + r_t + \sigma \tilde{\epsilon}_t) a_t + w_t l_t + d_t - c_t,
\]

Note connection to asset pricing.
Arrow-Pratt in a Dynamic Model

Consider a one-shot gamble in period $t$:

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Consider a one-shot gamble in period $t$:

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vs.

$$a_{t+1} = (1 + r_t)a_t + w_t l_t + d_t - c_t - \mu.$$
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Welfare loss from $\mu$:

$$V_1(a_t; \theta_t) \frac{\mu}{(1 + r_t)}$$
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Arrow-Pratt in a Dynamic Model

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Welfare loss from $\mu$:

$$\beta E_t V_1(a^*_t; \theta_{t+1}) \mu.$$

Loss from $\sigma$:

$$\beta E_t V_{11}(a^*_t; \theta_{t+1}) \frac{\sigma^2}{2}.$$
Proposition 1. The household’s coefficient of absolute risk aversion at \((a_t; \theta_t)\) is given by:

\[-\frac{E_t V_{11}(a^*_{t+1}; \theta_{t+1})}{E_t V_1(a^*_{t+1}; \theta_{t+1})}.
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Proposition 1. The household’s coefficient of absolute risk aversion at \((a_t; \theta_t)\) is given by:

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Coefficient of Absolute Risk Aversion

**Proposition 1.** *The household’s coefficient of absolute risk aversion at \((a_t; \theta_t)\) is given by:*

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- \frac{E_t V_{11}(a_{t+1}^*; \theta_{t+1})}{E_t V_1(a_{t+1}^*; \theta_{t+1})}.
\]

*Evaluated at the nonstochastic steady state, this simplifies to:*

\[
- \frac{V_{11}(a; \theta)}{V_1(a; \theta)}.
\]

Solve for $V_1$ and $V_{11}$

Benveniste-Scheinkman:

$$V_1(a_t; \theta_t) = (1 + r_t) u_1(c^*_t, l^*_t).$$  \hfill (\ast)
Solve for $V_1$ and $V_{11}$

Benveniste-Scheinkman:

$$V_1(a_t; \theta_t) = (1 + r_t) u_1(c^*_t, l^*_t).$$ \hfill (\star)

Differentiate (\star) to get:

$$V_{11}(a_t; \theta_t) = (1 + r_t) \left[ u_{11}(c^*_t, l^*_t) \frac{\partial c^*_t}{\partial a_t} + u_{12}(c^*_t, l^*_t) \frac{\partial l^*_t}{\partial a_t} \right].$$
Solve for $\frac{\partial l^*_t}{\partial a_t}$ and $\frac{\partial c^*_t}{\partial a_t}$

Household intratemporal optimality: $-u_2(c^*_t, l^*_t) = w_t u_1(c^*_t, l^*_t)$. 
Solve for $\partial l_t^*/\partial a_t$ and $\partial c_t^*/\partial a_t$

Household intratemporal optimality: $-u_2(c_t^*, l_t^*) = w_t u_1(c_t^*, l_t^*)$.

Differentiate to get:

$$\frac{\partial l_t^*}{\partial a_t} = -\lambda_t \frac{\partial c_t^*}{\partial a_t},$$

$$\lambda_t \equiv \frac{w_t u_{11}(c_t^*, l_t^*) + u_{12}(c_t^*, l_t^*)}{u_{22}(c_t^*, l_t^*) + w_t u_{12}(c_t^*, l_t^*)}.$$
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Use Euler equation and budget constraint to derive:

$$\frac{\partial c_t^*}{\partial a_t} = \frac{r}{1 + w\lambda}.$$
Solve for Coefficient of Absolute Risk Aversion

\[ V_1(a; \theta) = (1 + r) u_1(c, l), \]
Solve for Coefficient of Absolute Risk Aversion

\[ V_1(a; \theta) = (1 + r) u_1(c, l), \]

\[ V_{11}(a; \theta) = (1 + r) \left[ u_{11}(c, l) \frac{\partial c^*_t}{\partial a_t} + u_{12}(c, l) \frac{\partial l^*_t}{\partial a_t} \right], \]
Solve for Coefficient of Absolute Risk Aversion

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\[ \frac{\partial l^*_t}{\partial a_t} = -\lambda \frac{\partial c^*_t}{\partial a_t}, \]

\[ \frac{\partial c^*_t}{\partial a_t} = \frac{r}{1 + w\lambda}. \]
Solve for Coefficient of Absolute Risk Aversion

\[ V_1(a; \theta) = (1 + r) u_1(c, l), \]

\[ V_{11}(a; \theta) = (1 + r) \left[ u_{11}(c, l) \frac{\partial c^*}{\partial a_t} + u_{12}(c, l) \frac{\partial l^*}{\partial a_t} \right], \]

\[ \frac{\partial l^*}{\partial a_t} = -\lambda \frac{\partial c^*}{\partial a_t}, \]

\[ \frac{\partial c^*}{\partial a_t} = \frac{r}{1 + w\lambda}. \]

**Proposition 2.** The household’s coefficient of absolute risk aversion in Proposition 1, evaluated at steady state, satisfies:

\[ \frac{- V_{11}(a; \theta)}{V_1(a; \theta)} = -\frac{u_{11}}{u_1} + \frac{\lambda u_{12}}{1 + w\lambda} \frac{r}{1 + w\lambda}. \]
Consider Arrow-Pratt gamble of general size $A_t$:

$$a_{t+1} = (1 + r_t) a_t + w_t l_t + d_t - c_t + A_t \sigma \varepsilon_{t+1},$$

vs.

$$a_{t+1} = (1 + r_t) a_t + w_t l_t + d_t - c_t - A_t \mu.$$
Consider Arrow-Pratt gamble of general size $A_t$:

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$$a_{t+1} = (1 + r_t)a_t + w_t l_t + d_t - c_t - A_t \mu.$$

Risk aversion coefficient for this gamble:

$$- \frac{A_t E_t V_{11}(a^*_{t+1}; \theta_{t+1})}{E_t V_1(a^*_{t+1}; \theta_{t+1})} \quad (*)$$

A natural benchmark for $A_t$ is household wealth at time $t$. 

Relative Risk Aversion
Consider Arrow-Pratt gamble of general size $A_t$:

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A natural benchmark for $A_t$ is household wealth at time $t$. 
Household Wealth

In DSGE framework, household wealth has more than one component:

- present value of labor income, $w_t l_t$
- present value of net transfers, $d_t$
- present value of leisure, $w_t (\bar{l} - l_t)$
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- present value of labor income, $w_t l_t$
- present value of net transfers, $d_t$
- present value of leisure, $w_t (\bar{l} - l_t)$?

Leisure, in particular, can be hard to define, e.g.,

$$u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \eta \frac{l_t^{1+\chi}}{1+\chi}$$

and $\bar{l}$ is arbitrary.
Household Wealth

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and $\bar{l}$ is arbitrary.

Different definitions of household wealth lead to different definitions of relative risk aversion.
Two Coefficients of Relative Risk Aversion

**Definition 1.** *The consumption-based coefficient of relative risk aversion is given by (\(*\)), with* \( A_t \equiv (1 + r_t)^{-1} E_t \sum_{\tau=t}^{\infty} m_{t, \tau} c_\tau^* \).

In steady state:

\[
- \frac{A V_{11}(a; \theta)}{V_1(a; \theta)} = \frac{-u_{11} + \lambda u_{12}}{u_1} c \frac{c}{1 + w \lambda}.
\]
Two Coefficients of Relative Risk Aversion

Definition 1. The consumption-based coefficient of relative risk aversion is given by $(*)$, with $A_t \equiv (1 + r_t)^{-1} E_t \sum_{\tau=t}^{\infty} m_{t,\tau} c^*_\tau$.

In steady state:

$$-A \frac{V_{11}(a; \theta)}{V_1(a; \theta)} = -u_{11} + \lambda u_{12} \frac{c}{1 + w\lambda}.$$ 

Definition 2. The consumption-and-leisure-based coefficient of relative risk aversion is given by $(*)$, with $\tilde{A}_t \equiv (1 + r_t)^{-1} E_t \sum_{\tau=t}^{\infty} m_{t,\tau} (c^*_\tau + w_{\tau}(\bar{l} - l^*_\tau))$.

In steady state:

$$-\tilde{A} \frac{V_{11}(a; \theta)}{V_1(a; \theta)} = -u_{11} + \lambda u_{12} \frac{c + w(\bar{l} - l)}{1 + w\lambda}.$$
Example 1

Utility kernel:

\[ u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \eta \frac{l_t^{1+\chi}}{1+\chi} \]
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Consumption-based coefficient of relative risk aversion is:

\[ \frac{-u_{11} + \lambda u_{12}}{u_1} \frac{c}{1 + w\lambda} \]
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Utility kernel:

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Consumption-based coefficient of relative risk aversion is:

\[ \frac{-u_{11} + \lambda u_{12}}{u_1} \frac{c}{1 + w\lambda} = \frac{-c u_{11}}{u_1} \frac{1}{1 + w\lambda} \]
Example 1

Utility kernel:

\[ u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1 - \gamma} - \eta \frac{l_t^{1+\chi}}{1 + \chi} \]

Consumption-based coefficient of relative risk aversion is:

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\[ = \gamma \frac{1}{1 + \gamma/\chi} \]
Example 1

Utility kernel:

\[ u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \eta \frac{l_t^{1+\chi}}{1+\chi} \]

Consumption-based coefficient of relative risk aversion is:

\[
\frac{-u_{11} + \lambda u_{12}}{u_1} \frac{c}{1 + w\lambda} = \frac{-cu_{11}}{u_1} \frac{1}{1 + w\lambda} = \gamma \frac{1}{\frac{1}{\gamma} + \frac{1}{\chi}}
\]
Example 1

Coefficient of relative risk aversion

\( \chi = 0 \)
\( \chi = 1 \)
\( \chi = 2 \)
\( \chi = 3 \)
\( \chi = 4 \)
\( \chi = 5 \)
\( \chi = \infty \)
Risk Aversion Away from the Steady State

Utility:

\[ u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \eta \frac{l_t^{1+\chi}}{1+\chi} \quad \gamma = 2, \chi = 1.5 \]
Risk Aversion Away from the Steady State

Utility:

\[ u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \eta \frac{l_t^{1+\chi}}{1+\chi} \]

\[ \gamma = 2, \quad \chi = 1.5 \]

Plus standard RBC model, solved numerically:
Risk Aversion Away from the Steady State

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\[ u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \eta \frac{l_t^{1+\chi}}{1+\chi} \]

\[ \gamma = 2, \quad \chi = 1.5 \]

Plus standard RBC model, solved numerically:
Risk Aversion and the Equity Premium ($\gamma = 200$)

![Graph showing the relationship between risk aversion and the equity premium. The x-axis represents the coefficient of relative risk aversion ($R_c$), and the y-axis represents the equity premium in percentage per annum. The graph illustrates how the equity premium increases with increasing risk aversion.]
Conclusions

1. The labor margin has dramatic effects on risk aversion

2. Risk aversion is the right concept for asset pricing, $E_t m_{t+1} p_{t+1}$

3. Arrow-Pratt risk neutrality holds for any $u$ with $u_{11} u_{22} - u_{12}^2 = 0$

4. Risk aversion and the intertemporal elasticity of substitution are nonreciprocal when there is labor in the model

5. Simple, closed-form expressions for risk aversion in DSGE models with:
   - expected utility preferences
   - Epstein-Zin preferences
   - external or internal habits
   - valid away from steady state