Comparative Valuation Dynamics in Models with Financing Restrictions

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Impulse problem

Ragnar Frisch (1933):

There are several alternative ways in which one may approach the impulse problem .... One way which I believe is particularly fruitful and promising is to study what would become of the solution of a determinate dynamic system if it were exposed to a stream of erratic shocks that constantly upsets the continuous evolution ...

Irving Fisher (1930):

The manner in which risk operates upon time preference will differ, among other things, according to the particular periods in the future to which the risk applies.
An asset pricing perspective on impulses and propagation

Imagine an impulse or shock $W_1$ that happens tomorrow.

▷ This shock has an impact on a macro time series or a cash flow at future times 1, 2, ... .
▷ Exposure in the future of the underlying time series to this shock requires compensation today, say time zero. The magnitude of the compensation or price depends on the date of the cash flow.
▷ Alternative shocks require different compensations or “prices”.
▷ Exposures to the uncertainty are state dependent.

Dynamic macroeconomic models imply impulse responses.

Dynamic models of asset prices imply compensations to shock exposures.
Outline

- Asset pricing perspective
- Impulse responses and shock elasticities
- VAR example
- Recursive utility example
- Market segmentation and financing frictions
Models of asset valuation

Two channels:

- **Stochastic growth** modeled as a process \( G = \{G_t\} \) where \( G_t \) captures growth between dates zero and \( t \).

- **Stochastic discounting** modeled as a process \( S = \{S_t\} \) where \( S_t \) assigns risk-adjusted prices to cash flows at date \( t \).

Date zero prices of a payoff \( G_t \) are

\[
\pi = E(S_t G_t | \mathcal{F}_0)
\]

where \( \mathcal{F}_0 \) captures current period information.

**Stochastic discounting** reflects investor preferences through the intertemporal marginal rate of substitution for *marginal* investors.
Risk-return tradeoffs

Dynamic asset pricing through altering cash flow exposure to shocks.

- Study implication on the price today of changing the exposure tomorrow on a cash flow at some future date.
- Represent shock price elasticities by normalizing the exposure and studying the impact on the logarithms of the expected returns.
- Construct pricing counterpart to impulse response functions.
Elasticities

Counterparts to impulse response functions pertinent to valuation:

- shock-exposure elasticities
- shock-price elasticities

These are the ingredients to risk premia, and they have a term structure induced by the changes in the investment horizons.

Hansen-Borovička (Handbook of Macroeconomics) with many references
Proportional risk premia

Recall: Date zero price of a payoff $G_t$ is

$$\pi = E(S_t G_t | F_0)$$

$$r_{prem} = \log E (G_t | F_0) - \log E (S_t G_t | F_0) + \log E (S_t | F_0)$$

log expected return minus log riskfree return

Trace out a risk-return frontier by changing payoff $G_t$ by altering the risk exposure. Characterize market compensations for risk exposure.
Discrete-time model

Ingredients:

- $W$ is a vector of shocks
- State evolution:
  \[ X_{t+1} = \psi(X_t, W_{t+1}) \]
- Multiplicative process $M$ evolution:
  \[ \log M_{t+1} - \log M_t = \phi(X_t, W_{t+1}) \]

Comments:

- $\log M$ has stationary increments
- Use $M$ to model stochastic discount factor $S$ and macroeconomic growth $G$. 
Special structure

- Shock vector $W_{t+1}$ is a multivariate standard normal
- $M$ evolution:

$$\log M_{t+1} - \log M_t = \beta_m(X_t) + \alpha_m(X_t) \cdot W_{t+1}$$
One-period shock elasticities

Parameterize a family of random variables $H_1 (r)$

$$\log H_1 (r) = r \eta (X_0) \cdot W_1 - \frac{r^2}{2} |\eta (X_0)|^2$$

where $r$ is an auxiliary scalar parameter. The vector of exposures is normalized to $|\eta(x)| = 1$.

By construction:

$$E [H_1 (r) |X_0] = 1.$$
Stochastic perturbations continued

- Form a parameterized family of payoffs $M_1 H_1 (r)$:

$$
\log M_1 - \log M_0 + \log H_1 (r) = \left[ \alpha_m (X_0) + r \eta (X_0) \right] \cdot W_1 + \beta_m (X_0) - \frac{r^2}{2} |\eta (X_0)|^2 .
$$

- $H_1$ changes the exposure of $M$ to $W_1$.

- $H_1$ changes the distribution of $W_1$ and hence $M$. Altered distribution of the shock $W_1$ is normal with mean $r \eta (x)$.

Both equivalent roles for $H_1$ are of interest.
Stochastic perturbations continued

○ Recall:

\[\log M_1 - \log M_0 + \log H_1 (r) = \left[ \alpha_m (X_0) + r \eta (X_0) \right] \cdot W_1 + \beta_m (X_0) - \frac{r^2}{2} | \eta (X_0) |^2.\]

○ Differentiate with respect to \( r \) and evaluate at \( r = 0 \) to obtain the one-period shock elasticity

\[\varepsilon_m (x, 1) = \frac{d}{dr} \log E \left[ \left( \frac{M_1}{M_0} \right) H_1 (r) \mid X_0 = x \right] \bigg|_{r=0} = \eta (x) \cdot E \left[ \left( \frac{M_1}{M_0} \right) W_1 \mid X_0 = x \right] = \eta (x) \cdot \alpha_m (x)\]
Shock elasticities

- The one-period shock elasticity

\[ \varepsilon_m(x, 1) = \frac{d}{dr} \log E \left[ \left( \frac{M_1}{M_0} \right) H_1(r) \mid X_0 = x \right] \bigg|_{r=0} = \alpha_m(x) \cdot \eta(x) \]

- The \( t \) period elasticity replaces \( M_1 \) with \( M_t \) but continues to use \( H_1(r) \):

\[ \varepsilon_m(x, t) = \frac{d}{dr} \log E \left[ \left( \frac{M_t}{M_0} \right) H_1(r) \mid X_0 = x \right] \bigg|_{r=0} = \eta(x) \cdot \frac{E \left[ \left( \frac{M_t}{M_0} \right) W_1 \mid X_0 = x \right]}{E \left[ \left( \frac{M_t}{M_0} \right) \mid X_0 = x \right]} \]
Regression interpretation

Regress

$$\frac{\left( \frac{M_t}{M_0} \right)}{E \left[ \left( \frac{M_t}{M_0} \right) \mid X_0 = x \right]}$$

onto

$$\eta(x) \cdot W_1$$

conditioned on $X_0 = x$.

An approximation to this regression is often performed taking logarithms of the left-hand side variable.
A second experiment and construction

Imagine an impulse or shock $W_1, W_2, \ldots$ that happens in the future.
- This shock has a state dependent impact on a macro time series or a cash flow at future times 1, 2, \ldots.
- Exposure in the future of the underlying time series to this shock requires compensation today, say time zero.
- Alternative shock dates require different compensations or “prices”.

\[
s_m(x, t) = \frac{d}{dr} \log E \left[ \left( \frac{M_t}{M_0} \right) H_t(r) \mid X_0 = x \right] \bigg|_{r=0}
= \eta(x) \cdot \frac{E \left[ \left( \frac{M_t}{M_0} \right) W_t \mid X_0 = x \right]}{E \left[ \left( \frac{M_t}{M_0} \right) \mid X_0 = x \right]}
\]
Shock elasticity types

○ Shock exposure

\[ \varepsilon_g (x, t) = \eta (x) \cdot \frac{E \left[ \left( \frac{G_t}{G_0} \right) W_1 \mid X_0 = x \right]}{E \left[ \left( \frac{G_t}{G_0} \right) \mid X_0 = x \right]} \]

○ Shock price

\[ \varepsilon_p (x, t) = \eta (x) \cdot \frac{E \left[ \left( \frac{G_t}{G_0} \right) W_1 \mid X_0 = x \right]}{E \left[ \left( \frac{G_t}{G_0} \right) \mid X_0 = x \right]} - \eta (x) \cdot \frac{E \left[ \left( \frac{S_t G_t}{S_0 G_0} \right) W_1 \mid X_0 = x \right]}{E \left[ \left( \frac{S_t G_t}{S_0 G_0} \right) \mid X_0 = x \right]} \]
Observations

- Continuous-time diffusion limits are well behaved
- Characterize long-term elasticity limits with martingale factorization
- Allow alternative shock distributions. An analogous approach applies but need to construct a meaningful way to denominate risk compensation
- Incorporate jump processes (continuous time) or Markov regime shift models (discrete time) with an interpretable perturbation and implied compensation
- Global compensations require weighted integrals
VAR example

- **State evolution**:
  \[ X_{t+1} = \bar{\mu}X_t + \bar{\sigma}W_{t+1}. \]
  where the absolute values of eigenvalues of the matrix \( \bar{\mu} \) are strictly less than one.

- **Multiplicative process evolution**:
  \[
  \log M_{t+1} - \log M_t = \bar{\nu} + \bar{\beta} \cdot X_t + \bar{\alpha} \cdot W_{t+1}. \quad (1)
  \]
  The shock \( W_{t+1} \) is distributed as a multivariate standard normal.

- **Impulse response recursions**:
  \[
  \bar{\varrho}_{t+1} - \bar{\varrho}_t = (\bar{\zeta}_t)' \bar{\beta}
  \]
  with initial condition \( \bar{\varrho}_1 = \bar{\alpha} \),
  \[
  \bar{\zeta}_{t+1} = \bar{\mu} \bar{\zeta}_t
  \]
  with initial condition \( \bar{\zeta}_1 = \bar{\sigma} \).
Shock elasticities (lognormal)

- Shock elasticities coincide with the impulses responses measured by $\bar{\eta} \cdot \bar{\varrho}_t$ for $t = 1, 2, \ldots$ where $\bar{\eta}$ selects the shock under consideration.

- Shock exposure elasticities are $\bar{\eta} \cdot \bar{\varrho}_g,t$ computed with $M = G$.

- Shock price elasticity consists of the difference of shock elasticities for $G$ and $SG$. The additivity of the construction implies that the shock-price elasticities are $-\bar{\eta} \cdot \bar{\varrho}_s,t$.

In contrast to nonlinear models, there is no scope for state dependence.
Recursive valuation

▷ Use a recursive utility model (see Koopmans, Kreps & Porteus, Epstein & Zin, …) to highlight how uncertainty about future events affects asset valuation.

▷ Explore ways in which expectations and uncertainty about future growth rates influence risky claims to consumption.

The *forward-looking* nature of the recursive utility model provides an additional channel through which *perceptions* about the future matter. (Bansal-Yaron and many others.)
Recursive utility

Consider the aggregator specified in terms of $C_t$ the current period consumption and $V_t$ the continuation value:

$$V_t = \left[ (C_t)^{1-\rho} + \exp(-\delta \epsilon) \left[ \mathcal{R}_t(V_{t+\epsilon}) \right]^{1-\rho} \right]^{\frac{1}{1-\rho}}$$

where

$$\mathcal{R}_t (V_{t+\epsilon}) = \left( E \left[ (V_{t+\epsilon})^{1-\gamma} | \mathcal{F}_t \right] \right)^{\frac{1}{1-\gamma}}$$

adjusts the continuation value $V_{t+\epsilon}$ for risk.

- $\frac{1}{\rho}$ is the elasticity of intertemporal substitution
- $\delta$ is a subjective discount rate
- $\epsilon$ is the decision interval
Stochastic discount factor

\[
\frac{S_{t+\epsilon}}{S_t} = \exp(-\delta\epsilon) \left( \frac{C_{t+\epsilon}}{C_t} \right)^{-\rho} \left[ \frac{V_{t+\epsilon}}{\mathcal{R}_t(V_{t+\epsilon})} \right]^\rho - \gamma
\]

- Continuation value gives a structured way to enhance the impact of the perceptions about the future.
- Special case: Power utility sets \( \rho = \gamma \).
- Multiply to compound over multiple periods.
Quantitative example

Long-run risk (Bansal-Yaron) reinterpreted as an AK model with adjustment costs.

\[ dZ_t^{[1]} = -0.021Z_t^{[1]} dt + \sqrt{Z_t^{[2]}} \begin{bmatrix} .031 & -0.015 & 0 \end{bmatrix} dW_t \]

\[ dZ_t^{[2]} = -0.013 \left( Z_t^{[2]} - 1 \right) dt + \sqrt{Z_t^{[2]}} \begin{bmatrix} 0 & 0 & -0.038 \end{bmatrix} dW_t \]

\[ dY_t = .01(0.15 + Z_t^{[1]} ) dt + .01 \sqrt{Z_t^{[2]}} \begin{bmatrix} .34 & .7 & 0 \end{bmatrix} dW_t \]

- \( Y_t \) is the logarithm of consumption;
- Process \( Z^{[1]} \) captures **predictability** in growth rates;
- Process \( Z^{[2]} \) captures **stochastic volatility**;
- Components of \( dW_t \):
  - Permanent shock;
  - Transitory shock;
  - Stochastic volatility shock.
Impulse responses

Bands depict .1 and .9 deciles.
Shock-price elasticities

Recursive utility and Power utility. Bands depict .1 and .9 deciles.
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Part of ongoing MFM project to create tools and repositories for model comparison
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Examine macroeconomic models with financial frictions

- “Macro-Finance”: general equilibrium models with aggregate risk
- “Frictions”: imperfect risk sharing
Introduction

Part of ongoing MFM project to create tools and repositories for model comparison

Examine macroeconomic models with financial frictions
- “Macro-Finance”: general equilibrium models with aggregate risk
- “Frictions”: imperfect risk sharing

Today: within this class, we study the one-dimensional, continuous-time models, e.g.,
- He and Krishnamurthy (2013)
- Brunnermeier and Sannikov (2014)
Part I

Overview of Simple Macro Models with Financial Frictions
Net worth evolutions

“Experts”

\[ dn_{e,t} = (n_{e,t}r_t - c_{e,t})dt + q_t k_{e,t} (dR_{e,t}^k - r_t dt) \]

excess return on assets

\[ - (1 - \chi_t)q_t k_{e,t} (dR_{t}^{equity} - r_t dt), \quad k_{e,t} \geq 0. \]

returns paid to outside equity

“Households”

\[ dn_{h,t} = (n_{h,t}r_t - c_{h,t})dt + q_t k_{h,t} (dR_{h,t}^k - r_t dt) \]

excess return on assets

\[ + \theta_{h,t} (dR_{t}^{equity} - r_t dt), \quad k_{h,t} \geq 0, \quad dR_{h,t}^k < dR_{e,t}^k. \]

outside excess returns
Balance sheets

Experts

Physical Capital
$q_t k_{e,t} dR_{e,t}$

Riskless Debt
$(\chi_t q_t k_{e,t} - n_{e,t}) r_t dt$

Outside Equity
$(1 - \chi_t) q_t k_{e,t} dR_{\text{equity}}$

Expert Net Worth

Households

Riskless Debt
$(n_{h,t} - q_t k_{h,t} - \theta_{h,t}) r_t dt$

Outside Equity
$\theta_{h,t} dR_t^{\text{equity}}$

Physical Capital
$q_t k_{h,t} dR_{h,t}^k$

Household Net Worth
Financial frictions
Experts must keep sufficient “skin in the game”.

Equity issuance constraint: \( \chi_t \geq \chi \)

Inability to hedge aggregate risks: asset risk exposure \( \chi_t \sigma_{R,t} dW_t \)
Financial frictions
Experts must keep sufficient “skin in the game”.

Equity issuance constraint: \( \chi_t \geq \chi \)

Inability to hedge aggregate risks: asset risk exposure \( \chi_t \sigma_{R,t} dW_t \)

Expert wealth share characterizes Markov equilibria:

\[
\chi_t := \frac{n_{e,t}}{n_{e,t} + n_{h,t}}.
\]

- Financial frictions become prominent when \( \chi_t \) is low.
- When \( \chi_t \rightarrow 1 \), these economies become frictionless.
Some example models

Basak and Cuoco (1998):

- No equity issuance... $\chi = 1$
- Households cannot buy capital... $k_{h,t} = 0$
Some example models

He and Krishnamurthy (2013):

- Partial equity issuance... $\chi \in (0, 1)$
- Households cannot buy capital... $k_{h,t} = 0$

![Diagram showing financial components for experts and households.](image)
Some example models

Brunnermeier and Sannikov (2014):
- No equity issuance... \( \chi = 1 \)
- Households can buy capital... \( k_{h,t} \geq 0 \)

Experts

Households

Physical Capital

\( q_t k_{e,t} dR_{e,t} \)

Riskless Debt

\( (\chi_t q_t k_{e,t} - n_{e,t}) r_t dt \)

Outside Equity

\( (1 - \chi_t) q_t k_{e,t} dR^\text{equity}_{e,t} \)

Expert Net Worth

Household Net Worth

Physical Capital

\( q_t k_{h,t} dR_{h,t} \)

Riskless Debt

\( (n_{h,t} - q_t k_{h,t} - \theta_{h,t}) r_t dt \)

Outside Equity

\( \theta_{h,t} dR^\text{equity}_{h,t} \)
Part II

Traditional Diagnostics
Local stochastic discount factor dynamics

\[ d \log S_t = - \left[ r(X_t) + \frac{1}{2} \sigma_S(X_t) \right] dt - \sigma_S(X_t) dW_t \]

\( \equiv \mu_S(X_t) \)
Local stochastic discount factor dynamics

\[
d \log S_t = - \left[ r(X_t) + \frac{1}{2} \sigma_S(X_t) \right] dt - \sigma S(X_t) dW_t \\
\equiv \mu_S(X_t)
\]

He-Krishnamurthy (2013)  
Brunnermeier-Sannikov (2014)
State variable dynamics

\[ dX_t = \mu_X(X_t) \, dt + \sigma_X(X_t) \, dW_t \]
State variable dynamics

\[ dX_t = \mu_X(X_t)dt + \sigma_X(X_t)dW_t \]

He-Krishnamurthy (2013)

Brunnermeier-Sannikov (2014)
He-Krishnamurthy (2013)

Brunnermeier-Sannikov (2014)
Part III

Shock Elasticities and Non-Linear IRFs
Uses of shock elasticities

Model diagnostic, a la IRFs

Summary of complex model dynamics and their interplay with the SDF

Empirical model comparisons
Shock-price elasticities.

Difference between “shock-exposure” and “shock-cost” elasticities.

A multiplicative process:

\[
d \log M_t = \beta_M(X_t)dt + \alpha_M(X_t)dW_t.\]

Shock elasticity:

\[
\varepsilon_M(t, x) := \frac{\mathbb{E}[M_t D_0 \log M_t \mid X_0 = x]}{\mathbb{E}[M_t \mid X_0 = x]}.
\]

Shock-price elasticity for cash flow \( \{G_t\} \):

\[
\varepsilon_G(t, x) - \varepsilon_{SG}(t, x).
\]
He-Krishnamurthy with log utility.
Constant shock-price elasticities and permanent shocks.

\[ \varepsilon_M(t, x) = \frac{\mathbb{E}[M_t D_0 \log M_t | X_0 = x]}{\mathbb{E}[M_t | X_0 = x]} \]

\[ \varepsilon_G(0, x) - \varepsilon_{SG}(0, x) = \sigma_S(x). \]

*Cash flow is the aggregate endowment \( G = C \):
\[ d \log C_t = [\mu_Y - \frac{1}{2} \sigma_Y^2] dt + \sigma_Y dW_t \]
He-Krishnamurthy with log utility.
Large martingale components can show up.

\[
\varsigma_M(t, x) = \frac{\mathbb{E}[M_t D_t \log M_t \mid X_0 = x]}{\mathbb{E}[M_t \mid X_0 = x]}
\]

\[
\varsigma_G(0, x) - \varsigma_{SG}(0, x) = \sigma_S(x).
\]

*Cash flow is the aggregate endowment \( G = C \):
\[
d \log C_t = \left[ \mu_Y - \frac{1}{2} \sigma_Y^2 \right] dt + \sigma_Y dW_t
\]
Brunnermeier-Sannikov with log utility.
Household capital purchases lead to “slow recovery” and prevent sky-high risk prices.

*Cash flow is aggregate consumption.*
Khorrami (2016) with log utility.

Similar to Basak and Cuoco (1998)...

- No expert equity issuance
- No household risk-bearing
Khorrami (2016) with log utility.

Similar to Basak and Cuoco (1998)...

- No expert equity issuance
- No household risk-bearing

Allow households to become experts by paying an entry cost:

\[ n_{h,t} \quad \text{wealth before entry} \]
\[ (1 - \phi)n_{e,t} \quad \text{wealth after entry} \]
Khorrami (2016) with log utility.

Similar to Basak and Cuoco (1998)...

- No expert equity issuance
- No household risk-bearing

Allow households to become experts by paying an entry cost:

\[ n_{h,t} \] \quad \text{wealth before entry}
\[ (1 - \phi) n_{e,t} \] \quad \text{wealth after entry}

Result: entry occurs when risk premia become sufficiently high (low \( X_t \)).
Khorrami (2016) with log utility.
Entry prevents crises and kills extreme dynamics.
Khorrami (2016) with log utility.
No crises shows up as lower average risk price under twisted measure.

![Graph showing second-type shock-price elasticity for $C_t$]

*Kash flow is the aggregate endowment.*
Khorrami (2016) with log utility.
No crises shows up as lower average risk price under twisted measure.

*Cash flow is the aggregate endowment.*
Khorrami (2016) with log utility.
With higher entry costs, we reintroduce crises.

\[ \phi = 0.6 \]

**second-type shock-price elasticity for** \( C_t \)

- **x = 10th percentile**
- **x = 50th percentile**
- **x = 90th percentile**

*Cash flow is the aggregate endowment.*
Khorrami (2016) with log utility.
With higher entry costs, we reintroduce crises.

\[ \phi = 0.6 \]

second-type shock-price elasticity for \( C_t \)

\[ \phi = 1 \]

second-type shock-price elasticity for \( C_t \)
Khorrami (2016) with log utility.

With higher entry costs, we reintroduce crises.

\[ \phi = 0.6 \]

second-type shock-price elasticity for \( C_t \)

\[ \phi = 1 \]

second-type shock-price elasticity for \( C_t \)

stationary density of \( X_t \)
Frictionless model (with heterogeneous RRA) has no crises and slow convergence.

Garleanu-Panageas (2015)

stochastic discount factor

![Stochastic Discount Factor](image)

- \( r(x) \) (red dashed line)
- \( \sigma_S(x) \) (blue line)

expert wealth share \( x \)

0 0.2 0.4 0.6 0.8 1
-0.2 0 0.2 0.4 0.6 0.8

Dynamics of \( X_t \)

![Dynamics of X_t](image)

- \( \mu_X(x) \) (red dashed line)
- \( \sigma_X(x) \) (blue line)

expert wealth share \( x \)

0 0.2 0.4 0.6 0.8 1
0 0.02 0.04 0.06 0.08 0.1

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Frictionless model (with heterogeneous RRA) has no crises and slow convergence.

Garleanu-Panageas (2015)

Brunnermeier-Sannikov (2014)
Garleanu and Panageas (2015). Frictionless model (with heterogeneous RRA) has no crises and slow convergence.

Garleanu-Panageas (2015)

He-Krishnamurthy (2013)
These features show up in the second type of shock-price elasticity.
These features show up in the second type of shock-price elasticity.

He-Krishnamurthy (2013)  
Brunnermeier-Sannikov (2014)
A few takeaways

Shock elasticities help show that...

- Current risk price shocks perceived as permanent in financial frictions models (flat shock-price elasticities of the first kind).

- Endogenous disaster risks that build over time have large long-horizon pricing implications (steeply increasing shock-price elasticities of the second kind).

- Models with “deleveraging” avoid disasters but have slow recoveries, and this shows up in the term structure of risk prices (flatter and slower convergence).

- Frictionless models featuring preference (or belief) heterogeneity share some properties with frictional models featuring deleveraging episodes.
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- Frictionless models featuring preference (or belief) heterogeneity share some properties with frictional models featuring deleveraging episodes.
Challenges and work-in-progress

- Different models parameterized differently
- Other shocks (e.g., uncertainty shocks where exposure builds)
- Heterogeneous SDFs (e.g., experts marginal in capital; households marginal in outside equity)
- More general utility functions

***Please download the code and play around with it!***
Challenges and work-in-progress

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