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A Structural Model Of Sovereign Credit Risk

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Sovereign Credit: A Problem or a Solution

- Sovereign credit is tightly connected to the development of global macro imbalances:
  - Extensive government borrowing builds up a substantial proportion of financier portfolios
  - Mounting government debt endangers sustainability of sovereign credit quality
  - Major financial institutions invested in sovereign debt see their balance sheets deteriorate
  - Consequently, increased macro uncertainty depresses the broader financial markets

- Sovereign credit is viewed as a lifeline to slumping economies:
  - Governments borrow to finance spending and support banks
  - Spending supports real economy
  - Supporting banks enables the flow of credit in the real economy

Sovereign Credit Risk: Foundation

- Governments collect taxes, borrow money, and expend funds on social benefit goods and services; some governments can print money
- Credit is the blood flow of the economy and the banking sector is the vessel system in which credit circulates
- Governments have an interest to keep the banking sector operational
  - If the banking sector stalls, so does the economy, and so do tax revenues
- Hence, governments have a contingent commitment in the lower tail of the financial sector performance
- In times of crisis, a large portion of banking assets are in relatively safer government securities
- The financial hardship of sovereigns and the banking system are two sides of the same event and the credit qualities of a government would be the aggregate qualities of the financial services sector.

Sovereign Credit Risk: Foundation (cont'd)

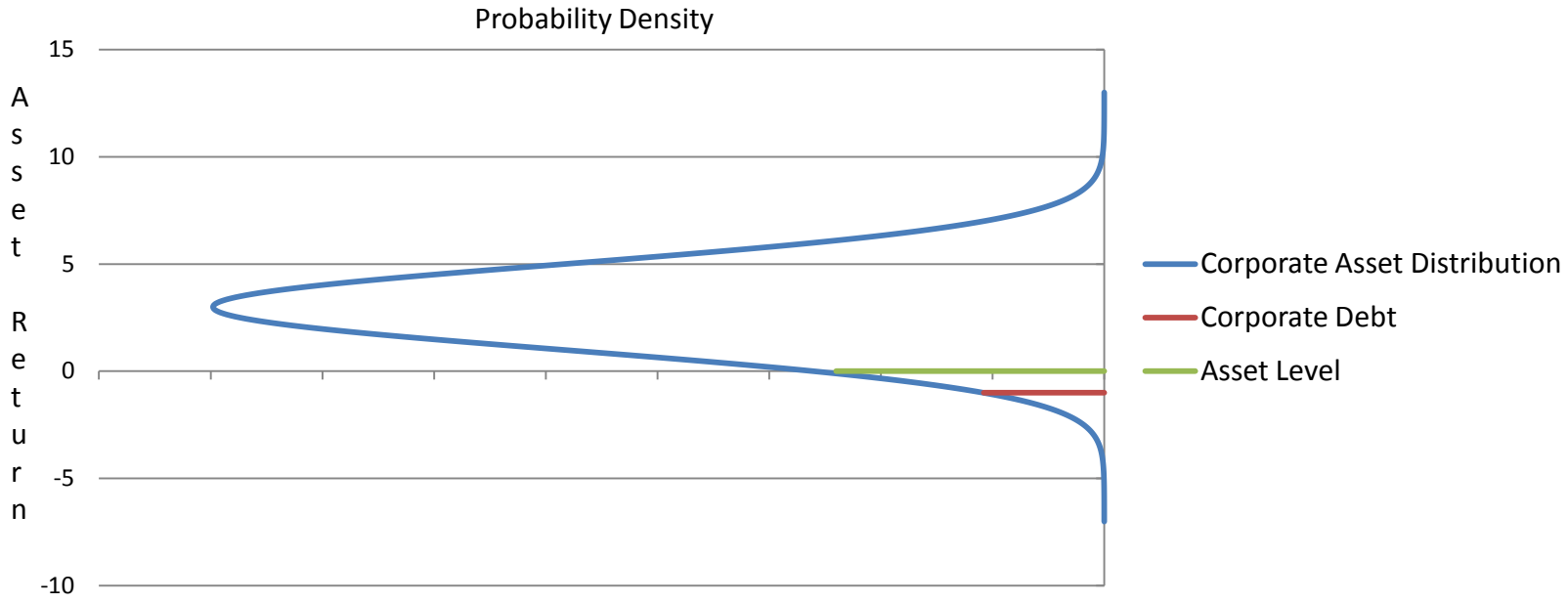
- Three ways Sovereigns can react to a crisis in the real / banking / government finance sector:

- Respond via fiscal means – increase taxation / divert tax revenues to prop banking capital and infrastructure investment *(Fiscally Responsive Sovereigns)*
  - Italy, 2011

- React "responsibly" with monetary means – increase supply of credit to support banking liquidity and assure sovereign financing *(Monetarily Responsive Sovereigns)*
  - United States, 2008-2011

- Engage in irresponsible money creation or ruthless default *(Rogue Sovereigns)*
  - Zimbabwe, 2001-2009

Analogy with Corporate Debt



Inputs to Credit Model: **σ** **Debt** **Asset Level**

Model States: $\beta_{bond} = \beta_{stock} * -(P_{stock} / P_{bond}) * (\Delta_{put} / \Delta_{call})$

Corollaries: ① LGD = P_{bond}* scalar; ② LGD & OAS ➔ Prob. Default

Existing Sovereign Structural Models in Theory

- **Type I:** Gray, Merton, Bodie (2006)
  - Models sovereign *assets* using implied asset volatility and level
  - Local currency and debt in local currency are akin sovereign equity
  - Foreign currency debt plays the role of strike price
  - Real and financial sector bailout entities and amounts are deterministic

  ❖ Implied inputs are relevant if a prior model can reproduce independently the observed market bond prices;
  ❖ The model assumes sovereign that can print money
  ❖ What if the severity of macro loss affects more bailout entities than expected

- **Type II:** Jeanneret (2008), Francois et al (2011)
  - Models sovereign *revenues* using explicit variables; default is considered when revenues fall under current debt service dues
  - Default occurs if renegotiation makes debt burden more costly; renegotiation split between local currency and foreign currency holders is based on a Nash equilibrium

  ❖ Revenue driven default does not consider the potential for future improvement
  ❖ Estimates of sanction size in "rational default decision" are subjective

Existing Models in Practice

- Based explicitly on CDS premiums
  - Theoretically ,CDS spreads should correspond to changing credit outlooks of underlying issuers; they could be used as a clear gauge for credit riskiness

  ❖ However, the thin CDS market make them suspect measures:
    ❖ 40% of sovereigns have less than one CDS trade per day (data: Kamakura Corporation)
    ❖ 93% of sovereigns have lass than six CDS trades per day
    ❖ Major issuers like US and Japan are among the most thinly traded
  ❖ A risk model vendor using CDS spreads in a risk model reports unintuitive negative correlation between bond credit spreads and CDS premiums for a range of issuers

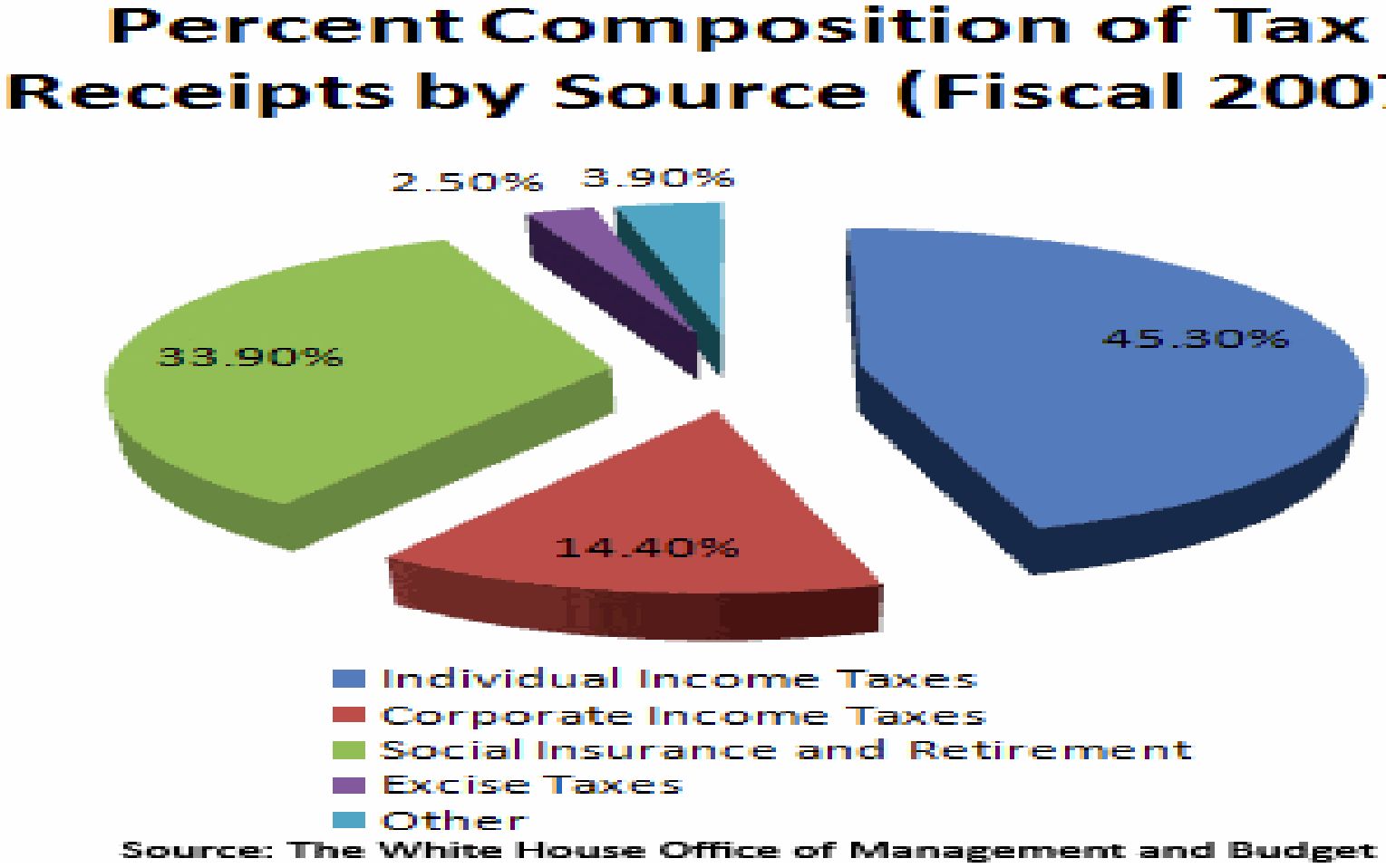
- Statistical on CDS spreads
  - Separates liquidity driven vol from macro drive credit vol, but

  ❖ Cannot separate liquidity driven vol from issuer specific credit vol
  ❖ The pure statistical nature of factors make them hard to interpret

Inputs to Sovereign Credit Model

- Asset Level is the sum of:
  - Domestic and foreign currency reserves, deposits in banks and receivables, commodities reserves, and others
  - The projected long term stream of taxes, fees, tariffs, exploration rights, all discounted to the present moment
- Given appropriate projections of GDP and its components – individual income, corporate income, and international trade, as well as established tax rates - we can find the second component
- What about Asset Volatility?

Inputs to Sovereign Credit Model (cont'd)



Inputs to Sovereign Credit Model (cont'd)

- **Sovereign Asset Volatility is very closely related to Stock Market Volatility**
- On one side
  - As net groups, companies are a relatively smaller number of providers and individuals are relatively larger number of price takers
  - Productivity growth gains (synonymous with GDP growth) accrue to capital owners
  - When economy shrinks, wages are rigid in downward direction, and brunt of the business loss is taken by capital owners
  - So, when economy booms, corporations accrue gains faster than individuals; when economy slumps, corporations accrue losses faster than individuals
- On the other side
  - Market Capitalization is the future corporate profit stream discounted to the present moment. A fixed tax rate applied to corporate profits results in the same volatility number for the corporation and the corporate tax stream
- **Consequently, volatility of the stock market puts an upper bound on sovereign asset volatility**

Inputs to Sovereign Credit Model (cont'd)

- Sovereign Asset Volatility continued:
  - Personal Income tax corresponds to approx. 80% of US federal tax revenue
  - Return on Personal Income is dependent on the same economic drivers as the stock market, but is exposed in a muted and lagged way for the reasons mentioned.
  - A lagged equation can link return on personal income to the risk model factors
  - Personal Income Tax stream then becomes just another "position" in the sovereign asset portfolio with known risk factor exposures
  - We can estimate σ for our default "option" model

Relationships of Revenues To Stock Market And the Economy

Spain:

Tax Revenue Proportional Changes with 1 period lag and GDP growth

Correlation: **0.72**, t-statistic: **3.69**

Worker's Compensation Proportional Changes with 1 period lag to the local market index

Correlation: **0.78**, t-statistic: **3.8**

Tax Revenue Proportional Changes with 1 period lag and S&P500

Correlation: **0.57**, t-statistic: **2.5**

Greece:

Tax Revenue Proportional Changes with 1 period lag and S&P500

Correlation: **0.84**, t-statistic: **5.4**

Statistics based on World Bank Data

GDP Projections and Demographics

- GDP discounted cash-flow model is the baseline for the sovereign asset level estimation
- Arnott and Chaves (2012) find a strong relationship between demographic variables (age group shares) and GDP growth
- Demographic trends are predictable out in the future with great degree of certainty. Today's 40 yr olds are next year's 41 yr olds.
- Demographics affect one more important input for the option default model– the strike price, or the level of debt
  - An aging population increases the dis-saving and divestment in "safe" assets, pushing down financial asset prices and increasing borrowing costs to the government, making debt service more onerous

Governments are Short the Bailout Put

- Governments need to keep the banking sector operational. Hence, governments have a contingent commitment in the lower tail of the financial sector performance

- The Crude Approach
- Banks are corporate entities. We can estimate PD of one corporate entity

- Any portfolio of 2 or more corporate bonds can be viewed as one bond of a holding company. Using the same techniques as for a single company debt we can estimate
  P (A U B) and hence P(A ∩ B). We can extend to any number of debtors (banks).

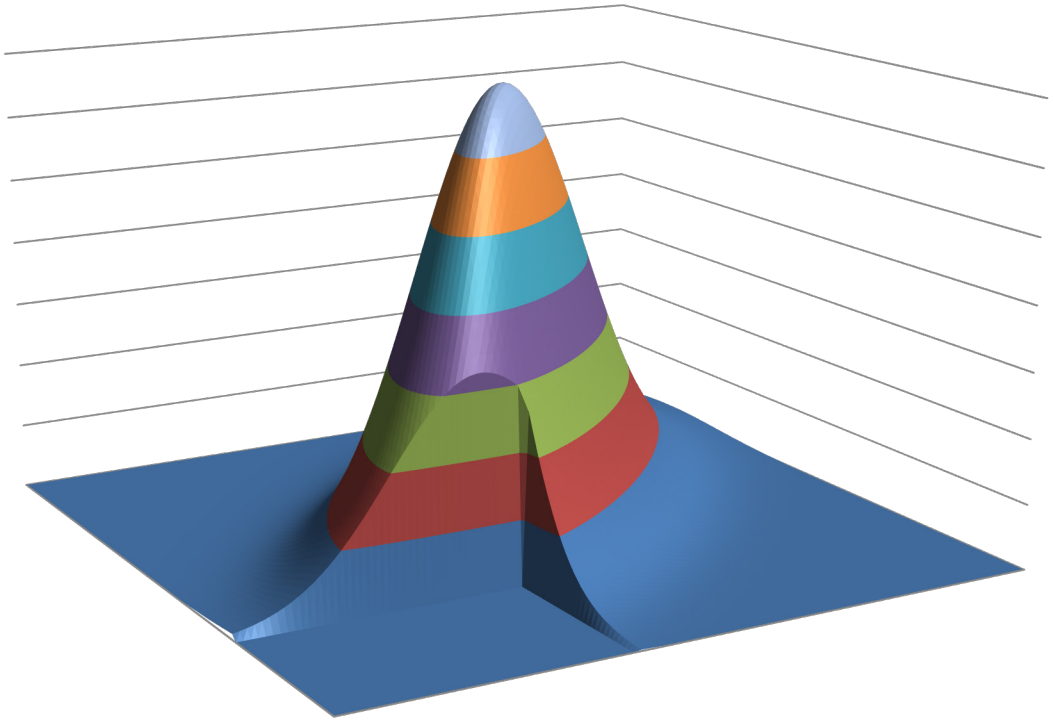
- The full set of various combinations of bank defaults (PD and LGD) in the sovereign jurisdiction result in a distribution of Default Losses.

- The distribution of sovereign assets without the Bailout Put gets modified by distribution of bank default losses. The results is a distribution reflective of the Bailout Put.

- We can develop an option-based model of the form: $\beta_{bond} = \beta_{asset} * f(\Delta_{default\_put}, \Delta_{default\_call})$

Distress zone

- The correlated expected tail loss on the bank side accumulates to the sovereign asset loss side at each density level, fattening the tail of the sovereign distribution



Types of Sovereign Credits

- Three ways in which Sovereigns can react to a crisis in the real / banking / government finance sector:
- Respond via fiscal means – increase taxation / divert tax revenues to prop banking capital and infrastructure investment *(Fiscally Responsive Sovereigns)*
- React "responsibly" with monetary means – increase supply of credit to support banking liquidity and assure sovereign financing *(Monetarily Responsive Sovereigns)*
- Engage in irresponsible money creation or ruthless default *(Rogue Sovereigns)*

Fiscally Responsive

- Governments are elected by taxpayers, not bondholders
- Consequently their priority is to save economy
- Credit outlook is supported in the long run, but shorter term credit quality takes back stage
- Action plans span a wide spectrum – from austerity support to “fiscal cliff” prevention

Fiscally Responsive (cont'd)

Put Value = $e^{-rt}\int_{-\infty}^{D}(D-x)p(x)dx$

$R^* = r + \beta R_M + R_S$

R^* - "risk-neutral" return; R_M – return on factor; R_S – asset specific return

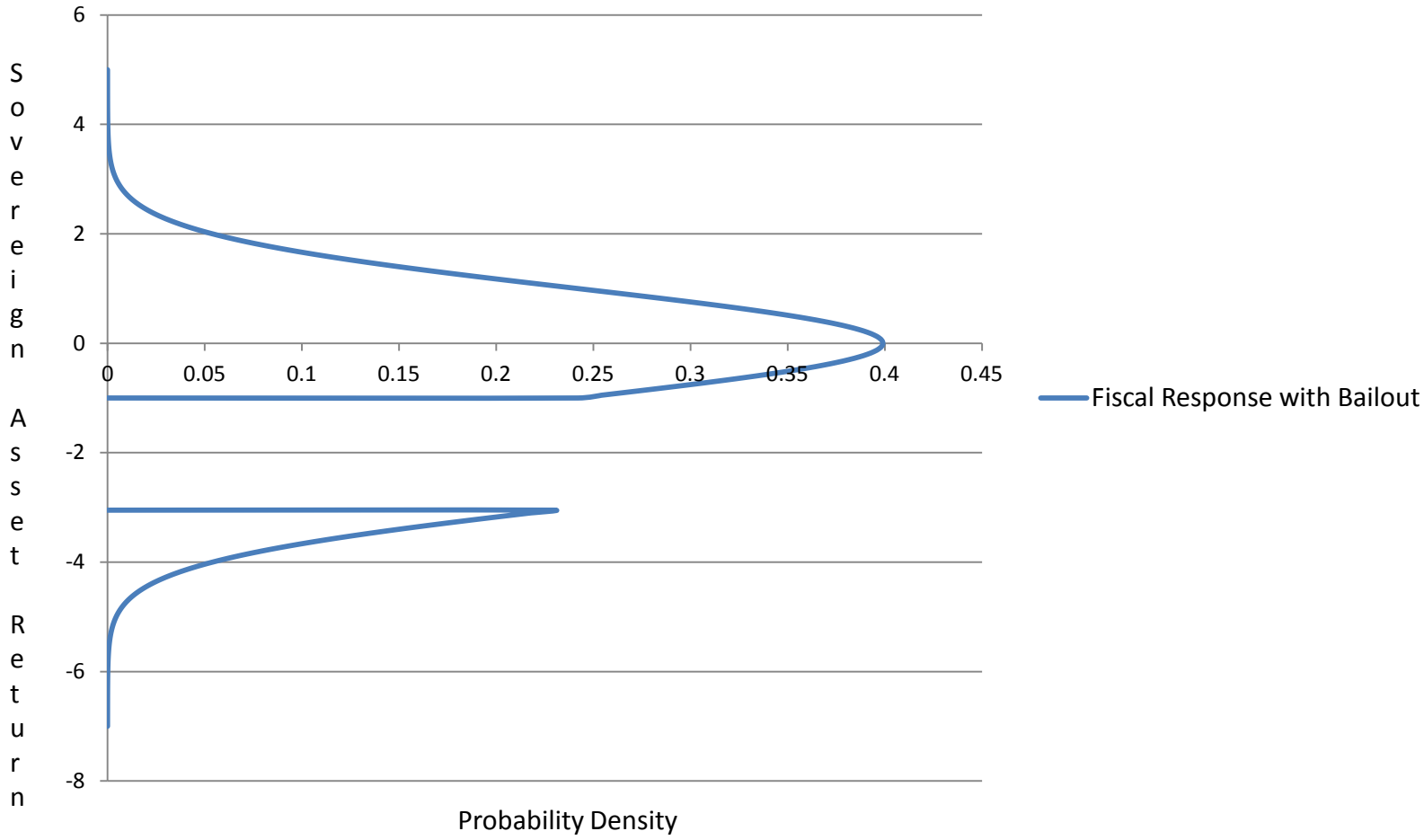
In the case of a Sovereign and a Single Bank bailout:

$$P = e^{-rt}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\max\left[0,(D - S_0e^{r+\beta R_M+R_S})\right]f_s(R_s|R_M)f_M(R_M)\partial R_s\,\partial R_M$$

In the case of a Sovereign and n – bank bailout:

$$P_{Sov\_FISC} = e^{-rt}\int_{-\infty}^{+\infty}\int\ldots\ldots\int_{-\infty}^{+\infty}\sum_{i=0}^{n}\max\left[0,(D - S_0e^{r+\beta R_M+R_{Si}})\right]\prod_{i=0}^{n}f_s(R_s|R_{sj>i},R_M)f_M(R_M)\partial R_{si}\ldots\partial R_{sn}\partial R_M$$

Fiscally Responsive (cont'd)



Monetarily Responsive

- Some governments are effectively able to control the amount of the national currency in circulation

- In times of crisis central banks have a similar objective and align their action with governments

- The “print” option is more subtle than tax hikes and does not require political approval

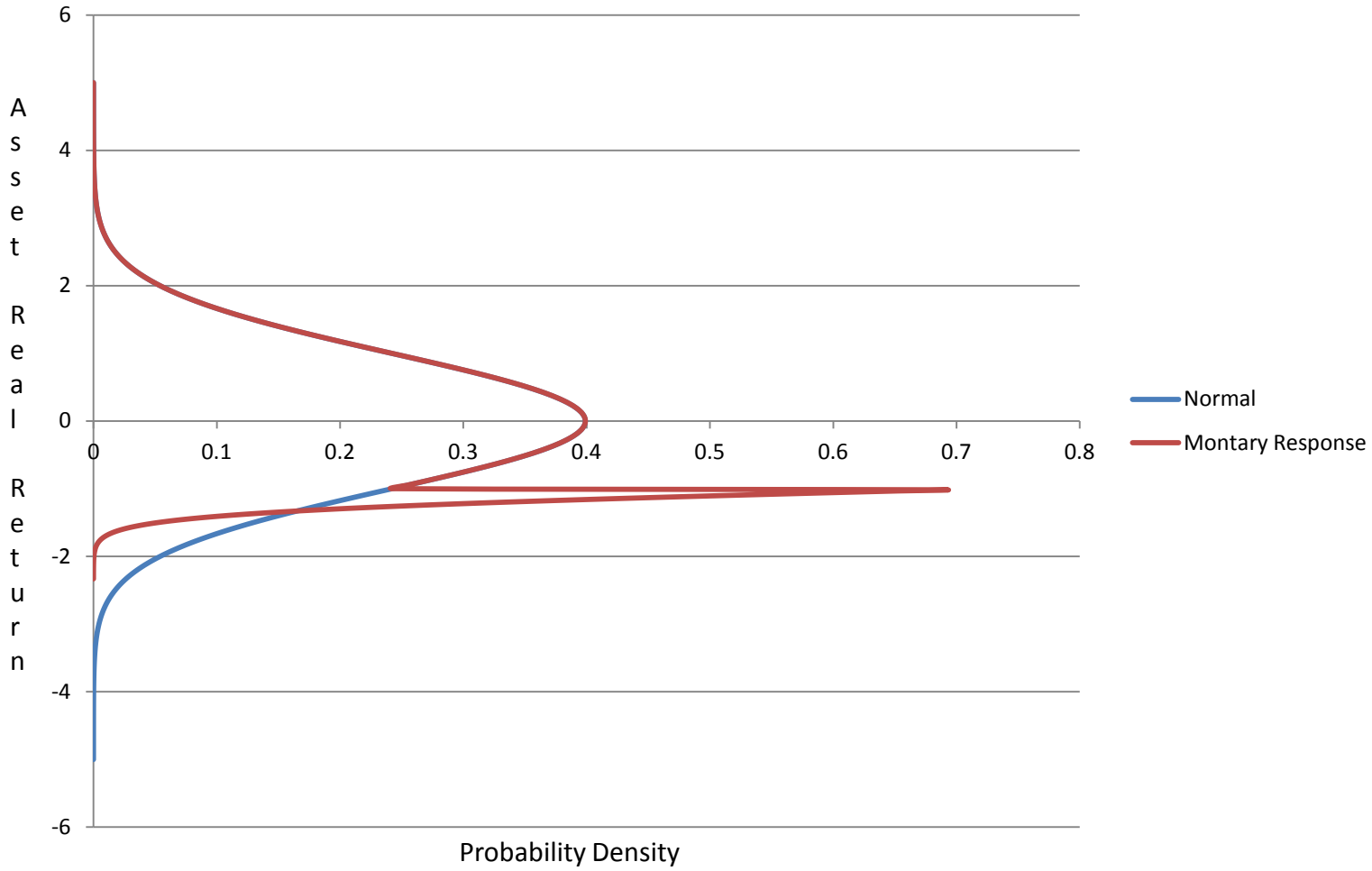
Monetarily Responsive (cont'd)

• The "print" scenario is also more advantageous to debt-holders as it spreads the credit loss with all users of the currency

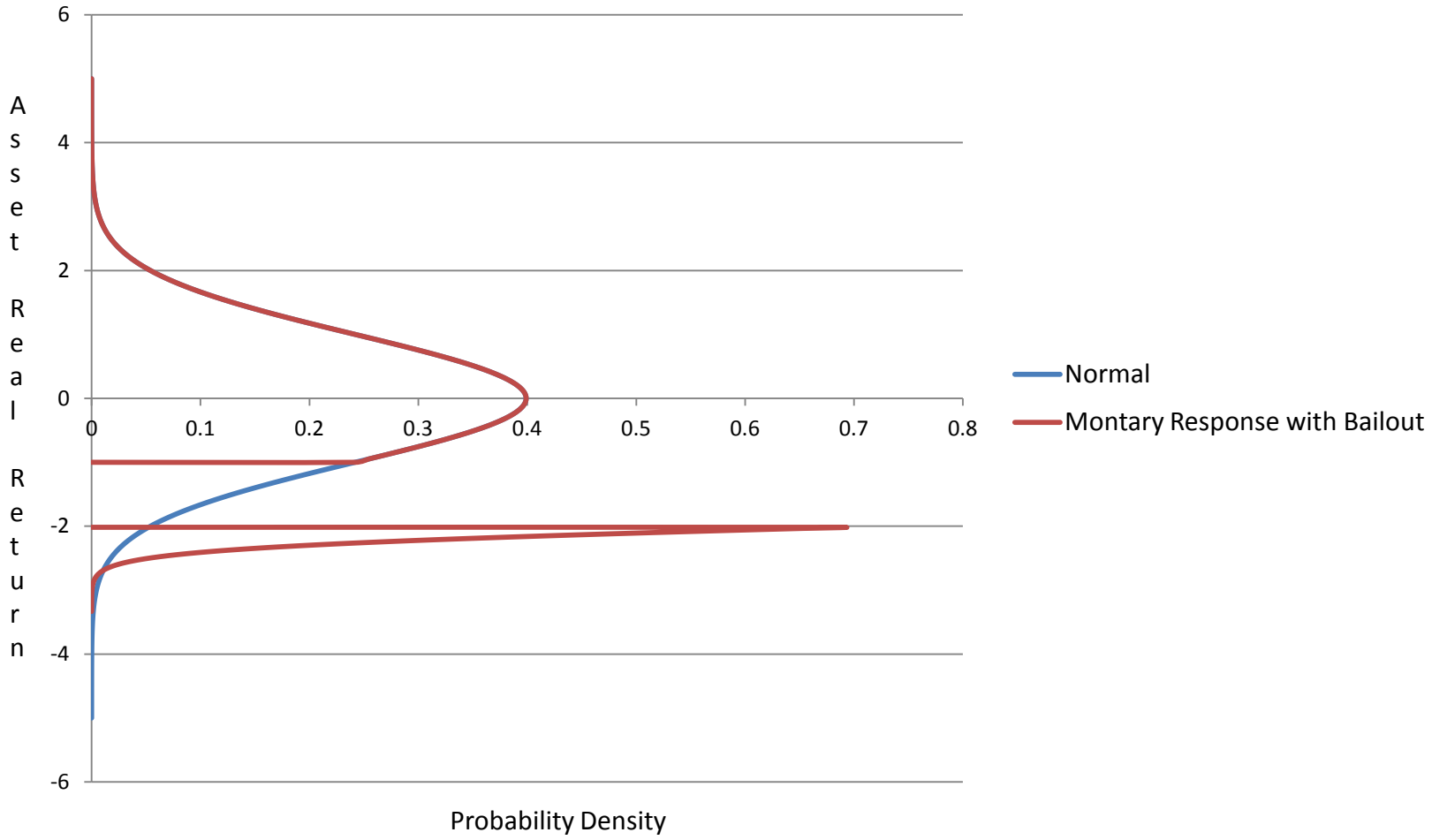
$P_{Sov} = (P_{Sov\_FISC} / MS) * P_{Sov\_FISC}$

MS - Money Supply in its narrowest definition - currency in circulation and cash equivalents.

Monetarily Responsive (cont'd)



Monetarily Responsive (cont'd)

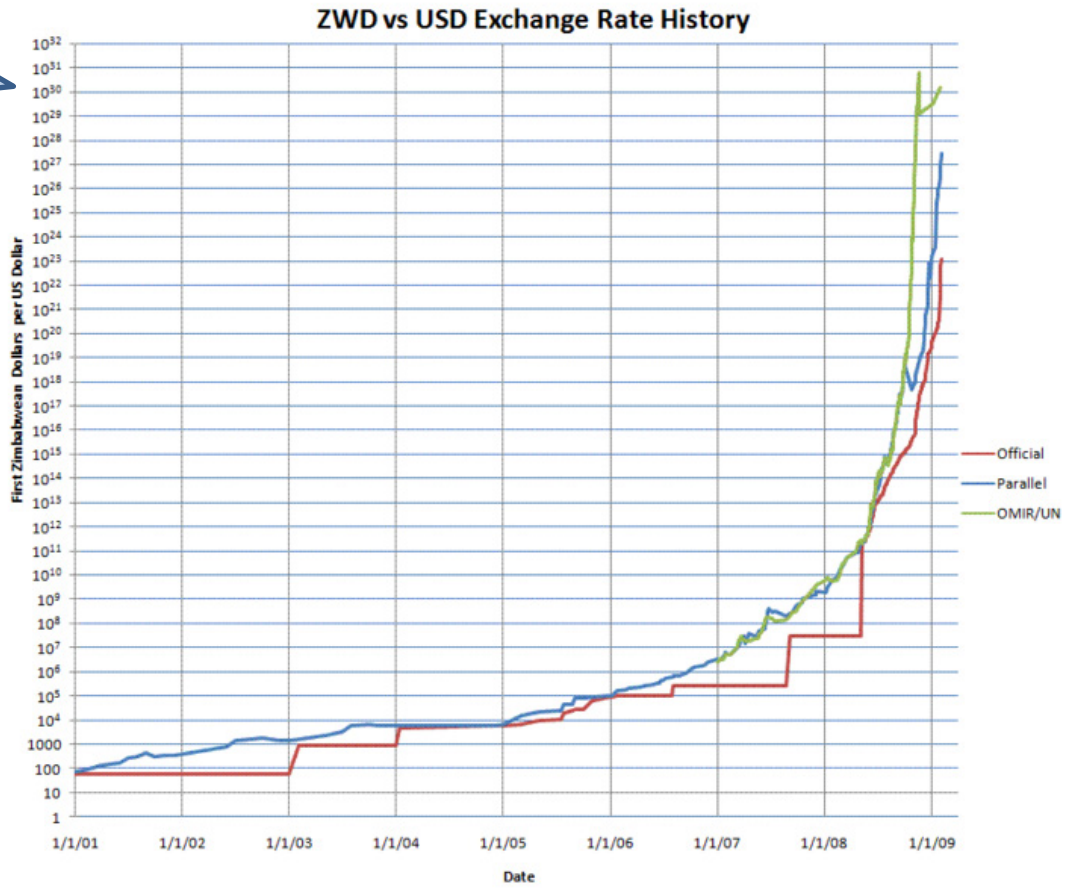


Rogue Sovereigns

- Rogue governments have little concern for taxpayers or the long term economic outlook
- As long as government revenues fall under the debt threshold, the print route is imminent
- Money is printed to meet ongoing government spending and current debt, not to pursue any real Keynesian effects to improve the economy
- As soon as price level increases, meeting the ongoing spending becomes a moving target. Inflation rate becomes exponentially related to time.

Rogue Sovereigns (cont'd)

10^{30}



Rogue Sovereigns (cont'd)

P_{Sov} = {D - [D / H(t)]} + [(1 / MS) $\exp(-rt)\int_{-\infty}^{D}(D-A)p(A)dA$]

H(t) is the projected level of hyperinflation process.

D is the Sovereign Debt level

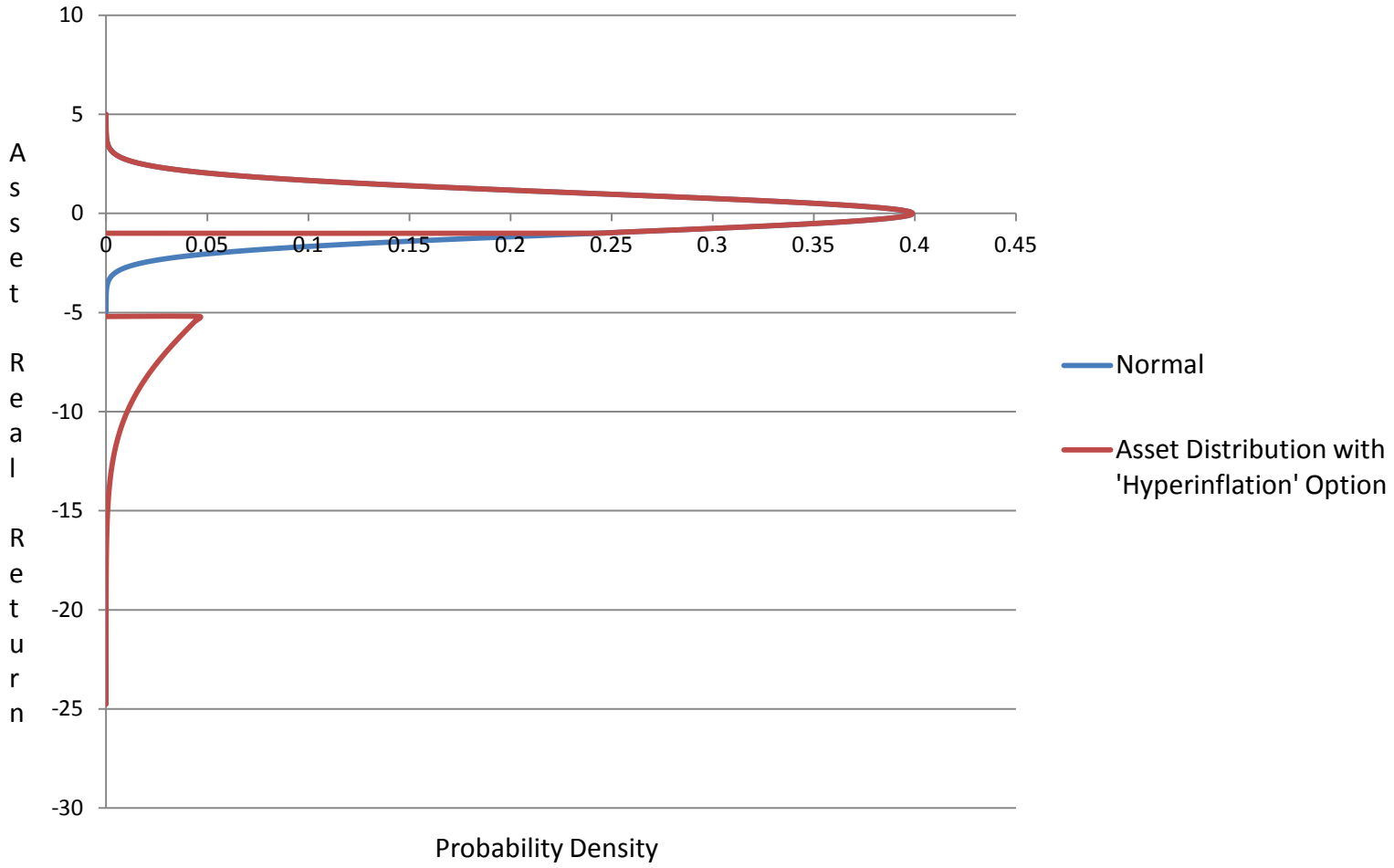
A is the Sovereign Asset level

- **What about asset volatility ?**
  - Rogue sovereign domiciles often don't have a liquid and transparent stock market which is an input to the credit model.

Rogue Sovereigns (cont'd)

- Sovereign asset volatility can be inferred:
  - Foreign currency debt is politically sensitive, prompting rogue government to grant it seniority
  - Foreign currency debt, hedged into local currency, is a portfolio of two call options:
    - A long call on sovereign assets with a strike = local currency debt value
    - A short call on sovereign assets with a strike = foreign currency debt value translated into local currency
  - We can use this portfolio to infer market implied sovereign asset volatility

Rogue Sovereigns (cont'd)



Sovereign Risk Model: Planned Extension

- Fiscal and Monetarily Responsive Sovereigns of distressed economies do not save all banks, but only the "too big to fail" ones
- In essence, this is a "kick-out" clause in the Bailout Put option
- Our framework allows us to incorporate the effect of real sector and financial sector credit on the economy, affecting government bailout behavior under each scenario
- We will incorporate macro econometric model to determine the "too important to fail" banks

Model Results: Spain

Asset Level: 3.97 trillion EUR

Debt Level: 500 billion

Asset Volatility (Surplus Proportional Changes): 73%

Debt Average Maturity: 7.4 Years

Default Put Option Value Over Average Maturity Horizon: **146 billion**

Model Predicted Yield To Maturity: **6.98%**

Market Yield To Maturity: **6.2%**

Probability Of Default: **1%** (1 year), **6%** (2 year), **14%** (3 year)

Model Results: Greece

Asset Level: 63 billion EUR

(this asset level assumes cap of deficits 1% of GDP; European Commission allows for 3%)

Debt Level: 300 billion

Asset Volatility (Surplus Proportional Changes): 35%

Debt Average Maturity: 8.3 Years

Default Put Option Value Over Average Maturity Horizon: **220 billion**

Model Predicted Yield To Maturity: **32%**

Market Yield To Maturity: **35%**

Conclusions

- The model that captures the dynamics of sovereign credit risk in an economically justified way
- The model offers results that are consistent with prices in the sovereign debt market
- This model limits the use of implied inputs, which is dominant in other models
- No assumptions and modeling of debt renegotiation; rational renegotiation is based on future prospects of the government finances which this model captures
- The methodology is comprehensive regarding the customary types of government responses to a credit crisis
- It is computationally tractable and does not pose insurmountable data requirements

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