International Journal of Economics, Commerce and Management
United Kingdom ISSN 2348 0386 Vol. IX, Issue 3, March 2021

http://ijecm.co.uk/

STOCHASTIC DYNAMICS IN THE CAUSAL RELATIONSHIP OF MONETARY POLICY TO SOVEREIGN DEBT CRISES

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Abstract

There is a causal relationship between the reaction function of monetary policy to the extrema evidenced in sovereign debt crises when monetary exchange rates are fixed while maintaining free capital flows which therefore requires an absence of autonomous monetary policy. The resultant infringement upon the servicing of debt obligations that in turn often spawns a sovereign debt crisis is rationally explained by the quantitative design in this study, namely a synergistic equation methodology that operationalizes selected indicators for variables. The quantitative research methodology utilizes deterministic system analysis and stochastic modelling in order to construct a framework through which this relationship may be further understood. The evidentiary record shows that deterministic system analysis and stochastic modelling are compatible—as opposed to incompatible—in explaining the debt crises attendant to monetary policy.

Keywords: Currency, Debt, Monetary, Policy, Stochastic

INTRODUCTION

That the association between elements of monetary policy and debt crises exceed a merely correlative nature is hardly made exceptional until one realizes the frequency with which they recur—one would expect, at least an Austrian School proponent, that a systematic preemptory framework would have become emergent fact. The Asian Financial Crisis of 1997 preceded by the context surrounding the UK's Currency Crisis of 1992, both of which are proceeded by the Argentine Debt Crisis and Turkey's Currency and Debt Crisis of 2018, are archetypal sovereign debt crises, by which their analyses elucidate the proximate and ultimate causal processes that animate their inflection points and nadirs.

In the aforesaid crises, the policy of each country's central bank was to fix their exchange rate to the U.S. dollar (USD). This implies that when the foreign currency appreciates (in this case the USD, due to various factors including interest rate hikes) the utility of the domestic currency decreases, making it more expensive to service that sovereign's foreign debt with their domestic currency, necessitating quantitative easing and thereby causing inflation. Fiat currency is represented by the indirect utility function as follows:

$$v(p, m) \ldots \ldots \ldots \ldots (1)$$

where; p denotes a vector of goods/services prices and m a figure of income (Jehle & Rehny, 2011). This axiom in conjunction with the above causal chain negates a necessary assumption of the former, namely that prices and income bear a correlation factor of -1 due to the relative economies, as previously stated, not being homogenous, where homogeneity is defined:

$$\alpha^k f(\mathrm{v}) \ldots \ldots \ldots (2)$$

presuming $f: V \rightarrow W$ over field F with degree k, $\forall \mathbb{Z}^* a \in F \wedge \mathrm{v} \in V \quad \mathbb{Z}^*$. The resulting disequilibrium not captured by what the currency fluctuations would predict reflects the absence of bijection constituted by the differing macroeconomic states. Per shadow price this is the indirect utility function extrapolated as:

$$u\big(x_1^*(p_1, p_2, w), x_2^*(p_1, p_2, w)\big) \ldots \ldots \ldots (3)$$

with the inverse being:

$$E(p_1, p_2, w) = p_1 x_1^*(p_1, p_2, w) + p_2 x_2^*(p_1, p_2, w) \ldots \ldots \ldots (4)$$

where; $x_1^*(.,.,.,.), x_2^*(.,.,.,.)$ denotes the demand functions; where p_1, p_2 denotes prices; where w denotes wealth;

letting λ^*solve for p_1, p_2, w;

$$\lambda^*\left(p_1 \frac{\partial x_1^*}{\partial w} + p_2 \frac{\partial x_2^*}{\partial w}\right) = \lambda^*\left(\frac{\partial E}{\partial w}\right)$$

$$\therefore \lambda^* = \frac{\partial U/\partial w}{\partial E/\partial w} \ldots \ldots \ldots (5)$$

which maps to the differential of optimal utility to expenditure.

CAUSAL & HISTORICAL EXPLICATION

The rationale underlying this state of affairs is expounded by Mundell's Trinity, which states that a country's economic policy cannot simultaneously maintain three (though choosing two) of the following: a pegged exchange rate, free capital flows, and an autonomous monetary policy (Warnock & Hammaker, 2011).

This framework tacitly assumes Arrow's Trilemma (1950), viz.:

$$F: L(A)^N \rightarrow L(A) \ \ldots\ldots..(6)$$

where; A is a set of conclusions; where N is a set of premises; where the set $\forall$ full order of A is $L(A)$; where $(R_1, \ldots R_N) \in L(A)^N$ denotes a preference profile with alternatives as a and b; subject to trichotomy:

1. $a \succ b \; \forall \; (R_1, \ldots R_N) \rightarrow a \succ b \; \forall \; F(R_1, \ldots R_N)$
2. $i \in \{1, \ldots N\} : \; \forall \; (R_1, \ldots R_N) \in L(A)^N, a \succ b \; \forall \; R_i \rightarrow a \succ b \; \forall \; F(R_1, \ldots R_N), \forall \; a \wedge b$
3. $(R_1, \ldots R_N) \wedge (S_1, \ldots S_N) : \; \forall \; i, a \wedge b \; º \in R_i \wedge S_i , \; a \wedge b \; º \in F(R_1, \ldots R_N) \wedge S(S_1, \ldots S_N) \ldots (7)$

In the early 1990's, the UK's exchange rate was fixed to Germany's Deutsche Mark and the country was open to cross-border capital flows, ergo its inability to maintain an independent monetary policy (Gregori, 2009). Germany's relationship with inflation and interest rates per their hyperinflationary crisis in the 1920's and the resultant austerity colored their rejection of lowering interest rates despite the prudence of doing so considering the anemic growth in as important an economy as the UK was. Moreover, the Asian financial crisis in the 1990's was indicative of the volatility of capital flows present in emerging markets (EM) including Latin America during that time, and Hong Kong's peg to the USD established a fixed exchange rate (Beja, 2007). Nonetheless, Hong Kong decided to retain a hybrid of sovereign monetary policy. Theoretically, a fixed exchange rate with unimpeded capital flows cannot be accompanied by a sovereign monetary policy, since disanalogous domestic and world interest rates would prohibit a fixed rate due to contravention of interest rate parity. Interest rate parity is given by the following equation from Bodie (2018, p. 801):

$$F_0 = E_0 \frac{1 + r_x}{1 + r_y}^{\;T} \ \ldots\ldots..(8)$$

where; F_0 is the forward price for exchanging currency *x* for *y* to the series of time *T*; where E_0 is the spot exchange rate between currency *x* and *y*; where r_x and r_y are the risk-free rates in the different countries, respectively. Any risk-free differential is compensated for by the forward premium differential and vice-versa, i.e., the forward premium counteracts any advantage from the higher interest rate of the opposing risk-free rate whereby parity is covered from arbitrage. However, given the earlier observation of a lack of homogeneity in the different economies, the EM's pegged currency concurrently appreciates with a comparatively intrinsically strong currency relative to still weaker currencies. It follows that in the national income formula:

$$S - I = NX \ \ldots\ldots..(9)$$

where; $S - I$ is net capital outflow and NX is net exports; net capital outflow would decrease since those with the foreign currency would deem recoupment unlikely due to the likelihood of default and the appreciated domestic currency would increase the expense of lending to foreign currency holders. This relationship is corroborated by the liquidity preference-money supply curve depicted in Figure 1, given by the formula:

$$M/P = L(i, Y) \ldots\ldots..(10)$$

with; M/P representing the differential of the inflation-adjusted money supply with respect to P as the general price level; where $L(i, Y)$ has as inputs i and Y for the interest rate and inflation-adjusted income, respectively, for output L as the inflation-adjusted demand for currency.

Incongruity is had when exogenous variables, such as increases in GDP, explain the appreciation in the foreign currency to which the sovereign currency is pegged absent, for example, an accompanying increase in the sovereign's GDP (or similar adequate growth measures). The concavity of the function illustrates that interest rates are negatively correlated with liquidity preferences. In an expansionary economy the liquidity market is robust in order to satisfy productivity demands, with the inverse holding true for economies lacking growth (Gordon, 2009); the latter would rather wish to deploy capital towards gainful use. A corollary of this—as implied by a Keynesian assumption in the model—is that rates negatively correlate with the hoarding of cash, requiring the sovereign (disabled from changing rates) to do similarly. Foreign Direct Investment (FDI) and capital flows into the sovereign from said country, often the exact country to which the sovereign's currency is pegged, and others, would thereby decrease. An increase in interest rates is the most common reaction of a sovereign's monetary authority for combatting inflation (Kunt & Detragiache, 1998). The primary tenet of this reasoning is that a currency surplus will continue to chase a progressively shrinking amount of resources, fueling inflation. The LM curve evinces a progressively heightened opportunity cost between the proportion of current assets to capital allocation with a growing nonzero interest rate because it becomes more difficult to extract profit due to the rate environ. In contradistinction to this dictum is the relationship in 1992 between the stagnant UK and robust economy of Germany, wherein the latter's Bundesbank was resistant to decreasing rates which would have provided the necessary stimulus to the UK given their fastening to Germany's monetary policy. Where the causes of inflation posited by the Austrian School are informed by supply side theory (Hayek, 1931), and the Keynesian school is informed by a predilection for demand (Keynes, 1936), Hayek argued that a central bank's response to contractions through the lowering of interest rates and quantitative easing encourages investment that is of a utility that begets the unnecessary cyclical nature of the business cycle.

Turkish President Erdogan's response to inflation in 2018 was a hybrid of this viewpoint, with the central bank loosening terms of short-term credit unaccompanied by an increase in rates. In 2018 Turkey was running a 12-month $51.6b current account deficit, one of the largest in the world (Trading Econ, 2019). The Lira was pegged to the USD and required capital inflows, with the majority of their debt being denominated in foreign currencies (Economist, 2018). The central bank was highly leveraged with only $85b in reserves which needed to fund an annual aggregating $200b account balance (Pitel, 2018). Evincing political vitriol like that seen by the Argentine debt crisis, liquidity risk materialized when Erdogan disputed with primary suppliers of net capital flows, the party of which the Turkish central bank presupposed in the financing of their foreign denominated debt obligations (Daragahi, 2018). As inflows thusly began to dissipate and Q2 in the U.S. saw an equity rally & record GDP growth (Hofschire, 2019) with the Lira subsequently depreciating against the USD, the monetary authority's mismatching of currency on their balance sheet caused the central bank to increase rates by 625 basis points in September 2018 to necessitate the aforesaid monetary policy response conditions, i.e., offer an attractive interest differential as to increase net capital flows.

In effect, one of the principal attractions an EM has in fixing their currency to another such as the greenback is the reduction in international transaction costs (Schumacher, 2000), which is synonymous with these countries' capital channels and hence increase in capital flows. However, empirically this may place these countries in a dilemma where a country's domestic consumers become disincentivized from holding and purchasing local currency and debt if the foreign country is deemed by the domestic consumer to contain greater investment potential than the domestic one. Capital flows here become doubly impinged by domestic and foreign net capital outflows, with the pursuant difficulty of servicing the foreign debt as the spread of the interest rate differential widens between certain of the countries independent of the sovereign.

While these effects are inherently neither an endorsement nor an indictment of the Monetarist view of reactionary monetary policy (Caballero & Krishnamurthy, 2001), they predict and illustrate the contagion behavior of sovereign debt crises, with Turkey's incident metastasizing to Lebanon, Colombia & South Africa (IIF, 2018). Continuing, Hong Kong's trouble with leverage ratios was preceded by Taiwan's debt crisis, and UK's currency target revealed issues of overly leveraged foreign denominated debt held by Portugal & Ireland in 1992. Species of currency crises that follow a contagion model having been empirically observed to be the fault of speculators (Morris & Shin, 2003) may add verisimilitude to Erdogan's persistent faulting of the U.S. for currency manipulation that informed Turkey's inability to fund their dollar denominated debt. In any event, where foreign investors opine as they did in the Argentine case that the rate differential between the domestic and foreign currency was insufficiently compensatory due to lackluster GDP, a monetary authority's choice of running a deficit with a pegged currency to a country whose business cycles are disanalogous proffer an inefficient proxy of exchange value. Furthermore, the positive correlation capital inflows hold with FDI pursuant to Turkey's then improving economy would support the central bank's rate hike as to combat inflation. Nonetheless, whether this is sufficient to establish future EM's from ceding the independence of their monetary policy which is necessary in solving the resultant asset and liability currency discrepancy of their central bank's balance sheet to the pegged currency, which thereby necessitates refinancing & reinvestment risk and so could instead dispel suppliers of funds away from EM's, is what will partially determine the frequency with which sovereign debt crises recur. This former proposition is preconditioned by the fulfillment of the Marshall-Lerner condition that follows a J-curve, i.e.:

$$\frac{NX'}{e'} = M(\epsilon_x - \epsilon_m - 1) \dots\dots..(11)$$

where; $\frac{NX\prime}{e\prime}$ is the first derivative of net exports NX with reference to the velocity of price for foreign money in terms of domestic currency e; where M is equal to net imports; where $\epsilon_x - \epsilon_m$ denotes elasticities of exports and imports, respectively. A conditional entropy equation prescribed by Cover & Thomas (1991) can be modified to fit as such:

$$S(X|Y) = -\sum_{i,j} p(x_i, y_j) \log_e \frac{p(x_i, y_j)}{p(y_j)} \dots\dots.(12)$$

where; $p(x_i, y_j)$ is the prospect $X = x_i$ and $Y = y_j$; where base *e* is the Napierian digit for logarithm *log* custom to the J-curvature; where entropy is given by

$$S = k_{\mathrm{B}} \ln \Omega \dots\dots..(13)$$

for; S as entropy; where $k_B$is the Boltzmann constant; let $\ln \Omega$ be the Napierian logarithm of the microscopic permutations of microstates that could generate the macrostate. The degree to which a given set of macroscopic variables, e.g., inflation and liquidity pressure, in a macrostate are explained by and over an appreciating number of quanta microstate phenomena, e.g., contravariant components including velocity and jerk in the Phillips curve, with increasing probability, the greater is entropy. The joint entropy of the system describes the entropy of two discrete random variables, provided by:

$$S(X_1, \dots X_n) = -\sum_{x_1 \in X_1} \dots \sum_{x_n \in X_n} P(x_1, \dots x_n) \log_2[P(x_1, \dots x_n)] \dots\dots..(14)$$

where; $x_1, \dots x_n$ ∈ º $X_1, \dots X_n$; where; $P(x_1, \dots x_n)$ denotes the probability of simultaneity for the variables; where $P(x_1, \dots x_n)\, log_2[P(x_1, \dots x_n)]$ is found at 0 for $P(x_1, \dots x_n) = 0$.

The entropy rate $S(X)$ for a stochastic process bearing a countable index is the velocity of the joint entropy of n members for the quotient of stochastic process $X_K$by *n* for n *ad infinitum*:

$$\mathrm{S}(X) = \lim_{n \to \infty} \frac{1}{n} \mathrm{S}(X_1, \dots X_n) \dots\dots..(15)$$

The inference is that the asymptotic equipartition property is satisfied, which agrees with what the Mundell Trilemma predicts.

Prima facie the above results would seem to not only comport with but also help explain the causal relationship in question. As shown, the fixing of an exchange rate while abstaining from capital controls requires the ceding of domestic monetary policy to the pegged country's foreign monetary policy (Flood & Garber, 1984), irrespective of important differences including dissonant business cycles. To explain further, if the U.S. were departing a boom (which was the mood of 2018 per the tightening of monetary policy via increasing rates) yet the domestic country whose currency is pegged to the USD presumes growth and thus lower interest rates, the countries monetary policy goals clearly diverge. This is precisely the relationship Germany and the UK held circa 1992 (Krugman, 1979), and what contributed to Turkey's currency crisis in 2018. What commonly follows is a devaluation in the domestic country's currency which persuades the central bank to engage in quantitative easing to massage the lost utility of the currency. Nevertheless, this action does not negate the absence of a rich opportunity set of investment in the domestic market for which the surfeit of currency could otherwise be dispatched to, which thereby engenders a debt crisis.

The Argentine Debt Default of 2001 is characterized by this motif, where the sovereign's debt was primarily denominated in foreign dollars (Kitano, 2005), allowing speculators and arbitrageurs to exploit this via sizable short positions. Foreign investors deemed the interest rate differential that might otherwise be providence for fungible capital risk premia insufficient, similar to how the issuance of equity alerts shareholders to the prospect of financing issues (Ross, Westerfield, & Jordan, 2017). In 2001 the government received payment from the IMF, though the further issuance of debt to counteract currency devaluation precipitated continued inflation, regressing to the governments eventual substantial default on the debt. Here, the domestic sovereign is orthogonal to Nash equilibrium whereas the foreign is not, for the latter's strategy profile represented as:

$$u_i(s_i^*, s_{-i}^*) \geq u_i(s_i, s_{-i}^*) \forall s_i \in S_i \; \dots \dots . . (16)$$

where; S_i denotes the set of possible strategies for actor i, with $i = 1, \dots N$; where $s^* = (s_i^*, s_{-i}^*)$ is a strategy profile for each player, with s_{-i}^* quantifying $N - 1$ strategies sans player i; where $u_i(s_i, s_{-i}^*)$ is actor i's yield with respect to the strategies.

Hong Kong in the 1990's became a target proceeding the recession of highly levered Taiwan, an exemplar of the high debt-to-GDP ratios endemic to the Asian financial system at the time (Asian Development Bank, 2003). Although the Hong Kong economy was representative of many Asian provinces at the time, in contrast to those as well as Argentina, Hong Kong did not suffer a sovereign debt crisis. The Hong Kong Monetary Authority (HKMA) had a currency board with a monetary policy that was self-correcting: as capital flows increased, the monetary base expanded, which decreased interest rates, which decreased capital flows, which drove down the monetary base, which exerted upward pressure on interest rates, which increased capital flows, etc. The Pareto set of the HKMA is given by:

$$f: X \to \mathbb{R}^m \ \ldots\ldots(17)$$

with a compact space of tenable conclusions X in metric space $\mathbb{R}^n$; where Y is the tenable set of premise vectors contained in $\mathbb{R}^m$, viz.:

$$Y = y \in R^m : y = f(x), x \in X \ \ldots\ldots(18)$$

The Pareto frontier is found by:

$$P(Y) = \{y' \in Y : y'' \in Y : y'' \succ y', y' \neq y'' \neq \emptyset\} \ \ldots\ldots(19)$$

subject to the condition y'' succeeds y'.

To attempt to exploit the high leverage of the economy and deterministic monetary reaction, hedge funds engaged in immense carry trades, whereby speculators would borrow at the lower domestic rate (in this case Hong Kong) and then convert the local currency into the foreign currency (in this case USD), investing the sum at the higher foreign rate. The HKMA reacted out of lockstep apropos its monetary policy. Instead of debt issuance to thwart currency devaluation and hedge against capital outflows that commonly serves as the impetus for other debt crises, the HKMA began purchasing their domestic debt, owning at one point close to 10% of the market (Radelet & Sachs, 1998). The implication from the central bank to investors was that the local economy had an acceptable opportunity set, instilling both domestic and foreign investor confidence which aided in successfully averting both speculator attacks and a sovereign debt crisis.

The handicaps evidenced and the subsequent penalty of circumvention in the above cases for the sovereign can adapted to cores similar to Shapley & Shubik, (1966):

$$C_\varepsilon(v) = \left\{ x \in \mathbb{R}^N : \sum_{i \in N} x_i = v(N); \sum_{i \in S} x_i \geq v(S) - \varepsilon, \forall S \subseteq N \right\} \ldots\ldots(20)$$

where; the core C of game (v) is with penalty ε; $x \in \mathbb{R}^N$ an imputation; where $\sum_{i \in N} x_i = v(N)$ is the payoff; where $\sum_{i \in S} x_i \geq v(S) - \varepsilon, \forall S \subseteq N$ is subject to;

$$x_i \geq y_i \forall i \in C \vee \exists i \in C : x_i > y_i \ \ldots\ldots(21)$$

where; S may enforce x. *Nota bene*, the above implies that where ε is negative reward is conferred for seceding from the union, which characterizes the action made by the HKMA. More generally, it identifies the observation that when both a sovereign's currency is pegged to another and has free capital flows, it is restricted from having the other option, i.e., autonomous monetary policy that might otherwise allow it to circumvent economic issues given the counterfactual. Conversely, it also serves as the explanatory framework utilized by the foreign grand coalition, whichever side(s) of the trade it happens to be on as a function of time. Both the foreign and sovereign actors' processes in the above cases are governed by a discrete-time stochastic control process covered by a Bellman optimality equation:

$$V^{\pi*}(s) = \max_a\{R(s,a) + \gamma \sum_{s'} P(s' \mid s,a) V^{\pi*}(s')\} \ldots \ldots \ldots (22)$$

where; $V^{\pi*}$ is the value function of the optimum policy; where the state at time t as s_t $R(s,a)$ is the yield from action a in state s satisfying $a_t \in T(s_t), x_{t+1} = T(s_t, a_t)$ where $a \to s = T(s_t, a_t)$; where $\gamma \sum_{s'} P(s' \mid s,a) V^{\pi*}(s')$ is the lower incomplete gamma function γ of the sum of the conditional probability P of the velocity of state s given the yield from action a in state s with reference to the value function of the optimum policy with respect to the velocity of s over all of velocity of s.Accordingly, this decision tree supports the aforementioned claim regarding bijection vis-à-vis homogeneity per Mundell's Trilemma.

FRAMEWORK PROPOSAL

Sovereign debt crises and monetary policy are characterized by supersymmetric dynamical systems. The supersymmetric theory of stochastic dynamics specifies stochastic partial differential equations that satisfy topological supersymmetry. In the cases (supra) the open economy expresses an open subsystem that transacts energy and matter with a system with which it is derelict of thermodynamic equilibrium:

$$\mathrm{V}'(\mathrm{x(t)}) \le \mathrm{w}(\mathrm{u(t)}, \mathrm{y(t)}) \ldots \ldots \ldots (23)$$

where; $x(t)$ is the state, with input $u(t)$ and output $y(t)$ with ρ given by $\mathrm{w(u(t)}, \mathrm{y(t))}$; where $\exists\, V'(x(t)) : V(0) = 0, V(x(t)) \ge 0$. Dissipation occurs when the sovereign is in disequilibrium with the macroeconomy in which its exchange rate and capital flow conduct. Furthermore, the replicable steady state may be sourced independently or jointly sourced form time evolution of Mundell parameters or even contrivance. The transition to chaos is enumerated by a subcritical Poincaré-Andronov-Hopf bifurcation that births the chaos:

$$\frac{dz}{dt} = z\big((\lambda + i) + \alpha + i\beta|z|^2\big) \ldots \ldots \ldots (24)$$

where; z and $\alpha + i\beta$ are complex numbers and when $a(+)$. When $\lambda \approx 0$, the dynamical system describes movement from a stable fixed point with an unstable limit cycle to an unstable fixed point according to a chaos theoretic logistic map:

$$x_{n+1} = \mu x_n (1 - x_n) \ldots \ldots \ldots (25)$$

where; μ is on the interval $[0,4]$ so that x_n is on the interval $[0,1]$.

Because dynamical systems have stochasticity as exogenous variables, a chaos theoretic explanation of these crises is consistent with a stochastic environ. An approach similar to that of Slavík (2013) contextualizes Langevin stochastic differential equations in phase space $X = \mathbb{R}^N$ using a gradient flow vector field with additive Gaussian white noise:

$$x'(t) = -\partial U(x(t)) + (2\Theta)^{\frac{1}{2}}\xi(t) \ldots\ldots\ldots (26)$$

where; $x \in X, \xi \in \mathbb{R}^n$ is the noise variable; where Θ denotes noise intensity with $\partial U(x)$ at position $\delta^{ij}\partial_j U(x) \wedge \partial_i U(x)$ for the gradient flow vector; let $U(x)$ be the energy of the dissipative stochastic dynamical system. The SDE returns a displacement function $x(t) \in X$ for any noise arrangement ξ given *ab initio* velocity function $x(t') = x' \in X$, where $M_{tt'} : \mathrm{X} \longrightarrow \mathrm{X}$ for $x(t) = M_{tt'}(x')$. This is irrespective of whether the noise arrangements are differentiable, as the displacement function is differentiable with respect to the velocity function. The SDE establishes the indexed set of noise-arrangement-reliant diffeomorphisms for iterated functions of the phase space, *ipso facto* a collection for all noise-arrangement-reliant diffeomorphisms, respectively. The latter issues ϕ, $M^*_{t't}$: $\Omega(X) \longrightarrow \Omega(X)$; where $\Omega(X)$ are wavefunctions. Linearity of ϕ allows for arithmetically meaning $M^*_{t't}$ over ξ, defining the Stochastic Evolutionary Operator (SEO). This concurs with the Lefschetz-Hopf theorem (c.f. Dold, 1980). That is, for the iterative function $f: X \longrightarrow X$ as a continuous map with a compact triangulation with f having finite fixed points:

$$\sum_{x \in \mathrm{Fix}(f)} i(f, x) = \sum_{x \in \mathrm{Fix} M_{tt'}} \mathrm{sign}\det(\delta^i_j - \partial M^i_{tt'}(x)/\partial x^j) \ldots\ldots\ldots (27)$$

let; $\mathrm{Fix}(f)$ denote the set of fixed points of (f) and $i(f, x)$ equate to the index of the fixed point x. If the entity is nonzero, then $\exists\, x \in X : f(x) = x$. The Kronecker tensor is given by δ^i_j with covariant and contravariant index i and j, respectively:

$$\delta^i_j = \begin{cases} 0 & (i \neq j) \\ 1 & (i = j) \end{cases} \ldots\ldots\ldots (28)$$

Therefore, in this sense the Lefschetz-Hopf theorem may be viewed as the infimum/supremum tensor contraction of the SEO. Stochastic noise is a necessary condition of any dynamical system. That the statistic of the entropy in the system is positive sign nests the collapse of supersymmetry in the dissipative structure as the stochastic function of deterministic chaos.

SYNTHESIS

One of the behavioral economic reasons why sovereign debt crises recur is that the models, e.g., Ramsey-Cass-Koopmans, from which economic systems build themselves presume a particular level of growth. This is reflected in their utilization of exponential discounting, notwithstanding the long-term expectations invalidating the tacit assumptions thereof. The deference given to demand isn't controversial: read Keynes (1923) "In the long run we are all dead" (p. 80). The ceding of certain controls for an emerging market appears justified given the premium afforded in the short-term—not least given the priors—which even if not expected to hold in the long-term time horizon, is loosely assumed to have made organic growth by then so what likely repercussions stem from the uncertainty do not have as negative an impact as they otherwise would. This would peruse a model closer to hyperbolic discounting, following an equation similar to Sozou's (1998):

$$\int_0^{\infty} P(R_t|\lambda)p(\lambda)d\lambda \;\ldots\ldots\ldots (29)$$

subject to; $P(R_t|\lambda) = e^{-\lambda t}$

viz., subject to an observable force of mortality parameter λ unknown to the sovereign the probability that reward at time R_t for $T \geq t$; where $p(\lambda) = e^{(-\lambda/k)/k}$ denotes the prior of λ; viz., the integral of the probability that R_t occurs with λ present given the prior $p(\lambda)$ with respect to the derivative of λ on the interval $[0, \infty]$. From a logical standpoint the risk-premia are disproportionately higher in the short-term. The opposite is true for options contracts which have exponential decay, since as expiry approaches entropy decays.

What this is made to illustrate is that the predictability differential with respect to the initial conditions in the near- vs. long-term time horizon makes the latter appear to be more stochastic than it in fact is, when both are determined by the initial conditions—this is typical of chaos theoretic progressions which are always subject to stochasticity. Whether the outcome following the outlined causal chain is that of a debt crisis or not is dependent upon the reactant monetary policy. The degree to which this is satisfied is based in part on the conclusions made by foreign debt claimants given the domestic central bank's obeisance to the former's monetary policy and commonly disanalogous macroeconomic state, premised upon the likelihood and past effects of debt issuance by the domestic central bank designed to impair the momentum of currency devaluation, notwithstanding the local currency holders' handicap in purchasing the outstanding debt. The completion of the causal chain is intermediated by the determination made by holders of the devalued currency, i.e., whether they obtain an interest rate differential that sufficiently compensates their holding of the devaluing currency predicated on the reactant rate spawned per monetary policy that must countervail both inflation and currency depreciation. A subsidiary assumption of this condition is that foreign investors—whom the domestic country's monetary policy are now reliant upon and have seen constrained capital flows—deem it probable that projects will be recompensatory, not least offering a positive net present value (NPV). As illustrated, foreign denominated debt held locally is not held in a vacuum independent of a country's free capital flows, proposing that the lack of monetary autonomy and disanalogous macro features between economies creates the archetypal financial friction that begets sovereign debt crises. The ease with which the fixing of monetary policy is maintained and the immediate effects of capital flows on growth, especially in EM and its amenability towards net capital flows and FDI—the latter of which often originates from a comparatively more autonomous economy— helps resolve the inquiry regarding sovereign debt crises.

Sufficient black swans exist such that the causal chain does not invariably follow a deterministic system as that evinced in the method of reasoning espoused by certain neoclassical models. In fact, the evidence supports the conclusion that certain of the chain of events are explained by stochastic processes. This lends credence to the thesis that deterministic processes and stochastic processes are compatible in their explanation of the causal relationship of monetary policy to sovereign debt crises. An apposite dynamical systematic framework through which this is ascertained is via stochastic partial differential equations per the supersymmetric theory of stochastic dynamics. Research that attempts to model macroeconomic exogenous shocks from microeconomic phenomena should implement this understanding going forward.

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