An Exercise in Using System Dynamics to Enrich the Scenario Simulations Used in Another Research Paper

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Abstract

The December 4th , 2004 issue of "The Economist" had a 3-page Special Report entitled "The future of the dollar" which cites the following from the Roubini-Setser (R-S) paper [1]: "if the real trade-weighted value of the dollar remains close to its average in 1990-2003 (slightly above current levels) and there is no change in domestic policy, America's current-account deficit would rise to 8% of GDP in 2008 and its net debt would increase to over 50% of GDP". This projection came from one of three scenario simulations (their Baseline scenario) based on a model described in the R-S paper. The R-S paper's model, when replicated in Vensim [2], contains one positive feedback loop [3] to represent how interest on debt leads to exponential debt growth but excludes much of the of the paper's rich mental models which imply much more endogenous model structure than that used in the paper's scenario simulation model. This SD conference paper re-creates the R-S scenario simulation model and then presents another version which tries to include more endogenous model structure based on the R-S paper's own rich discussion and mental models.[4]

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[1] "The US as a Net Debtor: The Sustainability of the US External Imbalances" by Nouriel Roubini and Brad Setser (November 2004 draft). See References.

[2] Vensim is a System Dynamics modeling software product of Ventana Systems, Inc. See References.

[3] See Sterman 2000 pages 12-13 for a discussion of feedback loops both positive and negative.

[4] See Sterman 2000 page 95 for a discussion of the importance of endogenous versus exogenous factors. See Sterman 2000 Section 1.1 pages 16-18 for a discussion of 'mental models'.

Summary

The R-S paper's scenario simulations set the stage for their interpretation of an unsustainable state of external debt burden but do not include the transition from an unsustainable state to a sustainable one. The transition process and its catalysts are richly investigated and described in their paper but not included in their scenario simulations. This paper attempts to incorporate the transition process and its catalysts into their scenario simulation model by 'endogenizing' the R-S paper's own mental models. The author's intent is to demonstrate the ability of the System Dynamics (SD) modeling approach to map written descriptions of mental models into causal loop structure which make descriptive variable linkages both explicit and part of a structure that generates behavior. In order to go from causal loop structure to a model that generates behavior; the causal loop structure needs to be made into a simulation model. That crucial step of creating a simulation model from the causal loop structure is not addressed here. Regardless, this SD conference paper aims to illustrate the ability of the SD methodology to incorporate more of the described unsustainable state and its transition to a sustainable state quantitatively in a simulation model. Enhancing their scenario simulation model in this way allows researchers to investigate this important topic and represent it graphically which should support and enhance their rich written/descriptive viewpoint. It is important to acknowledge this paper was written without the opportunity to confer with Roubini & Setser. The author hopes this paper reaches the authors of the referenced work in that their research represents the rigor, balance, open discussion of assumptions and alterative modes of behavior that are the hallmarks of the System Dynamics methodology. If those researchers review this paper and pass it on to their colleagues; more people will learn about and possibly make use of System Dynamics [5]. Please note that "author" refers to the writer of this paper while "authors" refers to Roubini & Setser throughout this paper.

To demonstrate all of this; an elementary synopsis of the R-S paper will present their paper's mission and how they go about getting there. Then the R-S scenario simulation model will be presented to show how it illustrates their paper's conclusions. Their scenario simulation model will then be re-created in Vensim after which the addition of endogenous structure based on their paper's written mental models will be added and discussed in terms of causal loops[6] created by the endogenized structure. The resulting causal loop structure will be briefly

[5] John D. Sterman's text "Business Dynamics: Systems Thinking and Modeling for a Complex World" 2000, McGraw-Hill provides an excellent introduction to System Dynamics. Jay W. Forrester's application of engineering control theory to a broader group of problems including those in the social sciences in the 1950s came to be known as "System Dynamics". Forrester's book "Industrial Dynamics" is a timeless classic on System Dynamics. See References.

[6] Sterman 2000 Chapter 5 and Vensim DSS Reference manual on Structural Analysis tools.

reviewed using Vensim's Tree Diagram and Loops Structural Analysis tools available in Vensim DSS. The benefits and problems of "endogenizing" a model will be discussed in terms of the rapid increase in model complexity that results. The resulting complexity is both good and bad. Bad because it makes the model less tractable but good in the sense that it helps researchers gain more understanding from the descriptive information that the endogenous structure is based on .[7] The real value-added benefit of the added endogenous structure though is that it leads to a simulation model that allows researchers to delve more into how key variables interact before, during and after a transition from unsustainable to sustainable by first quantifying these terms and then relating the added endogenous structure to the dynamics of the transition from unsustainable to sustainable states.[8]

Appendix A Lists variables discussed as well as any abbreviations used.
Appendix B Shows the R-S scenario simulation model assumptions.
Appendix C Shows the R-S scenario simulation model results (R-S & Vensim)
Appendix D Shows a set of graphic views of the R-S scenario Vensim model
Appendix E Shows a set of graphic views of the 'endogenized' R-S model
Appendix F A list of the 11 loops that the variable "NIIP/GDP" is included in.

Synopsis of R-S Paper

The goal of the R-S paper is to establish that the current (late 2004) economic environment's low real US interest rates, large and growing US external debts, large fiscal deficits and dependence on Asian Central Banks for current account deficit funding makes the current economic environment unsustainable in terms of the stresses that will evolve from the current level of US's external debt burden. The authors are concerned that the transition from the current unsustainable state to a sustainable state will involve lower than expected growth in the US . The R-S paper concludes from its analysis that this transition to a more sustainable state will take place in a matter of years, not decades. The factors and paper focus follow here: The R-S paper describes the US current account deficit [9] (CAD) as a flow feeding the US net international investment position (NIIP).[10] In the paper

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[7] See Forrester 1961 Section 4.2's "Basis for a Model" on page 54 where the value of using 'descriptive information' comes from its use in a from-the-ground-up design perspective in modeling versus focusing on statistics and aggregated numerical data. The distinction here is that constructing a model from descriptive information of the separate parts of a model leads to a causally-based model while modeling based on aggregate numerical data and statistics only 'explains' the total process but lacks causality.

[8] See Sterman 2000 Chapter 4 "Structure and Behavior of Dynamic Systems"

[9] Current account deficit: CAD
See Appendix A for list of variables and their relationships.

[10] The rationale for this stock-flow relationship lies in the assumption that a country's or currency region's trade balance needs to be matched by an equal and opposite financial flow if the foreign exchange rate between the country and the rest of the world is to remain unchanged. From a System Dynamics

NIIP equals foreign owned US investments (FOUSI) less US owned foreign investments (USOFI). CAD effects NIIP by adding to FOUSI. The term "investment income balance" defines net returns on NIIP, that is "investment income balance" equals FOUSI*(FOUSI returns) – USOFI*(USOFI returns). From now on "investment income balance" will be referred to as "NIIP net return in dollars" or NNR-in-$ (see Appendix A). While the FOUSI & USOFI returns are discussed in terms of their asset type composition, the authors implement FOUSI returns in terms of a generic US real interest rate plus an inflation component. The essence of the authors' concern for the current state of affairs is that a rise in NIIP fed by a growing CAD will raise NNR which feeds back into a rising CAD inflow.

The authors discuss NIIP/GDP as a measure of financial burden for the US. Their insight relates the notion of burden to the notion of sustainability. As described in section 3.3.2 of the R-S paper "sustainable" is equated with "stable". If the current NIIP/GDP is sustainable then the perceptions of its financial burden in the present economic environment should not lead to rising risk premiums on FOUSI returns that foreign investors would require to protect themselves from dollar depreciation that can occur during trade balance adjustments that restore NIIP/GDP to a sustainable value. As NIIP/GDP departs from its sustainable value in a given economic environment, foreign investors will require higher returns on FOUSI to keep up the CAD funding inflows to FOUSI. Once risk perceptions rise on growing concerns of an unsustainable value of NIIP/GDP two things can happen; rates rise to reflect a rising risk premium or trade balance adjustments occur to lower NIIP/GDP back to a sustainable value. Trade balance adjustments that reduce CAD can coincide with expected dollar depreciation if it is resolved with higher exports. In turn expected dollar depreciation raises the risk premium on real US rates to compensate foreign investors. If lower imports instead of higher exports bring about the needed trade adjustment; lower US growth is implied. The authors voice concerns about these implications of the resulting trade adjustments and rising risk premiums in terms of lower growth and reduced wealth in the US .

The authors use the notion of a sustainable "primary external balance" (PEB) as a reference mode to measure the degree that a given NIIP/GDP departs from its sustainable value.

*Sustainable PEB = (Real NIIP Net Return - real GDP) * NIIP/GDP*
*with PEB = (-1*CAD) – NNR-in-$*

Abbreviation: Sustainable PEB = PEBsus

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perspective this relationship implies no delays, information smoothing or feedback between trade flows, financial flows and the foreign exchange rate. Note that R-S define NIIP = FOUSI – USOFI while the BEA defines NIIP = USOFI – FOUSI; it makes no difference as long as the approach is used consistently.

R-S apply their notion of a "resource gap" to reflect the degree of trade adjustment necessary to transition from the current NIIP/GDP value to one that is sustainable, that is one in which PEB = PEBsus. "Resource gap" equals the difference between the calculated Sustainable PEB (PEBsus) and current PEB. As an example in section 3.3.4 of their paper the authors calculate PEBsus as of the end of 2003 to be –1.33% as illustrated in a segment from the R-S paper:
(note in the description from their paper that "net foreign liabilities" mentioned = NIIP, the phrase "the balance of trade, transfers and remittances" = PEB., "net factor payments" = NNR-in-$, when NIIP > 0 the US is a "net debtor", "US assets" = USOFI and "US foreign liabilities" = FOUSI)

> 3.3.4. The current and permanent resource gap for the United States
> *The current resource gap.*
> At the end of 2003, the net foreign liabilities of the U.S. (at market value) were 24.1% of GDP. The trade deficit for the year was 4.52% of GDP and unilateral transfers were 0.61% of GDP. Consequently, the balance of trade, transfers and remittances was a negative 5.13% of GDP. Net factor payments – mostly the balance on investment income -- were a positive 0.30% of GDP, producing a current account deficit of 4.83% of GDP. The first point to observe here is that, at *current* values, net factor payments are still positive, even though the U.S. is a net debtor. As discussed earlier, the average return on U.S. assets abroad was greater than the average return on U.S. foreign liabilities. So, at 2003 values, the nominal interest rate on the net debt of the U.S. was a negative 1.5% (net debt times a negative rate produces a positive income stream). With inflation close to 1%, the real interest rate was roughly –2.5% (-1.5% - 1%). Real GDP growth in 2003 was 3%.
> Based on these figures, the external debt stabilizing trade, transfers and remittances balance is:
> (r – g) D/Y = (-0.025 -0.03) * 24.1% = -1.33%
> In other terms, since the current real interest rate is below the real growth rate of the economy, the U.S. can run forever a trade, transfers and remittances deficit equal to 1.33% of GDP (a trade, transfers and remittances balance of approximately 1.3% of GDP translates into a trade deficit of around 0.7% of GDP) and still stabilize the external debt ratio.

The key take away here is that whenever real growth exceeds real net NIIP returns (NNRreal); GDP growth in the denominator of NIIP/GDP will grow faster than the growth of NIIP in the numerator of NIIP/GDP whose growth rate is proxied by the real rate. This healthy state of affairs allows the current value of NIIP/GDP to be sustained as long as the PEB remains above –1.33% of GDP. R-S then continue to bring in the notion of the "resource gap" and its implications:
(note that "actual non-interest rate balance (trade deficit plus remittances)" = PEB and that "external debt to GDP ratio" = NIIP/GDP)

> However, this is hardly comforting, since the actual non-interest rate balance (trade deficit plus remittances) was 5.13%. Stabilizing debt levels at 2003 levels would require shrinking the trade balance deficit from 5.13% of GDP to 1.33%; the *current resource gap* is 3.8% of GDP (1.33% - 5.13%). Conversely, maintaining the 2003 trade deficits, real growth rates and real interest rates would lead to the external debt to GDP ratio would increase by about 3.8% per year.

The dynamics described in the R-S paper involving the PEBsus versus current PEB resource gap; how it evolves and the pressures that build up to restrain and

reverse such "resource gaps" represent the R-S paper's key contribution to the study of NIIP/GDP sustainability and its implications for the evolution of the CAD.

The authors (R-S) present a comprehensive assessment of the factors effecting NIIP/GDP, CAD and PEB from 2000 to 2004 including a review of the crucial role played by Asian Central Banks as a dominant influence in the rise of NIIP's FOUSI brought about by large purchases of mostly short-term U.S Treasury securities and U.S Agency debt. The Asian Central Banks' policy of supporting their exports by maintaining the value of the U.S dollar with Treasury purchases explains part of their behavior [11]. If the Asian Central Banks did not purchase Treasuries, the fact that US imports exceed U.S exports would lead to dollar depreciation versus the Asian currencies; making their exports more expensive, which could possibly reduce their export market growth.

Throughout the R-S paper, the interplay of imports, exports, FOUSI flows, Asian Central Bank policies and pressures, private foreign investor's dollar depreciation risk perceptions and resulting impact on US real rate risk premiums, US versus World growth, NIIP and CAD dynamics as well as the resulting pressures on U.S fiscal policy and the impact of oil prices are all richly described. The salient facets of this description and its relevance in assessing NIIP/GDP sustainability issues are distilled into three scenario simulations where all the authors' assumptions and dynamic theories are assembled in a consistent fashion in order to present an integrated model to substantiate their paper's conclusions that the present state of NIIP/GDP and CAD dynamics imply a period of instability in a matter of years not decades based on the "resource gap" measures generated from the three scenarios.

R-S paper's Analytical Core: Scenario Simulations

In order to demonstrate the anticipated instability in NIIP/GDP and CAD evolving over the next 12 years through the end of 2015, R-S generate three scenario simulations. Refer to Appendix A-C for a list of the relevant variables, a grid representation of the scenarios' assumptions from the R-S paper and the R-S paper's results. The R-S scenario simulation models are a collection of assumptions and descriptive variable linkages. The authors created the scenario simulation models in a spreadsheet or programming language to generate their results but the analytical models themselves are not presented in the paper. It is important to note that the R-S paper's scenario simulation numeric results and graphics are intended to illustrate a set of variable time series whose trends are interpreted by the authors (R-S) as raising pressure for change from an

[11] Asian Central Banks also amassed large US dollar reserves in the form of US Treasuries in the aftermath of the regions' 1997 meltdown as a store of reserves in dollars to use to strengthen their currencies in the event of a similar episode in the future.

unsustainable state to a sustainable one [12]. The R-S paper's scenario simulation results and graphics do not show a period of transition from an 'unsustainable' state to a 'sustainable' one. So while a transition is discussed, the scenario simulation results and graphics do not show a period of instability represented as chaotic behavior or exploding exponential growth or overshoot. The authors write about expected state transitions that are implied by the graphics presented; that is the graphics reflect a role in the pending state transition but not the state transition itself.

R-S use conservatism and historic precedent to guide the creation of their scenarios to strengthen the credibility of their conclusions. Each scenario is described in terms of a set of anchoring assumptions and a set of variable linkages.

Scenario #1 Baseline:
An assumed constant historic value of the dollar along with the average GDP, import and export growth rates from 1990 – 2003 anchor this scenario. Scenario #1's variable linkages relate the large and growing CAD and resulting high value of NIIP/GDP to a corresponding rise in US interest rates as the high NIIP/GDP raises the risk premium to compensate foreigners for investing in U.S debt as the risk of a dollar depreciation or rising-rate capital loses rise.

Scenario #2 Moderate Adjustment:
Scenario #2 is anchored on an assumed constant trade deficit of 5% and GDP growth rate. This is accomplished by assuming that export and import growth match nominal GDP growth from 2005 going forward. Maintaining a constant trade deficit over the course of the simulation calls for the dollar to depreciate 5-10%.

Scenario #3 Fast Adjustment:
While GDP growth is the same as the other two scenarios; here export growth is assumed to be much stronger such that the trade deficit drops by 0.5% per year from 2004 going forward. The 0.5% per year improvement in the trade deficit is linked to a rule-of-thumb that says every 10% depreciation in the dollar improves the trade deficit by 1% which results in an implied dollar depreciation of 50% over ten years. FOUSI returns do not rise as much as in the other two scenarios and in fact remain below the nominal GDP growth rate as the weakening dollar and improving trade deficit combine to reduce the risk premium foreigners require to take on dollar dominated securities.

[12] "Results" refer to those tabulated in Appendix C and the "Graphics" are those illustrated on pages 14-15 of this paper. Also see the R-S paper for graphics on pages 31 and 32 and results on pages 33-35 and page 42.

The results in Appendix C demonstrate that even in the "Fast Adjustment Scenario" by 2010 the resource gap is still 2.6%; which implies that by that year under the best of the scenarios; the PEB will either be declining by 2.6% annually or otherwise adjustments to trade balance, expected returns and/or dollar value will occur that hamper US growth below those the scenarios are based on. R-S acknowledge that their scenario assumptions are somewhat arbitrary but make the point that their scenarios represent three reasonable scenarios with which to provide a balanced set of expectations; all of which imply greater pressures from the resulting resource gaps in 2010.

Next, the R-S scenario simulations are re-created in Vensim. Using Vensim's "Uses" and "Causes" tree diagrams provide an efficient way to illustrate the scenario simulation model assumptions and explicit linkages.

The Vensim Model Representation of the R-S Scenario Simulations

Vensim provides a number of different model visualization tools that enable researchers to design and analyze models. Vensim "Views" present a graphic representation of the model in manageable chunks. Variables resident to a given view are in normal type while variables from other views are shaded and surrounded by "< >" brackets. "Causes" and "Uses" tree diagrams show variable relationships independent of their "View" orientation. Causal Loop Diagrams can be made to show variable feedback structure. Each of these model visualization tools will be shown in the remainder of this paper.

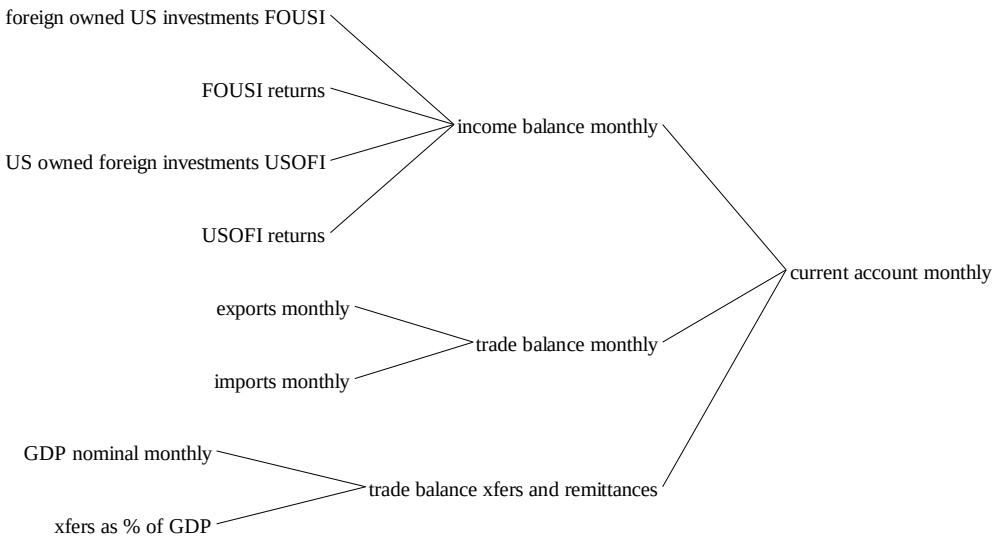
The R-S paper model uses parameter values for GDP, export and import growth. They use exogenous data feeds for FOUSI returns and USOFI returns defined in terms of their projected behavior in the 2004-2008 and 2008-2015 time frames as described in the scenario key assumptions on page 29 of their paper and in Appendix B of this paper. These are replicated in the Vensim model's "model 3.2 scenarios" view. A supporting Excel spreadsheet feeds in the return scenarios and time series data used to feed the 2000-2003 data series for GDP, exports, imports, NIIP, FOUSI & USOFI series; see the Vensim model's "spreadsheet data" view. This R-S paper replication Vensim model is RSpaperModel.mdl made available in the conference CD. Refer to Appendix D for the R-S Vensim model views.

A select set of Vensim model "Causes" trees are shown to illustrate the causal structure of the scenario simulation model, highlighting one positive feedback loop. Also the "Causes" trees for "resource gap" and "PEBsus" are shown as well as they are crucial variables in terms of assessing model behavior even though in this model neither has any loops associated with it in the Vensim version of the R-S model. In the "current account monthly" causes tree below you can trace from "FOUSI " to "income balance monthly" to "current account monthly" and in the "current account monthly" uses tree you can see how "current account monthly"

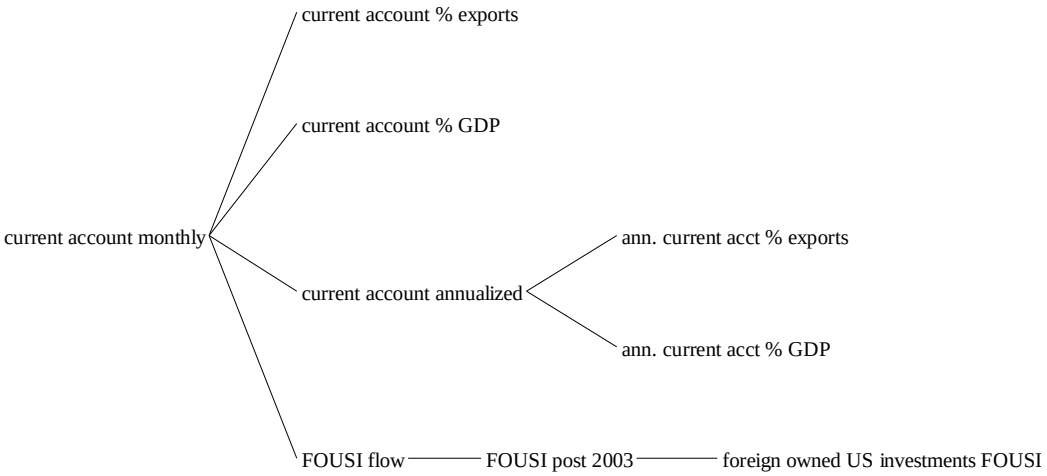
feeds "FOUSI flow" which feeds "FOUSI post 2003" which feeds "FOUSI". This illustrates the one and only loop in the R-S scenario simulation model. It is at this loop where an explanation of potential "instability" discussed in the R-S paper intersects with System Dynamics structure/behavior tenet of a positive feedback loop. Observing the "income balance monthly" tree below shows that the only exogenous factors that drive the different scenarios are the FOUSI & USOFI return scenarios that are driven by the described impact from the associated rise in NIIP/GDP that influence rates of return in each scenario. These data are fed in from an Excel spreadsheet for the Vensim model representation. Please note that while the "GDP real growth" variable is seen to be driven by the same three scenario drivers; it is actually set to the same value (3.5%) for all scenarios as shown in Appendix B.

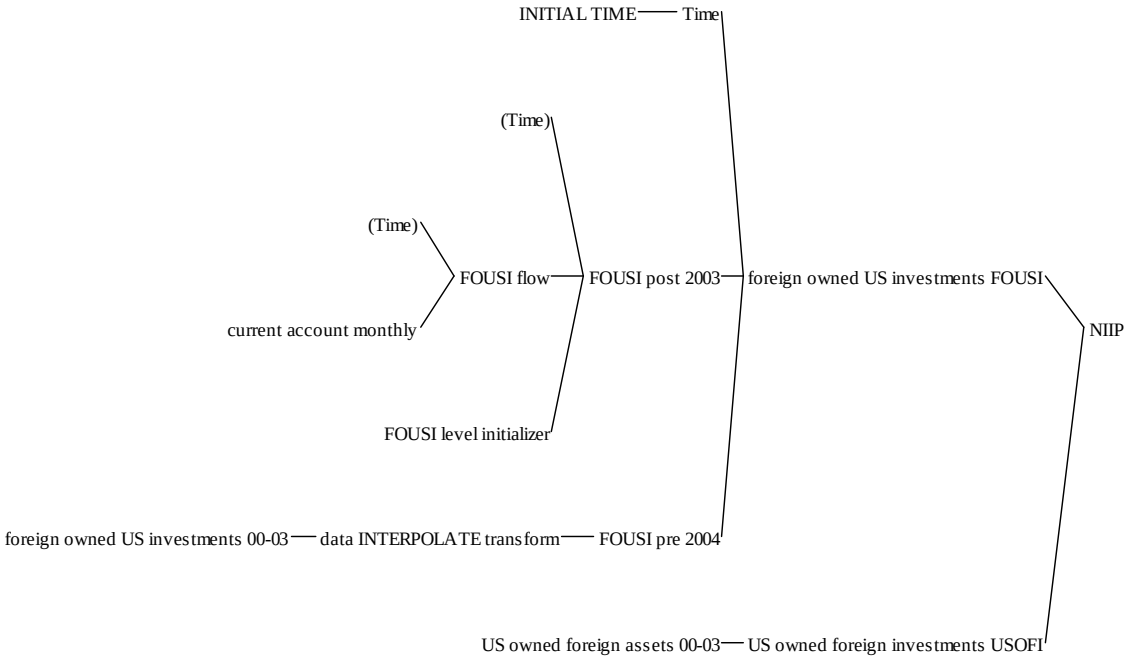
Please note in the "Causes" trees that "DoModRun" refers to the Constant Trade Deficit scenario while the "DoStrongRun" refers to the "Fast Adjustment" scenario.

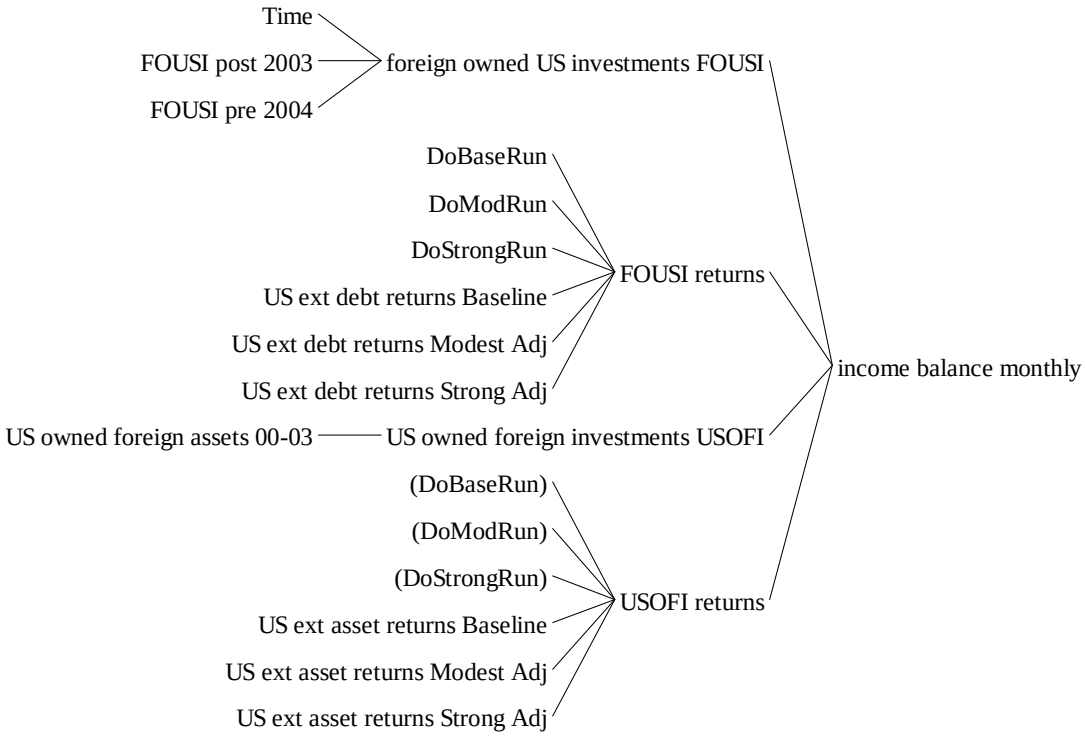
"Current account" causes tree showing how "FOUSI" causes "current account monthly" :

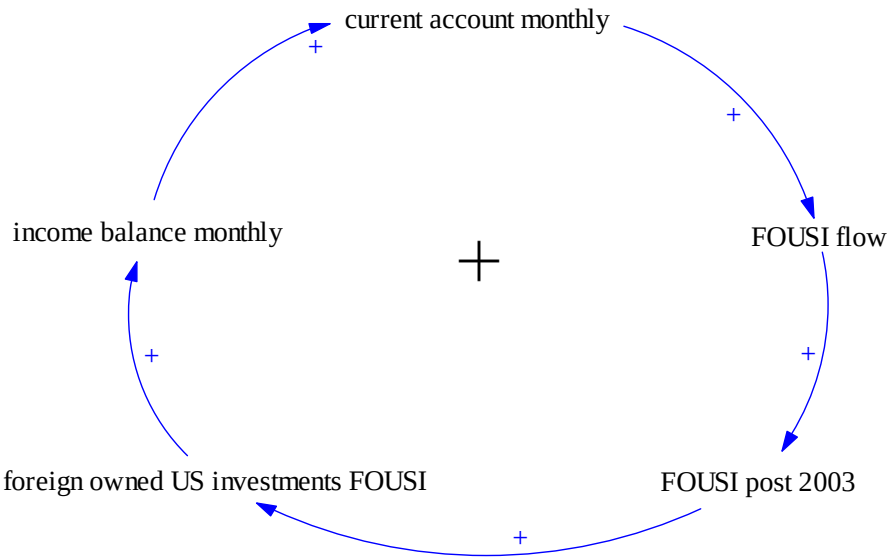


"Current account" uses tree showing how "current account monthly" drives "FOUSI" :

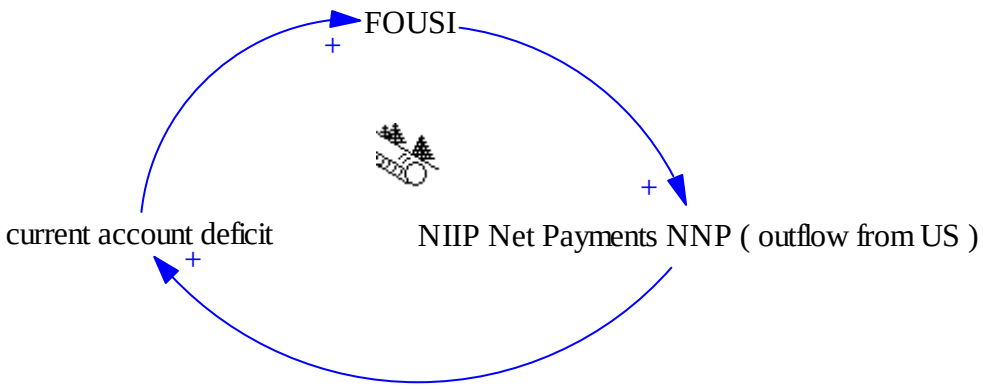




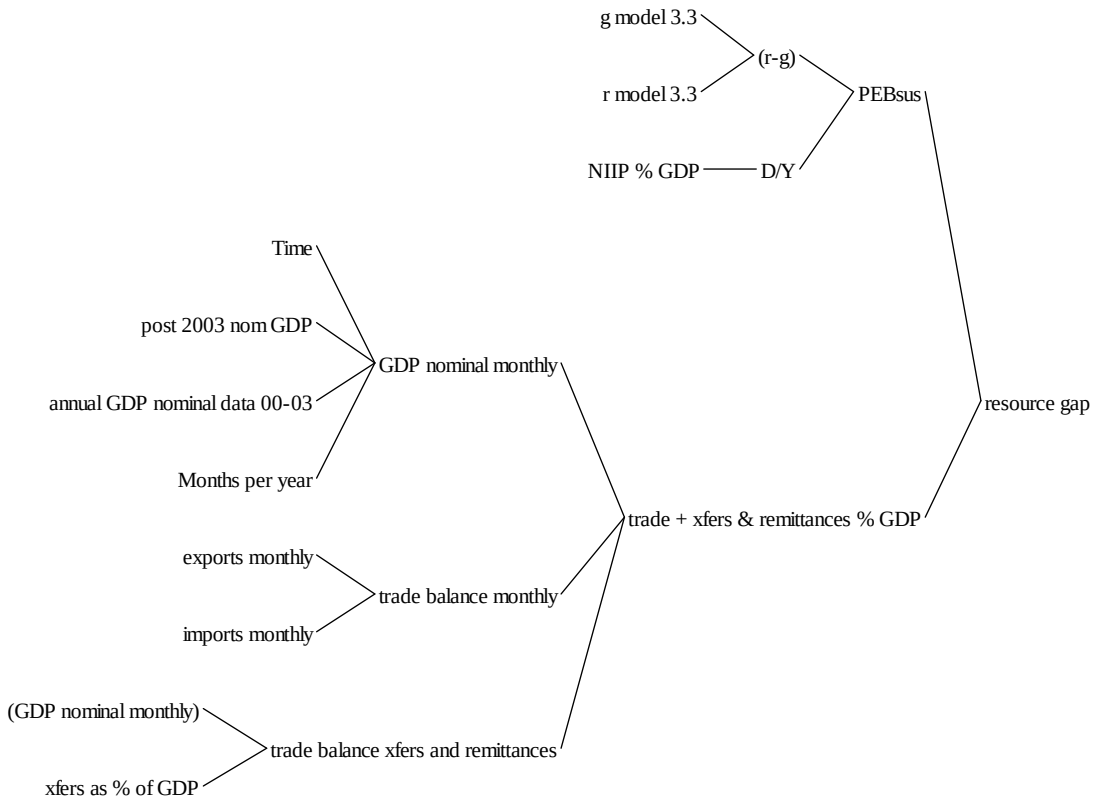

Time
FOUSI post 2003
FOUSI pre 2004
foreign owned US investments FOUSI
DoBaseRun
DoModRun
DoStrongRun
US ext debt returns Baseline
US ext debt returns Modest Adj
US ext debt returns Strong Adj
FOUSI returns
income balance monthly
US owned foreign assets 00-03
US owned foreign investments USOFI
(DoBaseRun)
(DoModRun)
(DoStrongRun)
US ext asset returns Baseline
US ext asset returns Modest Adj
US ext asset returns Strong Adj
USOFI returns

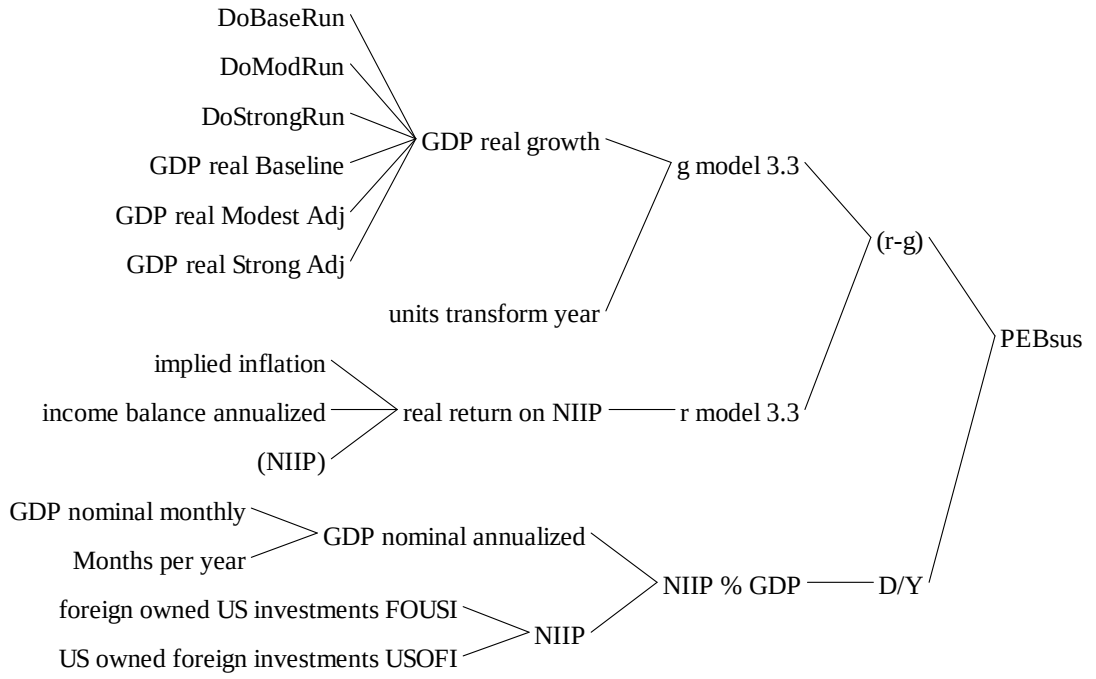

current account monthly
+
+
income balance monthly
FOUSI flow
+
+
foreign owned US investments FOUSI
FOUSI post 2003
+

Note that in the above causal loop diagram from the RSpaperModel.mdl Vensim model the ‘income balance monthly’ refers to net-NIIP-return-in-$. The loop above from the Vensim model abstracted into this presentation’s variable terminology is:

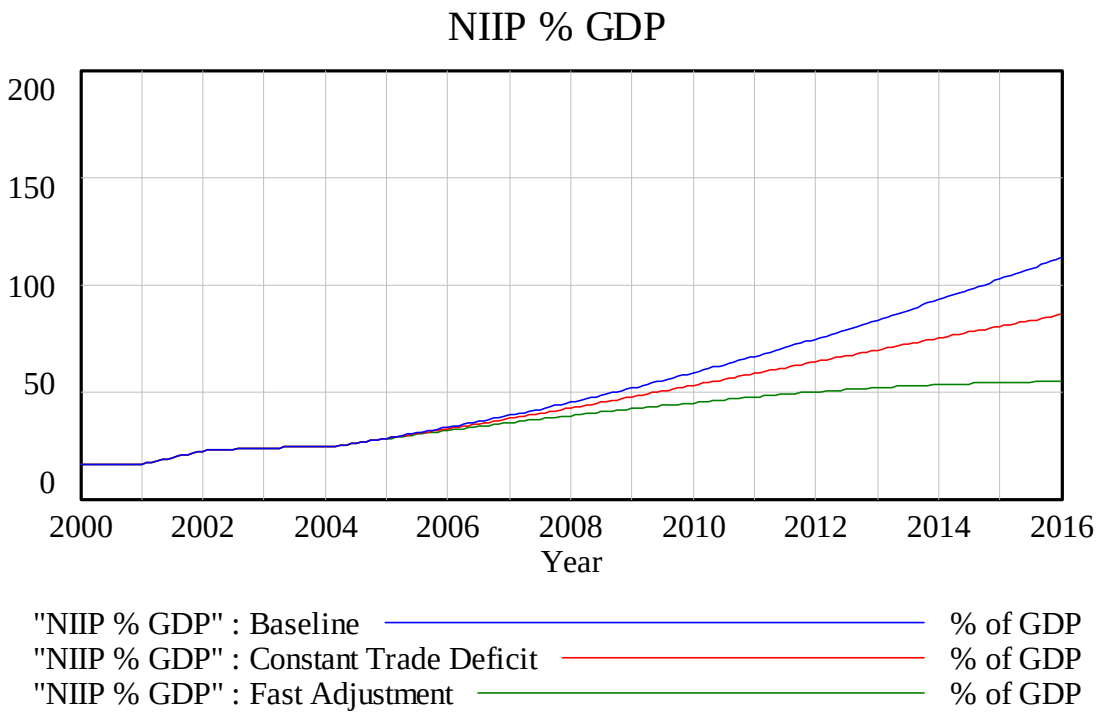


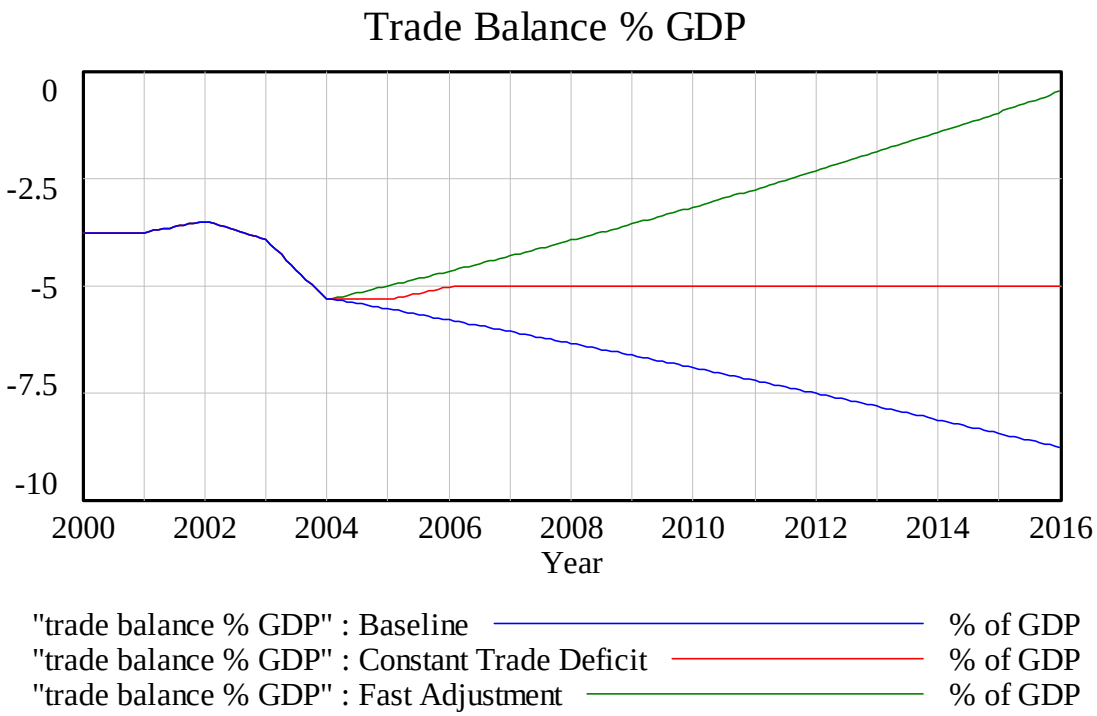
The ‘snowball’ symbol represents a “+” (reinforcing) feedback loop.

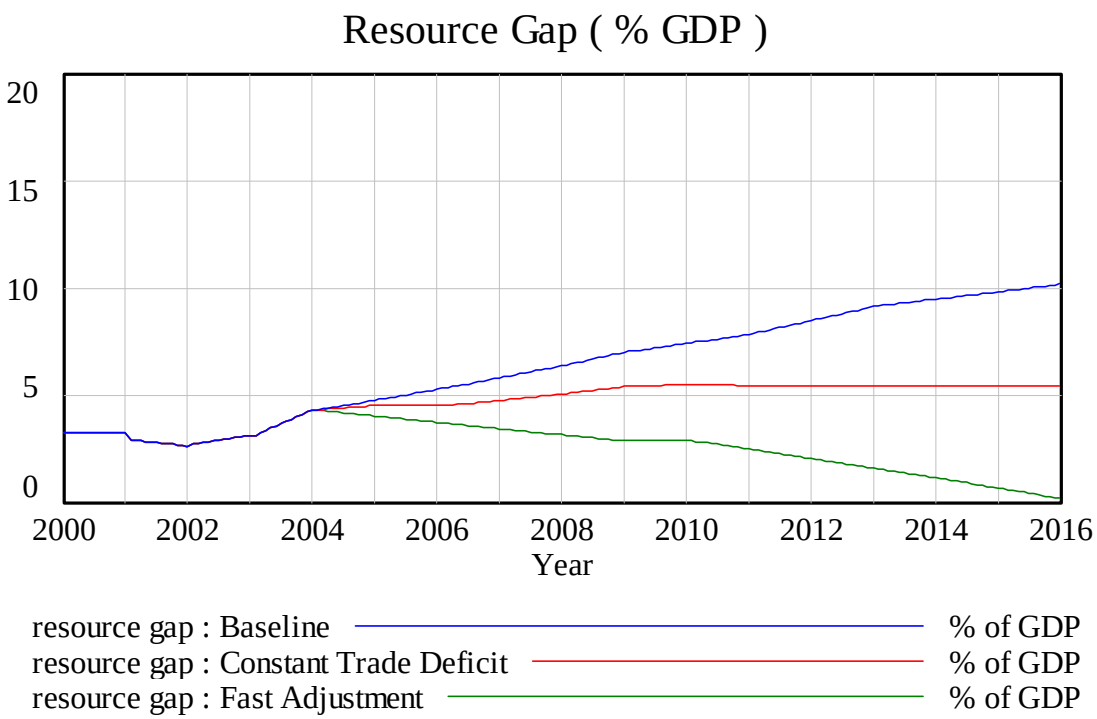

g model 3.3
(r-g)
r model 3.3
PEBsus
NIIP % GDP
D/Y
Time
post 2003 nom GDP
GDP nominal monthly
annual GDP nominal data 00-03
Months per year
resource gap
trade + xfers & remittances % GDP
exports monthly
trade balance monthly
imports monthly
(GDP nominal monthly)
trade balance xfers and remittances
xfers as % of GDP


DoBaseRun
DoModRun
DoStrongRun
GDP real Baseline
GDP real Modest Adj
GDP real Strong Adj
GDP real growth
g model 3.3
(r-g)
PEBsus
units transform year
implied inflation
income balance annualized
real return on NIIP
r model 3.3
(NIIP)
GDP nominal monthly
GDP nominal annualized
Months per year
NIIP % GDP
D/Y
foreign owned US investments FOUSI
NIIP
US owned foreign investments USOFI

The Vensim version scenario runs provide the following results that are consistent with the results presented in the R-S paper: (there are some discrepancies between the Vensim model results and those from the R-S paper shown in Appendix C but both illustrate the same essential behavior that is relevant to the conclusions)



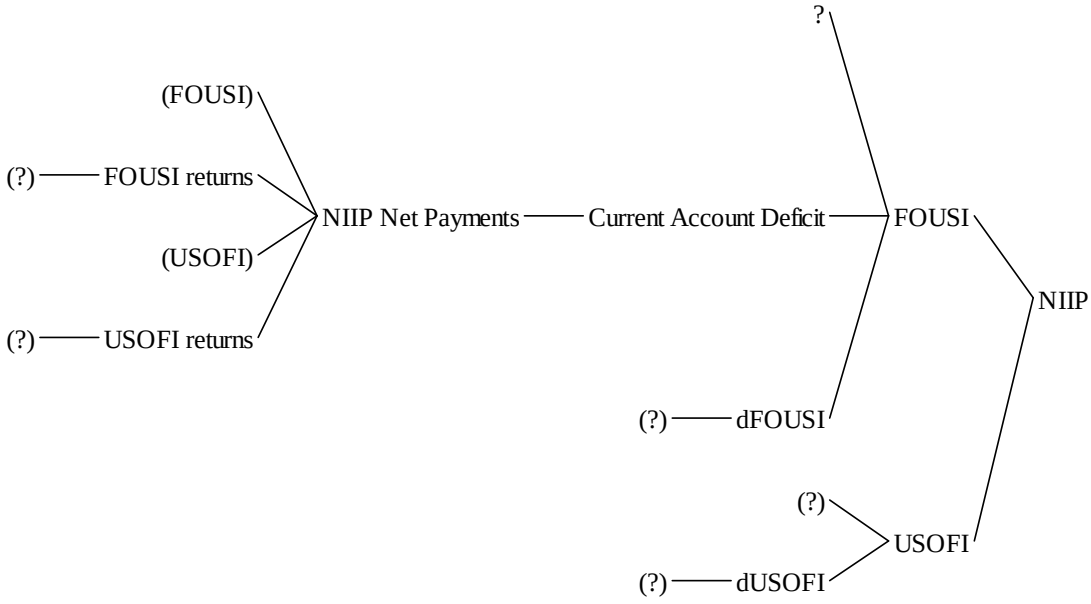


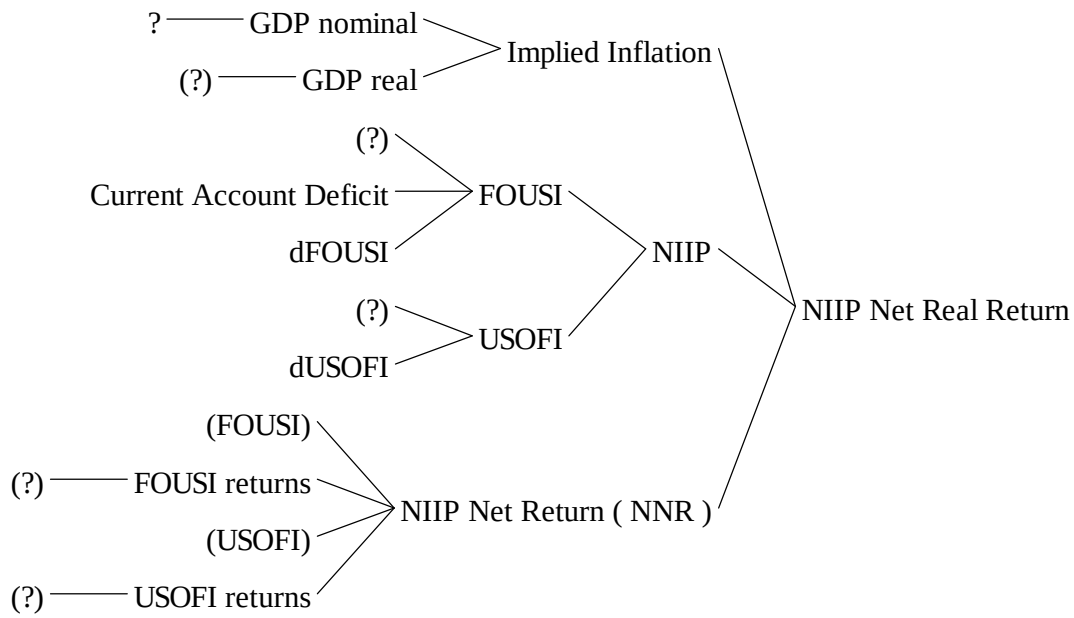


The next section shows how viewing “Causes” trees lead to considering how and where to add endogenous structure to the model.

Endogenous Structure Model Implied by Mental Models in the R-S paper

The following model had endogenous structure added to it so it should be considered a partially endogenized model; ideally models should have a limited number of exogenous feeds; this notion is addressed when View #2 is covered below. Viewing the "Causes" trees in the Vensim version of the R-S scenario model led to the following question; where do any or all of these "?" (question marks) go ? Should they link to exogenous data or should they link up to other model variables to create more endogenous structure ? Refer to the trees directly below.





Reviewing these Vensim "Causes" trees in the R-S scenario model led to the following new but related Vensim model called RSendogenousModel.mdl (available in the conference CD supplement) which has the following views:

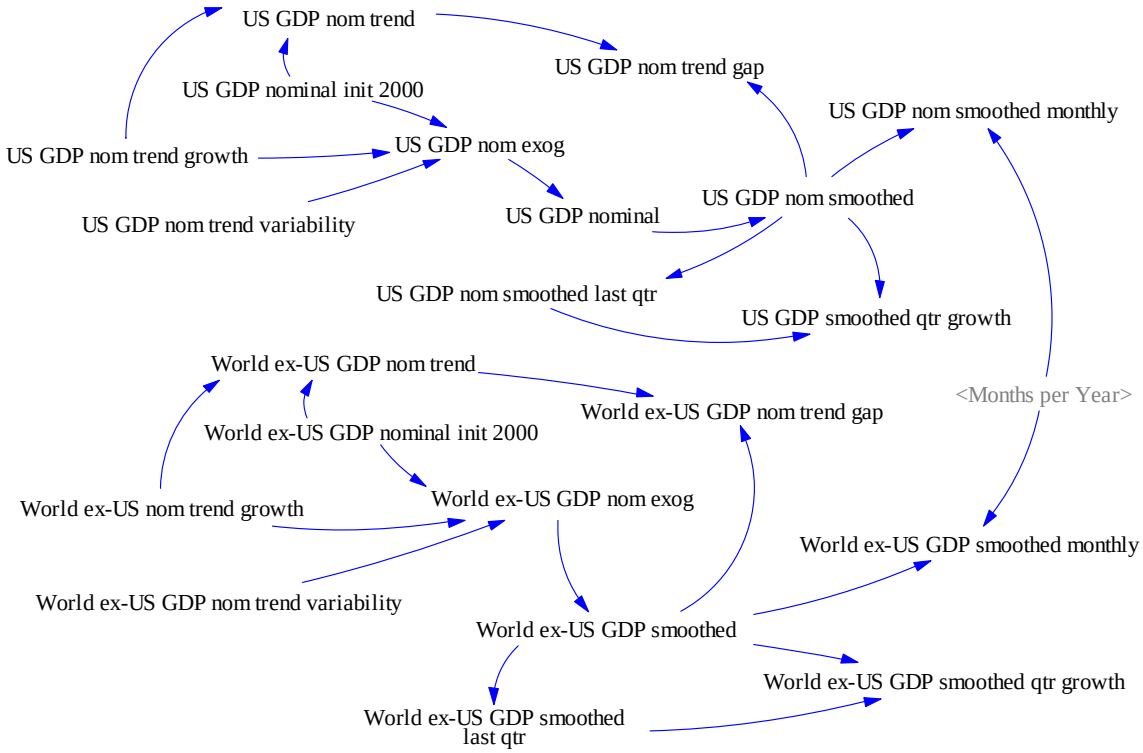
View 01: Exogenous US & World ex-US GDP
View 02: Exogenous US & World ex-US real rate
View 03: US Exports & Imports
View 04: FOUSI (Foreign Owned US Investments)
View 05: USOFI (US Owned foreign Investments)
View 06: Asian Central Bank FOUSI
View 07: Current Account & Primary Balance
View 08: FX Driven by Net Flows
View 09: R-S's Resource Gap Concept

Each Vensim View will be described in terms of its exogenous inputs, structure/functionality and endogenous linkages with other View variables. Note that the Vensim model RSendogenousModel.mdl's equations are for the most part blank and only include equations in the most elementary form in order to facilitate loop polarity analysis[13]. Therefore its only relevant in terms of

[13] See Sterman 2000 pages 143-147 for a discussion on loop polarity.

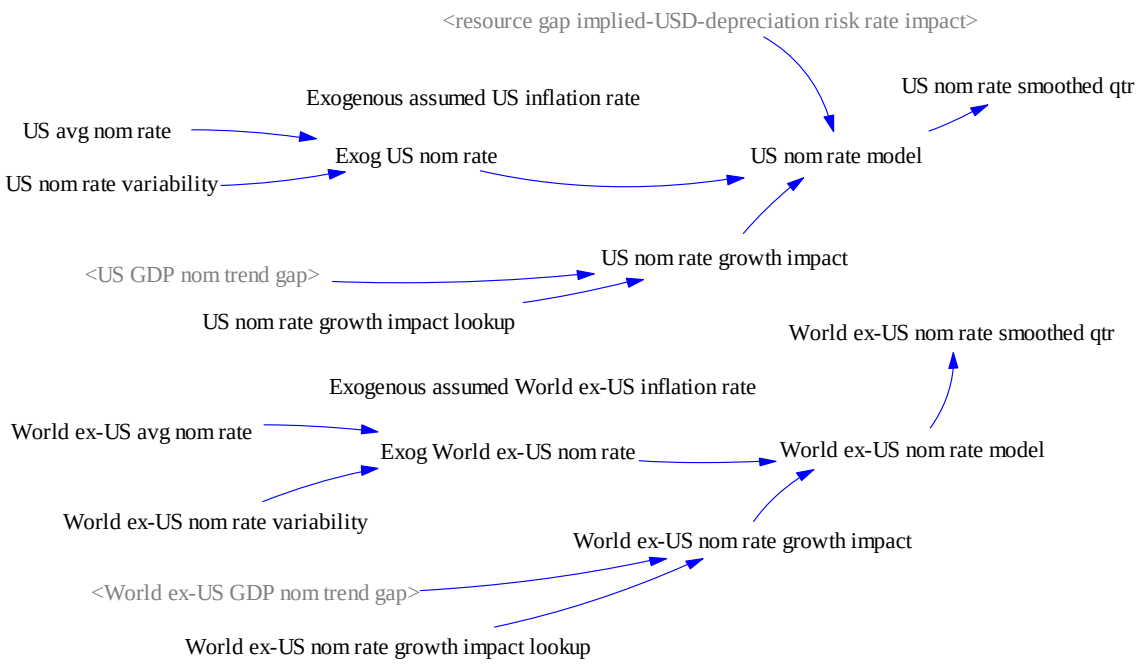
assessing the causal loop structure of the model and not simulated behavior. This should not be a detraction in that much can be communicated in terms of a discussion that focuses on the resulting endogenous loop structure. The endogenous linkages are related to discussion points in the R-S paper, predominantly from the R-S paper's Executive Summary, but also from Section 5 of the paper that discusses the policy interaction between Asian Central Banks and US policy as the Bretton Woods II Agreement. All the model Views are also in Appendix E.

View 01: Exog US & World ex-US GDP



View 01: Exogenous US & World ex-US GDP
This View shows how the US & World ex-US GDP variables are generated based on initial values as of the year 2000, a trend growth assumption, and a variability/noise generating parameter used to add noise to the series in order to create trend deviations that exist in reality and that are used to drive the behavior of other variables in the model. All variables in this view are exogenous in that they are not part of any endogenous circular linkages which are called loops in Vensim/System Dynamics parlance.

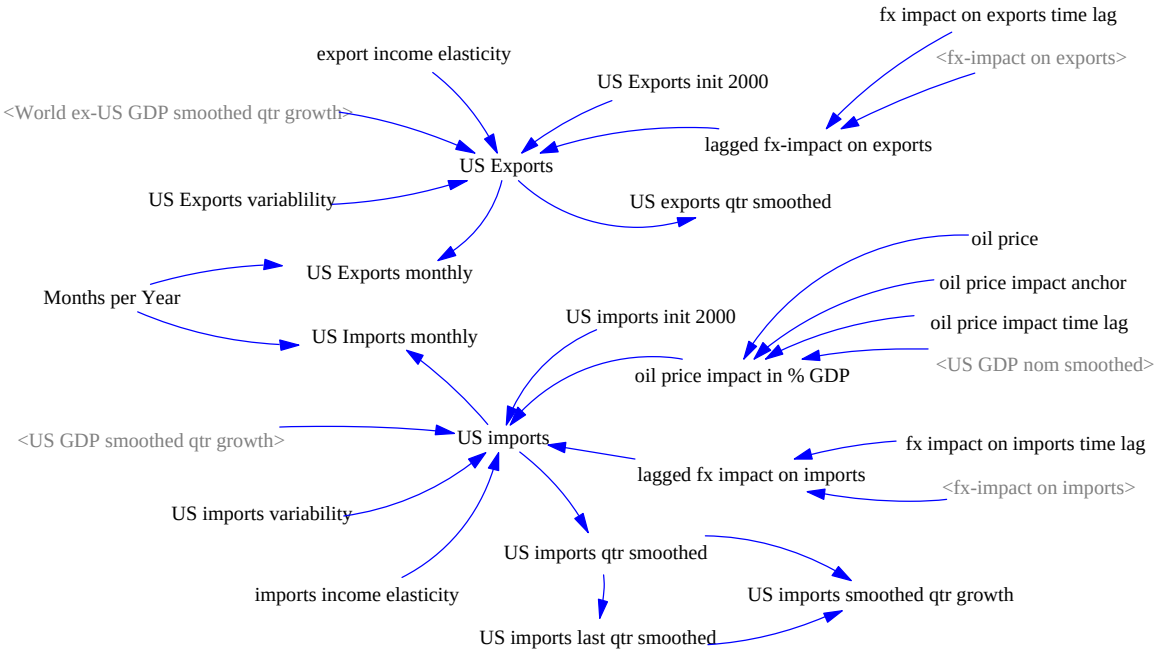
View 02: Exog US & World ex-US interest rates



View 02: Exogenous US & World ex-US real rate

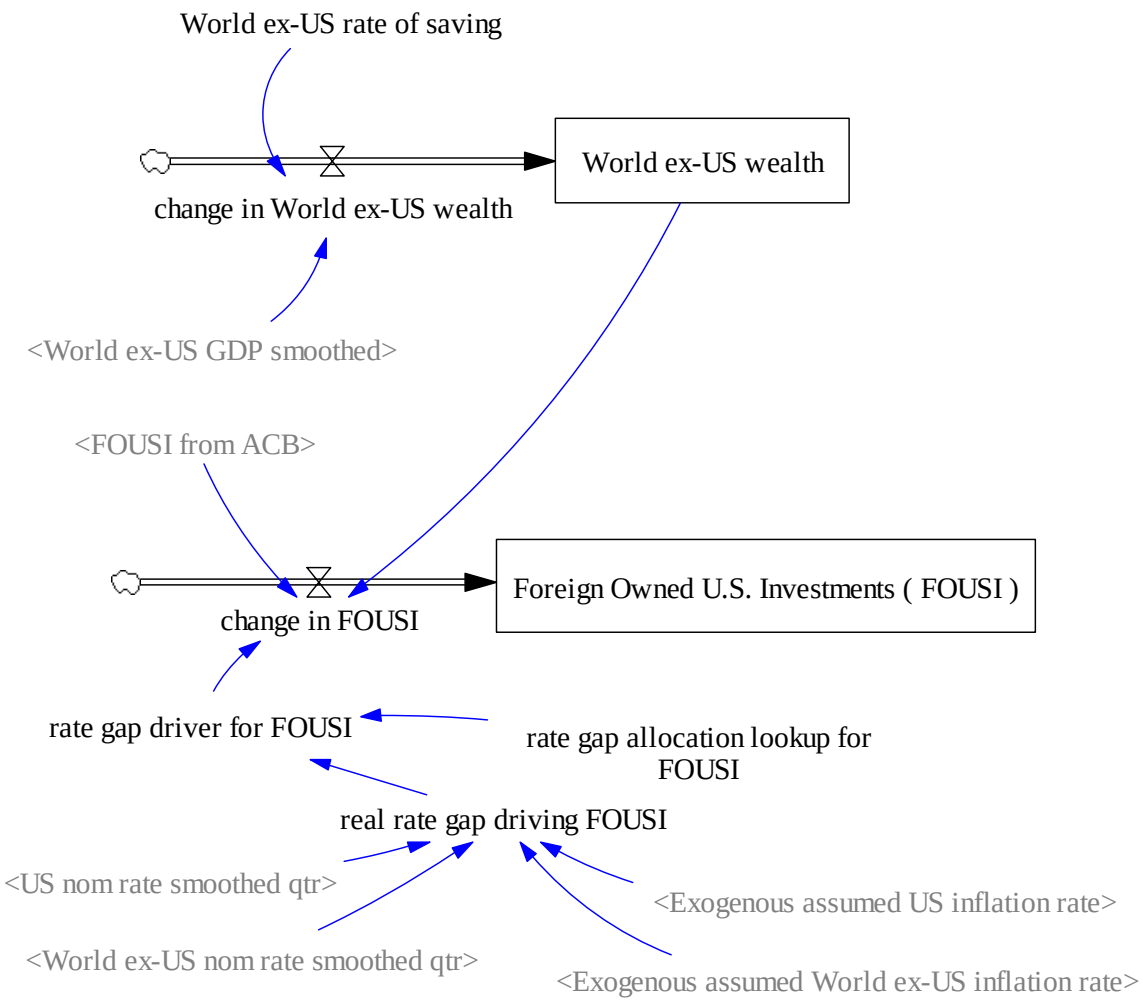
US and World ex-US interest rates have both exogenous and endogenous determinants. It needs to be stated here that such combinations of exogenous and endogenous variable drivers confound the meaningfulness of the exogenous factors. This problem is inherent in adding endogenous structure to a model that was originally driven exogenously. Regardless, the US & World ex-US rates are driven by the same construct used to drive US & World ex-US GDP growth in the previous View. The rates determined in this View are also influenced endogenously by US & World ex-US GDP trend gap variables. As stated in the R-S paper's Executive Summary; rates are influenced by growth in the economy. Additionally the US nominal interest rate referred to as "US nom rate model" is also influenced by a risk premium increment driven by the "resource gap"; see View 09, "R-S Resource Gap Concept" View.

View 03: US Exports & Imports



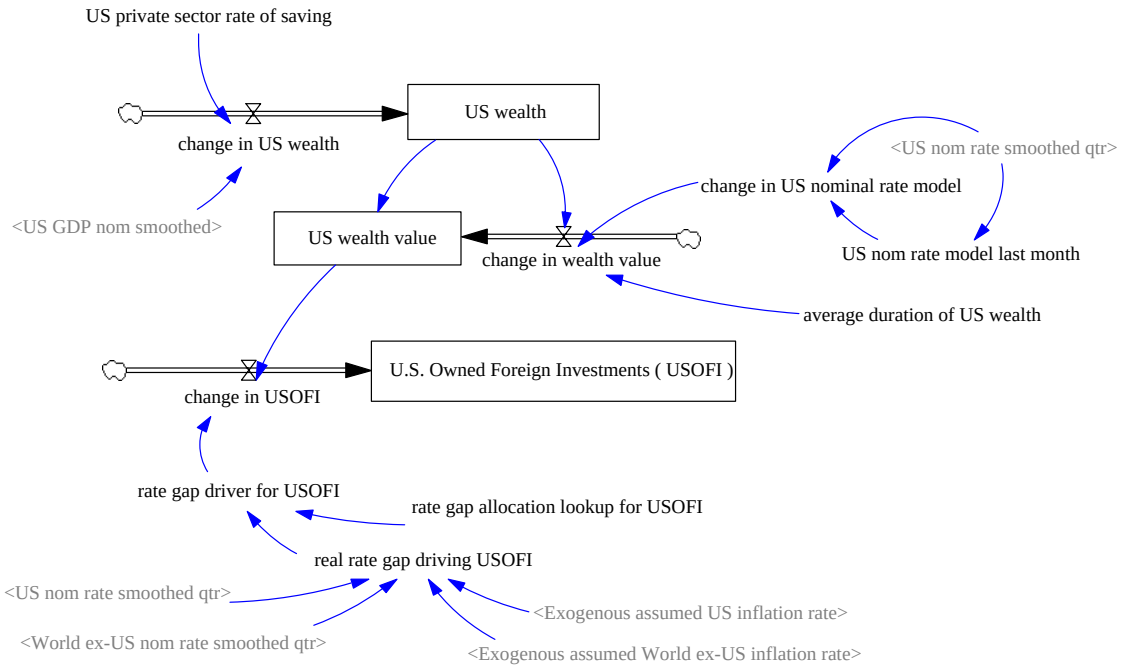
View 03: US Exports and Imports:
Exports and Imports are driven by World ex-US and US GDP respectively along with a static income elasticity parameter and a noise/variability parameter used to reflect unexpected disturbances in the series. USD value influences both exports and imports although here a price elasticity factor is not explicitly included. While oil's potential impact is discussed in the R-S paper, it is assumed constant at $42/barrel in the scenarios; see Appendix B. Here a time lag is added to delay the impact of changing oil price on imports.

View 04: FOUSI



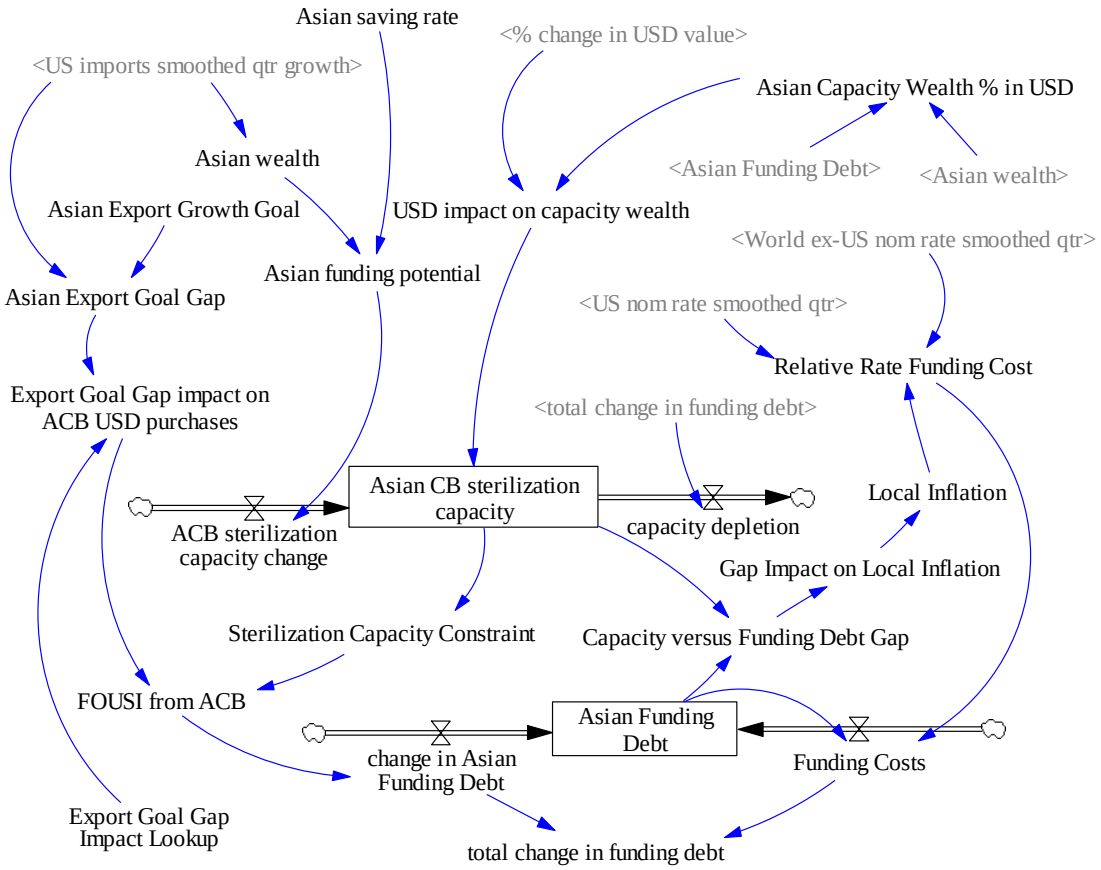
View 04: FOUSI (Foreign Owned US Investments)
Here private foreign investor's FOUSI flows are driven by their wealth and saving propensity which in turn is driven by World ex-US GDP growth. For a given stock of wealth, its flow into FOUSI is set via the relative return opportunity represented here by the spread between World ex-US and US real rates. FOUSI flows are rate-driven for private foreign investors while FOUSI flows from Asian Central Banks reflect primarily non-rate policy goals. See View 06, whose Asian CB FOUSI flow is fed in here too.

View 05: USOFI



View 05: USOFI (US Owned foreign Investments)
The rate-driven flows into FOUSI are selected here for USOFI as well. An additional structure added for USOFI (not applied for FOUSI) is the wealth influence not only from US GDP growth and the saving propensity but also from the wealth valuation impacts brought about by changes in interest rates.
“Duration” is the present-value weighted average time to cash flows expected in the future associated with the amassed wealth. “Duration” approximates the first derivative of wealth with respect to changes in the interest rate where a rise in rates lowers wealth value.

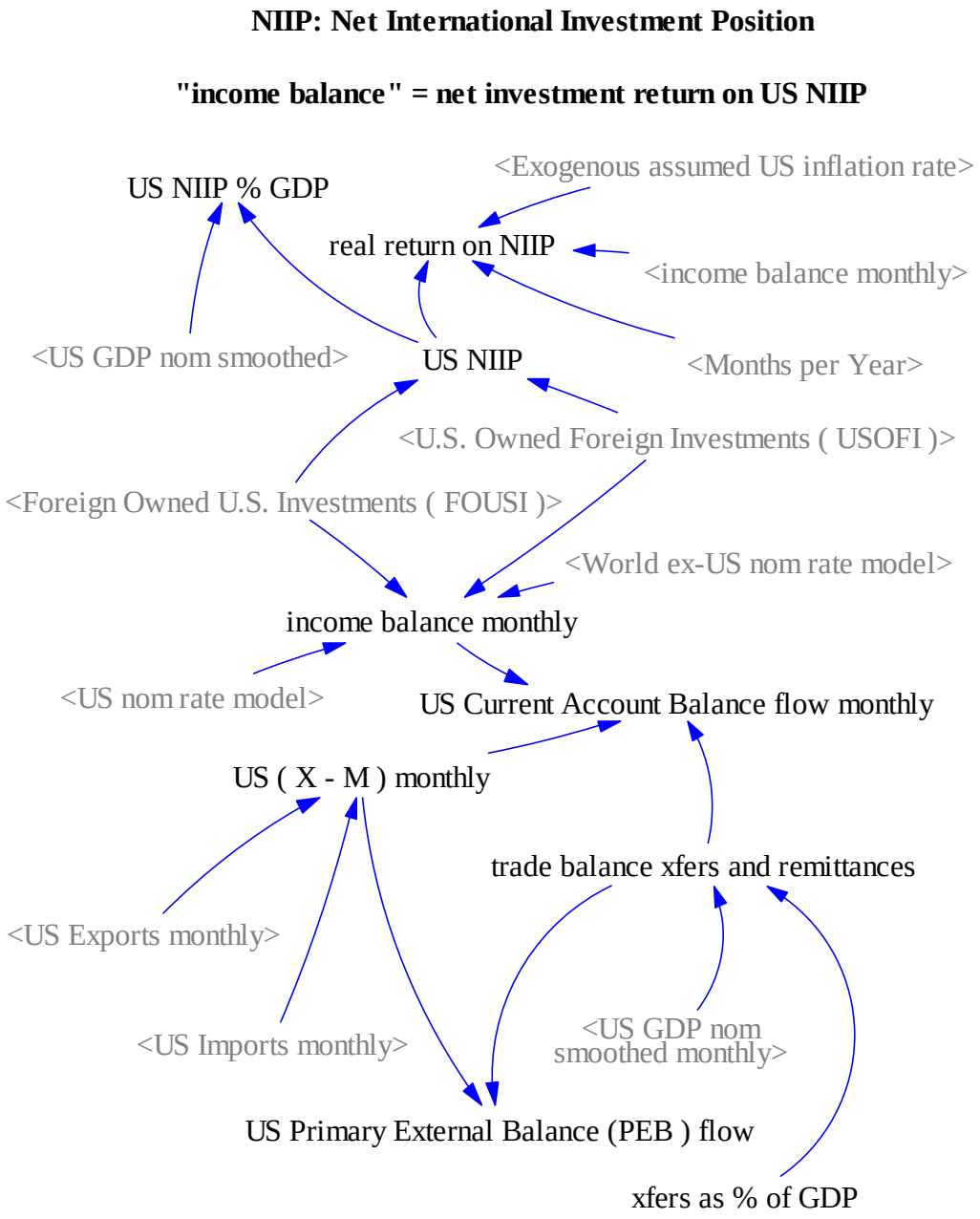
View 06: Asian CB FOUSI



View 06: Asian Central Bank FOUSI

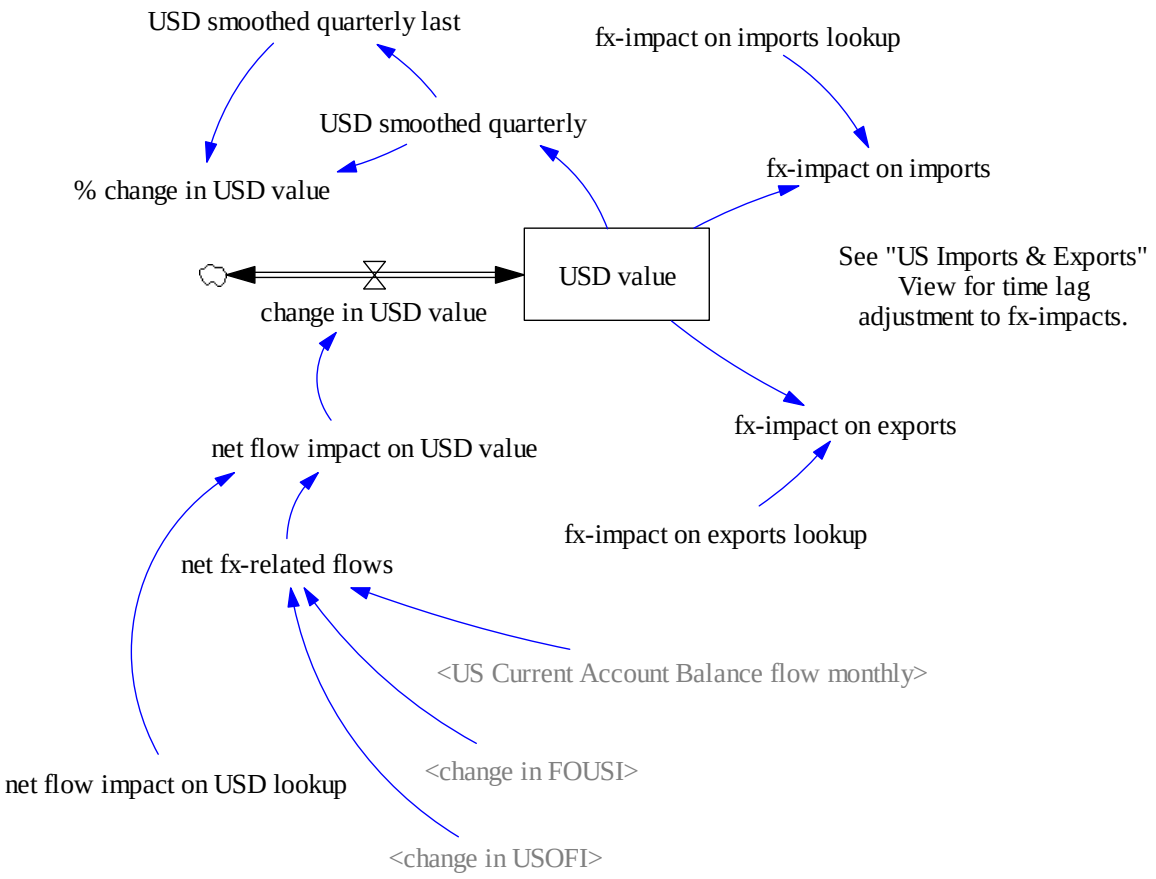
This View is the most involved and the most tenuous attempt at adding endogenous structure to the R-S scenario simulation model. The key factors include the “Asian Export Goal” which influences ACB FOUSI flow based on the difference between Asia’s Export growth goal and the average rate of US import growth. US imports influence the ACB FOUSI flow but also act as an inflow to Asian wealth which helps determine the capacity of the ACB to sterilize FOUSI purchases with debt issuance. ACB FOUSI flows that are sterilized expand Asian Funding Debt. Asian Funding Debt growth is constrained by the wealth-driven capacity of ACB to sterilize ACB FOUSI flows. When Asian Funding Debt exceeds its sterilizing capacity, inflation erupts which feeds back to raise Debt Funding costs and hence Asian Debt Funding. While this structure is an attempt to reflect the discussion in Section 5 of the R-S paper; the reader is invited to scrutinize it and presume flaws in my attempt here. Regardless, note the influences that drive policy here; US imports versus the Asian export growth goal, wealth-driven debt funding capacity versus debt outstanding that puts constraints on the process and the constraining impact from endogenously aggravated inflation. Also note the influence of US versus World interest rates in determining relative debt costs along with local inflation.

View 07: Current Account and Primary Balance



View 07: Current Account & Primary Balance
This View's variables do not add any endogenous structure per se, it represents the creation of a set of variables derived from variables in other views.

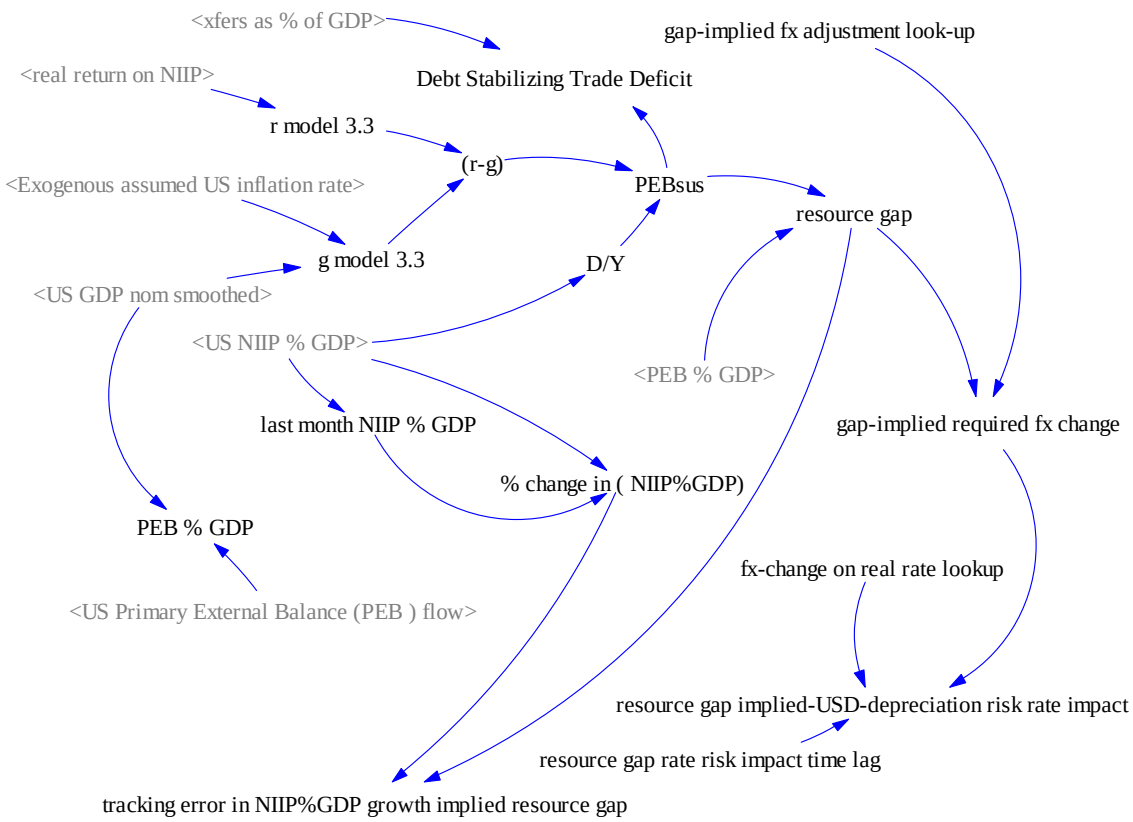
View 08: FX Driven by Net Flows



View 08: FX Driven by Net Flows

This is simple enough; net trade and financial flows determine changes in USD value. The net flows here refer to current account flow, changes in FOUSI and changes in USOFI. Net flows are mapped into USD value changes via a lookup function whose general character is such that net inflows in USD raise USD value and net flows out of USD reduce it. The intent here is a simple and feasible structure to ‘endogenize’ USD in the model. Here within the View the impact of USD on imports and exports are shown. A key view-to-view linkage involves the “% change in USD” variable. This variable impacts “Asian Central Bank Sterilization Capacity” in Asian CB FOUSI View (View 06). This behavior is discussed in Section 5 of the R-S paper. See above and View #6 of Appendix E.

View 09: R-S's Resource Gap Concept



View 09: R-S's Resource Gap Concept

While the "resource gap" was introduced in the Synopsis section of this paper; reviewing the structure as represented in this View is worthwhile to help nail down this important metric. The View supports all the variables needed to calculate "resource gap" where

Resource gap = PEBsus – PEBactual
*PEBsus = (real NNR – real growth) * (NIIP / GDP)*

The new endogenous feature added in this View is the US interest rate risk premium adjustment added here based on a two-stage process in which the resource gap implies a needed trade adjustment which in turn implies a needed change in USD value. The change in USD in turn represents depreciation risk that requires a greater interest rate risk premium to compensate foreign investors in USD assets from the implied USD depreciation's value impact on their USD investments. The resulting adjustment in US rates can be seen in View #2.

The "Endogenized R-S Scenario Simulation Model" So What ?

In comparing the initial Vensim model which replicated the R-S paper model and the new model with endogenous structure there is a key difference to note; the presence of time lags, variable smoothing and averages that represent different forms of time delays in the variable interactions. These time delays determine much of the dynamic behavior when models have endogenous loop structure[14]. While this delay-determined behavior can't be observed here with only causal loop structure to work with, the delays represent a crucial difference between the two models. Note that while the authors exclude delays from their scenario simulations they do stress the crucial importance of delays when discussing the importance of starting the required adjustment process earlier rather than later. [15]

Recall that the replicated R-S model had only one loop involving CAD to FOUSI to FOUSI returns and back to CAD. The new model with added endogenous structure now has many loops. For example the "nom US rate model" variable is included in 168 loops, resource gap in 91 loops and NIIP/GDP is in 11 loops. To investigate a tractable example take a look at the 11 loops that NIIP/GDP is included in to see what it implies about model behavior. Refer to the list in Appendix F. The exercise that can be done with each of these loops is to follow each loop variable by variable to determine the step-by-step causal linkage; that is ask at each variable-to-variable intersection in the loop; does one variable make the next variable go up or down as that variable goes up or down. Looking at the first loop in Appendix F for example ; does "D/Y" make "PEBsus" go up or down as it goes up or down; does "resource gap" go up or down as "PEBsus" goes up or down ? Doing this through the entire list of variables in each loop gets a complete circle of "+"s and "-"s where "+" is assigned when one variable change makes the next variable move in the same direction and a "-" is assigned where one variable's change makes the next variable change in the opposite direction.[16] In simplistic terms; if there are an odd number of "-" signs in the loop it is a balancing loop where an increase in one variable occurs; the loops' variable-to-variable linkages tend to reduce that same variable after the impacts transition through the loop. If there are none or an even number of "-" the loop is reinforcing. Balancing loops are also referred to as negative feedback loops and reinforcing loops are referred to as positive feedback loops.[17] Doing this kind of analysis for all the loops in a model leads to an understanding of how all variables impact all other variables. This loop analysis leads to an understanding of the modeled process that is causally-based, under the control of the modeler and an analysis that can be robust over time and across various economic environments.

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[14] See Sterman 2000 Chapter 11 on Delays.

[15] See the second to last paragraph on page 6 and the 1st full paragraph at the top of page 59 of the R-S paper where delays are discussed.

[16] See Sterman 2000 pages 143 – 147 for guidance on loop polarity

[17] See Sterman 2000 Chapter 1 or more specifically pages 12-20.

With this kind of modeling; historic data can be compared to the model results to see how the model relates to real world phenomenon but with this kind of model there is never a need to cede accountability of the model results to the data; a problem that is pervasive with most data-driven models. The point here is that researchers and model developers need to be accountable for the model results; most often today researchers of data-driven models cede their accountability to the data.

Doing this kind of loop analysis with the new model would be a huge task but there are special analytical techniques that do the job efficiently. Ultimately as with any research or modeling approach the benefit is always in the discipline the approach brings to the research process. Unfortunately not much of substance can be done here without the new model's variable equations carefully constructed so as to relate to robust assessments of real world behavior.

The issue with adding all these loops to the original R-S model and its merit should be viewed in terms of the insights into System Dynamics modeling Jay Forrester has communicated (see footnote 7) in terms of the importance building models by constructing all its component parts. The huge number of loops created in the 'endogenized' R-S model, using the authors' own mental models reflects the model's component parts and their interactions. Only by investigating all these component parts and their interactions can one come to an understanding of the model that is consistent with the mental models reflected in the R-S paper.

In the **R-S paper's Analytical Core: Scenario Simulations** section above it was noted that the graphics of NIIP/GDP reflected a role in the pending state transition but not the state transition itself; with the added endogenous structure; it is possible to build a simulation model that can illustrate the transition dynamics as well.

Conclusion

The R-S paper's mental models imply an extremely complex causal loop structure as represented by my attempt to create such a structure based on some of their own rich mental models. How is this perspective reconciled with the scenario simulation model they actually used ? Does this mean that the authors created a similarly complex model, walked through hundreds of model structure loops, assessing their reinforcing or balancing nature and then weighed the odds of which set of loops (reinforcing or balancing) would come to dominate in a given economic environment ? In a manner of speaking yes they did. Through some combination of data analysis, experience, studying history and theoretical economic insights the authors concluded that the reinforcing external debt burden loop would come to dominate the situation and apply pressures that would force a state transition from one that is currently unsustainable to another that is sustainable that will lead to lower growth in the US unless Asia spends more. The endogenous causal structure presented reflects a more explicit and integrated representation of that difficult task.

The limited focus and individual effort of this paper means that it omits many important issues and factors raised in the R-S paper. For example the authors' discussion of fiscal deficit policy and its impact the transition process is excluded. Also the most important step of the System Dynamics methodology; that of creating a simulation model from the causal structure that in turn enables an analysis of behavior is excluded. Learn what you can from it but understand its shortcomings as well. The author would appreciate a heads up on any errors found in spite of an effort to remove any and all beforehand.

Footnotes:

[1] "The US as a Net Debtor: The Sustainability of the US External Imbalances" by Nouriel Roubini and Brad Setser (November 2004 draft). See References.

[2] Vensim is a System Dynamics modeling software product of Ventana Systems, Inc. See References.

[3] See Sterman 2000 pages 12-13 for a discussion of feedback loops both positive and negative.

[4] See Sterman 2000 page 95 for a discussion of the importance of endogenous versus exogenous factors. See Sterman 2000 Section 1.1 pages 16-18 for a discussion of 'mental models'.

[5] John D. Sterman's text "Business Dynamics: Systems Thinking and Modeling for a Complex World" 2000, McGraw-Hill provides an excellent introduction to System Dynamics. Jay W. Forrester's application of engineering control theory to a broader group of problems including those in the social sciences in the 1950s came to be known as "System Dynamics". Forrester's book "Industrial Dynamics" is a timeless classic on System Dynamics. See References.

[6] Sterman 2000 Chapter 5 and Vensim DSS Reference manual on Structural Analysis tools.

[7] See Forrester 1961 Section 4.2's "Basis for a Model" on page 54 where the value of using 'descriptive information' comes from its use in a from-the-ground-up design perspective in modeling versus focusing on statistics and aggregated numerical data. The distinction here is that constructing a model from descriptive information of the separate parts of a model leads to a causally-based model while modeling based on aggregate numerical data and statistics only 'explains' the total process but lacks causality.

[8] See Sterman 2000 Chapter 4 "Structure and Behavior of Dynamic Systems"

[9] Current account deficit: CAD
See Appendix A for list of variables and their relationships.

[10] The rationale for this stock-flow relationship lies in the assumption that a country's or currency region's trade balance needs to be matched by an equal and opposite financial flow if the foreign exchange rate between the country and the rest of the world is to remain unchanged. From a System Dynamics perspective this relationship implies no delays, information smoothing or feedback between trade flows, financial flows and the foreign exchange rate. Note that R-S define NIIP = FOUSI – USOFI while the BEA defines NIIP = USOFI – FOUSI; it makes no difference as long as the approach is used consistently.

[11] Asian Central Banks also amassed large US dollar reserves in the form of US Treasuries in the aftermath of the regions' 1997 meltdown as a store of reserves in dollars to use to strengthen their currencies in the event of a similar episode in the future.

[12] "Results" refer to those tabulated in Appendix C and the "Graphics" are those illustrated on pages 14-15 of this paper. Also see the R-S paper for graphics on pages 31 and 32 and results on pages 33-35 and page 42.

[13] See Sterman 2000 pages 143-147 for a discussion on loop polarity.

[14] See Sterman 2000 Chapter 11 on Delays.

[15] See the second to last paragraph on page 6 and the 1st full paragraph at the top of page 59 of the R-S paper where delays are discussed.

[16] See Sterman 2000 pages 143 – 147 for guidance on loop polarity

[17] See Sterman 2000 Chapter 1 or more specifically pages 12-20.

References:

Forrester, Jay W., 1961. *Industrial Dynamics,* Productivity Press, Cambridge MA.

Roubini, Nouriel & Setser, Brad. 2004. *The US as a Net Debtor: The Sustainability of the US External Imbalances* , New York. New York University Stern School of Business. Available on the World Wide Web at <http://www.stern.nyu.edu/globalmacro/Roubini-Setser-US-External-Imbalances.pdf>

Sterman, John D., 2000. *Business Dynamics Systems Thinking and Modeling for a Complex World,* The McGraw-Hill Companies Inc.

Vensim, The Ventana Simulation Environment, Vensim DSS32 Version 5.4a, Ventana Systems Inc. (includes Reference, Modeling Guide and User's Guide manuals) Available on the World Wide Web at <http://www.vensim.com>

Appendix A: Variable abbreviations list with relationships:

Current Account Deficit:	CAD
Net International Investment Position:	NIIP
Foreign-Owned US Investments:	FOUSI
US-Owned Foreign Investments:	USOFI
NIIP Net Return:	NNR
Real NIIP Net Return:	NNRreal
Gross Domestic Product:	GDP
Primary External Balance:	PEB
Sustainable Primary External Balance:	PEBsus

NIIP = FOUSI – USOFI

NNR-in-$ = NIIP*NNR
= FOUSI*return-on-FOUSI – USOFI*return-on-USOFI

PEB = (Exports – Imports) – Transfers and Remittances

Current account balance = PEB - NNR-in-$

CAD is a deficit; if its value is > 0 then the corresponding current account balance is negative.

CAD = (-1*PEB) + NNR-in-$

PEB = current account balance – NNR-in-$
= (-1*CAD) – NNR-in-$

PEBsus = (NNRreal – real GDP)*(NIIP/GDP)
= in % GDP terms, the PEB that leaves NIIP/GDP stable according to the R-S paper.

Resource Gap = PEBsus – PEBactual
= degree of change required in PEB to reach sustainable NIIP/GDP

for example if PEBsus = -1.3% and PEBactual = -5.3%
PEBactual needs to improve 4% of GDP in order to reach an economic environment in which NIIP/GDP is stable.

The R-S paper uses NIIP and the term “net external debt” interchangeably even though NIIP involves fixed income, equity, foreign direct investment and bank loans. The authors address this in their paper’s footnote #44.

Appendix B : R-S paper scenario simulation model assumptions:

Key Assumptions	Baseline	Modest Adjustment	Fast Adjustment
Nominal GDP Growth	0.051	0.051	0.051
Real GDP Growth	0.035	0.035	0.035
Import Growth	0.075 (avg of past 14 years)	0.051 (same as nominal GDP)	0.051
Export Growth	0.055 (avg of past 14 years)	0.087 (in 2005 then .051 after 2005	0.09
Income Payments	Between 2004 and 2008, the nominal returns on external assets held by the US will rise from 3.7% to 4,7% and the return foreigners receive on the US assets (US liabilities) will increase from 2.4% to 4.8%. Growing US debt will lead the returns foreigners demand in US to rise to 5.1% in 2010 and 5.7% in 2012.	Between 2004 and 2008, the nominal returns on external assets held by the US will rise from 3.7% to 4,7% and the return foreigners receive on the US assets (US liabilities) will increase from 2.4% to 4.8%. After 2008, both rates then converge to 5.1%, to the nominal interest rate while the real rate converges to the rate of real GDP.	Between 2004 and 2008, the nominal returns on external assets held by the US will rise from 3.7% to 4,7% and the return foreigners receive on the US assets (US liabilities) will increase from 2.4% to 3.6%. After 2008, returns on US liabilities rise to 4.1%.
Implicit exchange rate assumption	Real exchange rate remains around 93 (on JP Morgan real exchange rate index)	Real exchange rate depreciates - roughly to the mid or upper 80s on the JP Morgan real index -- and then stabilizes.	Real exchange rate depreciates substantially over time.
Implicit fiscal policy adjustment	Fiscal deficit remains @ 4% of GDP.	Fiscal deficit remains constant or is reduced somewhat.	Fiscal deficit is reduced to 2% of GDP by 2008 and eliminated by 2012.
Implicit oil price assumption	Annual average price of WTI is $42/ barrel	Annual average price of WTI is $42/ barrel	Annual average price of WTI is $42/ barrel

Appendix C: R-S paper scenario simulation model results:

The term "income balance" = -1*NNR-in-$
where NNR = NIIP Net Return as defined in Appendix A

Flow indicators– Base scenario

	2004	2008	2010	2012
Trade balance (% of GDP)	-5.21	-6.32	-6.91	-7.54
Vensim model replication	-5.55	-6.64	-7.22	-7.82
Primary External balance (% of GDP)	-5.87	-6.99	-7.58	-8.2
Vensim model replication	-6.05	-7.14	-7.72	-8.32
Income balance (% of GDP)	0.15	-1.63	-3.05	-4.6
Vensim model replication	-0.14	-2.47	-3.49	-5.05
Income as % of exports --	--	16	31	46
Vensim model replication	2	27	38	55
Current account (% of GDP)	-5.72	-8.61	-10.63	-12.8
Vensim model replication	-6.19	-9.61	-11.21	-13.37
Current account as % of exports	59	86	106	127
Vensim model replication	69	106	123	145

Flow indicators – constant trade deficit

	2004	2008	2010	2012
Trade balance (% of GDP)	-5.21	-5.01	-5.01	-5.01
Vensim model replication	-5.32	-5.01	-5.01	-5.01
Primary External balance (% of GDP)	-5.87	-5.62	-5.62	-5.62
Vensim model replication	-5.82	-5.51	-5.51	-5.51
Income balance (% of GDP)	0.15	-1.53	-2.6	-3.15
Vensim model replication	-0.13	-2.28	-2.91	-3.46
Income as % of exports --	--	15	26	32
Vensim model replication	1	25	32	38
Current account (% of GDP)	-5.72	-7.15	-8.22	-8.77
Vensim model replication	-5.95	-7.79	-8.42	-8.97
Current account as % of exports	59	72	83	88
Vensim model replication	67	85	92	98

Flow indicators – strong, smooth adjustment

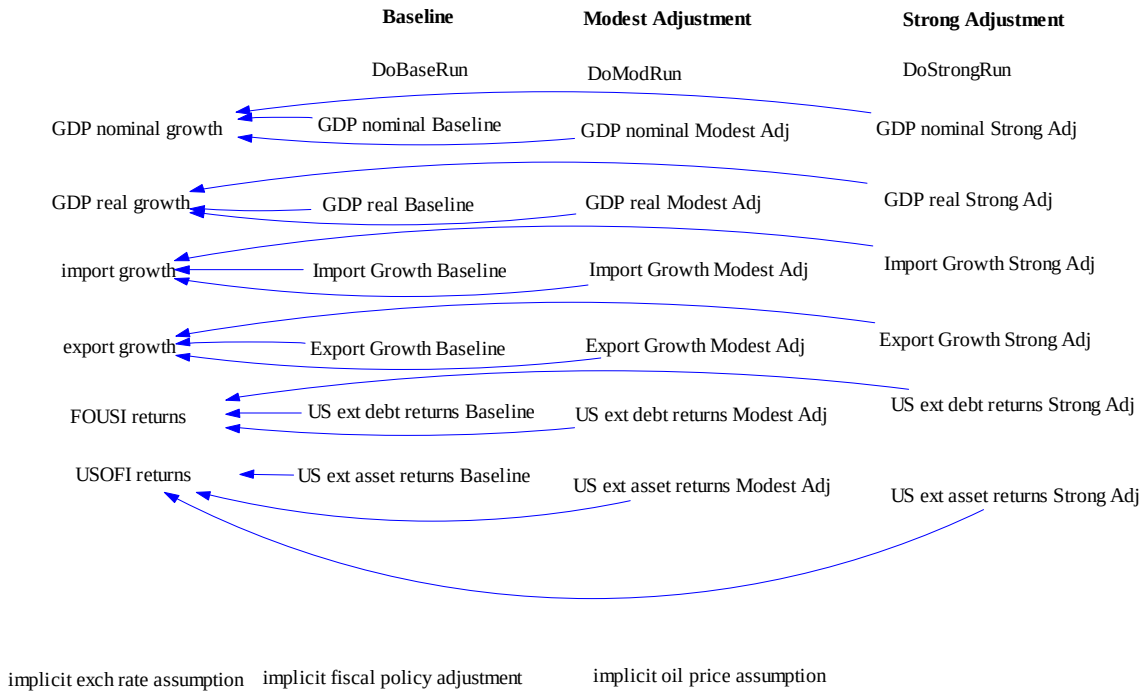
	2004	2008	2010	2012
Trade balance (% of GDP)	-5.21	-3.67	-2.82	-1.9
Vensim model replication	-5.01	-3.57	-2.77	-1.90
Primary External balance (% of GDP)	-5.87	-4.29	-3.43	-2.51
Vensim model replication	-5.51	-4.07	-3.27	-2.40
Income balance (% of GDP)	0.15	-0.77	-1.53	-1.75
Vensim model replication	0.08	-0.91	-1.63	-1.83
Income as % of exports --	--	7	13	13
Vensim model replication	-1	9	14	15
Current account (% of GDP)	-5.72	-5.08	-4.96	-4.27
Vensim model replication	-5.44	-4.98	-4.90	-4.23
Current account as % of exports	59	45	41	33
Vensim model replication	59	47	43	34

Scenario simulation Results at end 2010	**Primary External Balance**	**Real Net NIIP Return**	**Real GDP**	**Real NIIP Net Return Less Real GDP**	**NIIP/GDP**	**Debt Stabilizing Trade Deficit**	**Resource Gap**
Baseline	7.60%	3.80%	3.50%	0.30%	66%	-0.20%	7.80%
Vensim replication	7.71%	3.66%	3.50%	0.16%	66%	-0.61%	7.83%
Constant Trade Deficit	5.60%	3.30%	3.50%	-0.20%	59%	0.10%	5.50%
Vensim replication	5.51%	3.38%	3.50%	-0.12	58%	-0.43%	5.44%
Fast Adjustment	3.40%	1.90%	3.50%	-1.60%	49%	0.80%	2.60%
Vensim replication	3.27%	1.83%	3.50%	-1.67%	47%	0.29%	2.48%

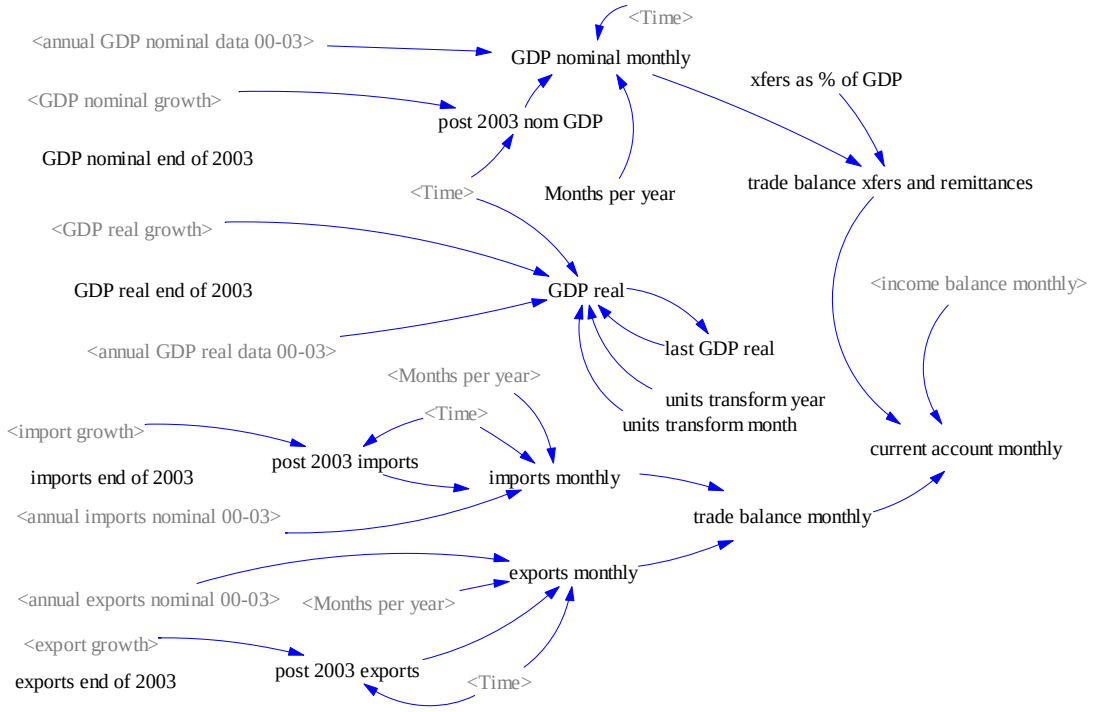
Appendix D: Views of Replicated R-S Scenario Simulation Model

from RSpaperModel.mdl

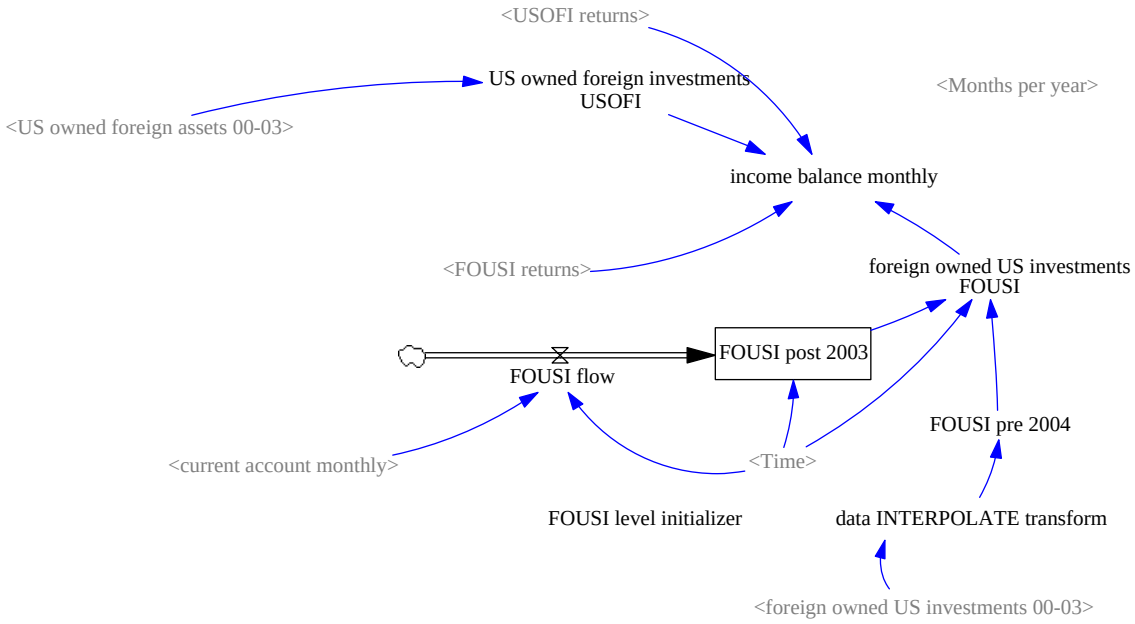
View #1 : Model 3.2 Scenarios



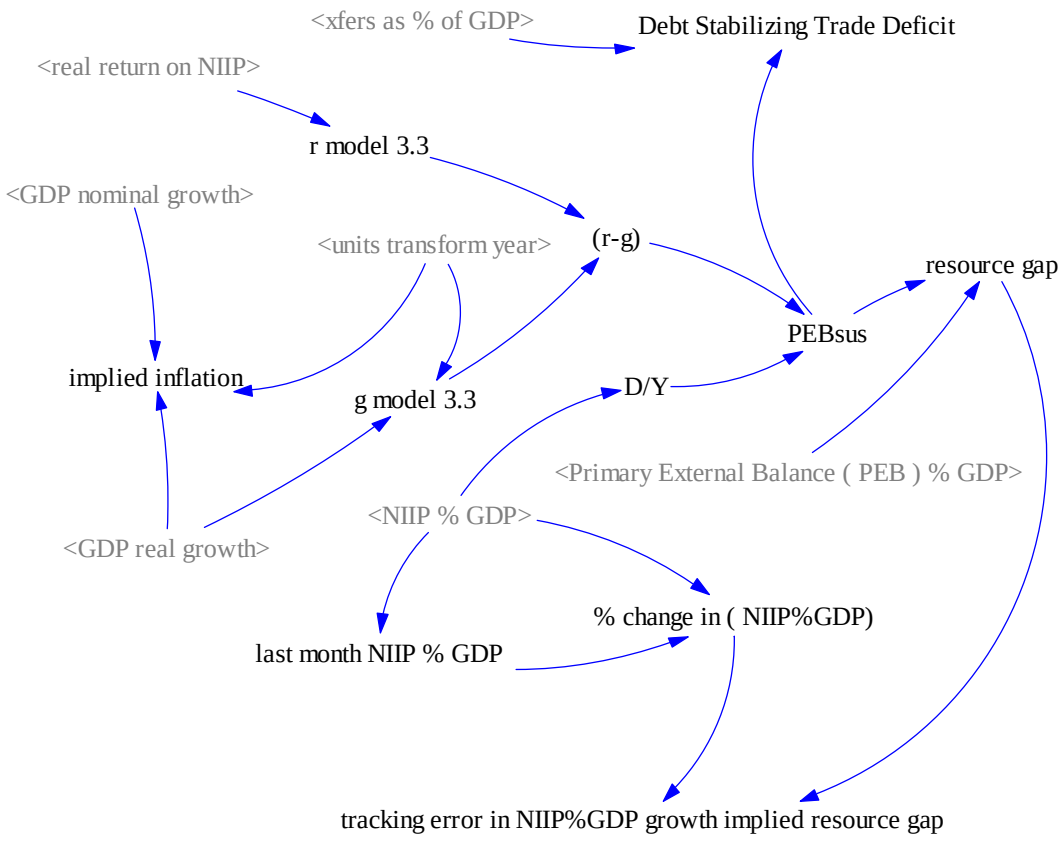
View #2 : sect 3.2 model GDP, EXP, IMP



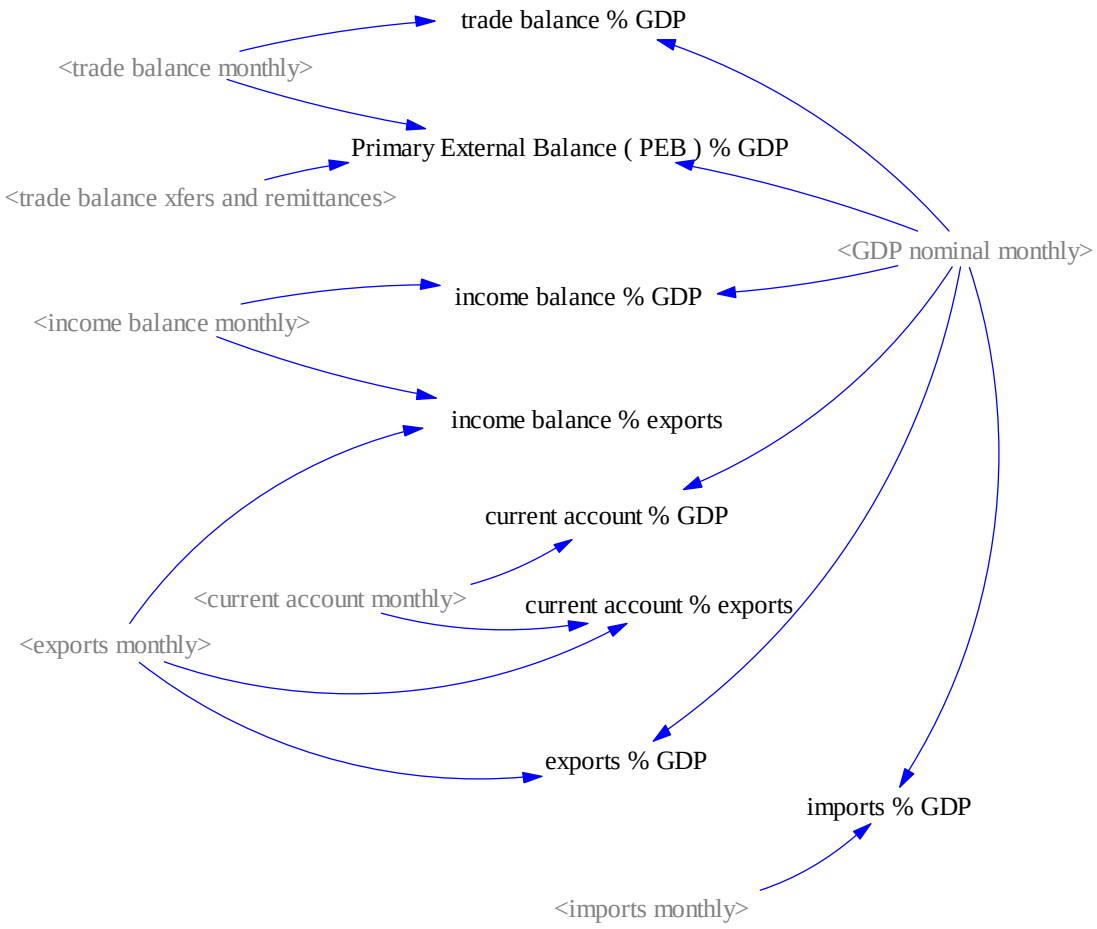
View #3: FOUSI



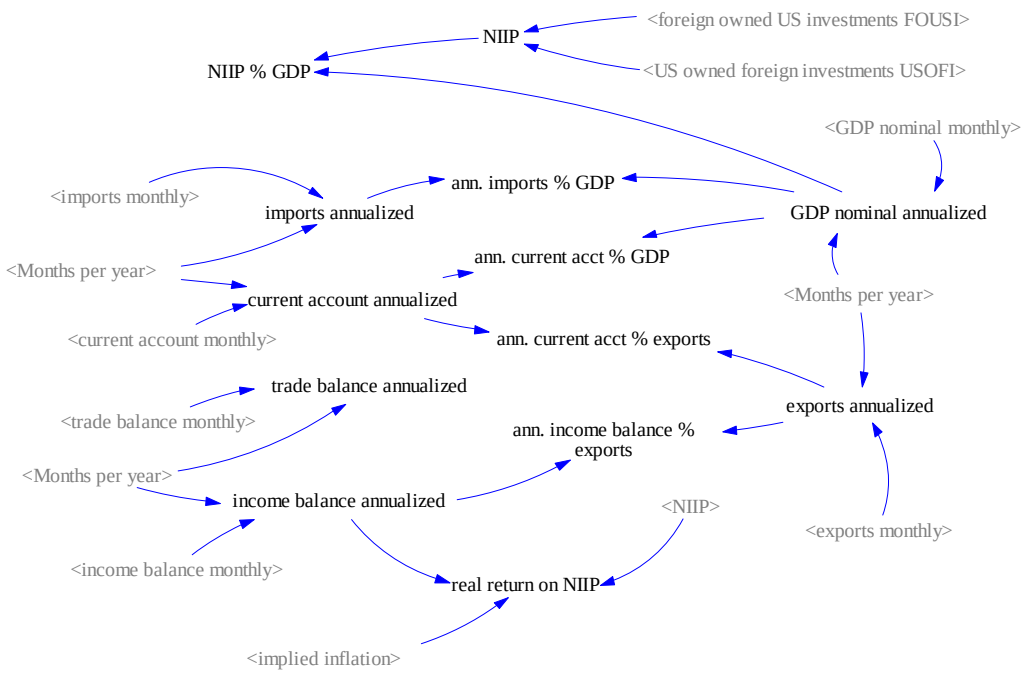
View #4: Resource Gap



View #5: Results part 1



View #6: Results part 2



View #7: Spreadsheet data

annual GDP nominal data 00-03

annual GDP real data 00-03

annual exports nominal 00-03

annual imports nominal 00-03

foreign owned US investments 00-03

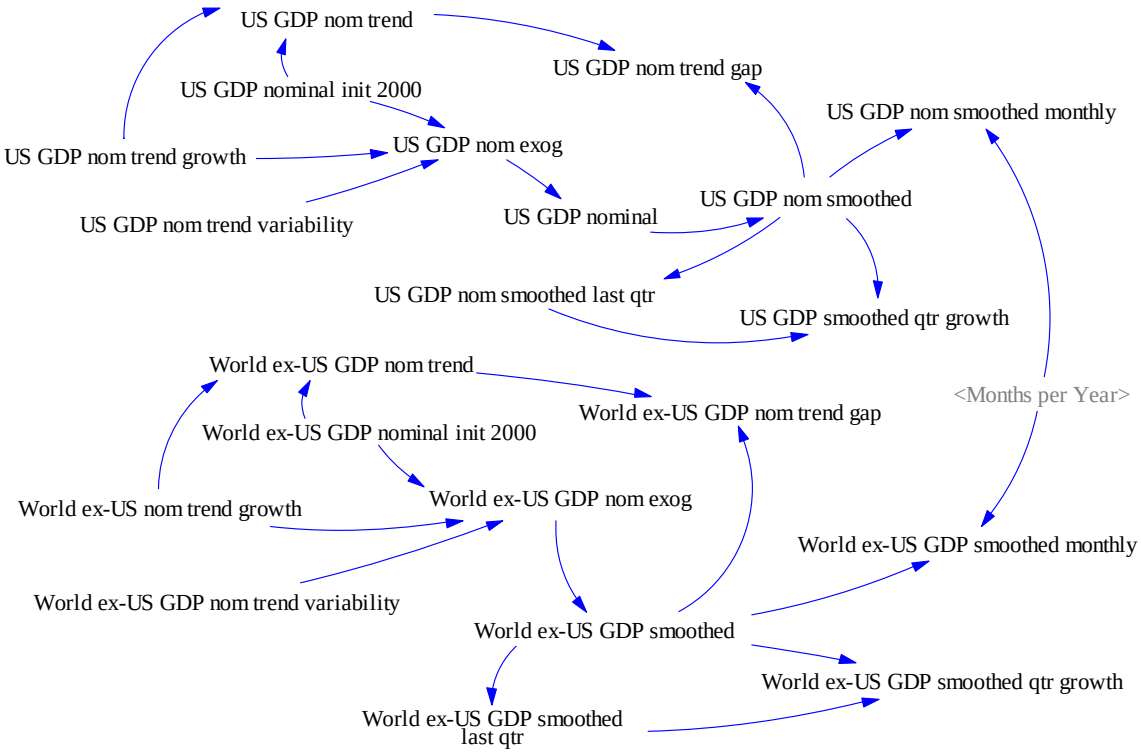
US owned foreign assets 00-03

NIIP mkt value basis00-03

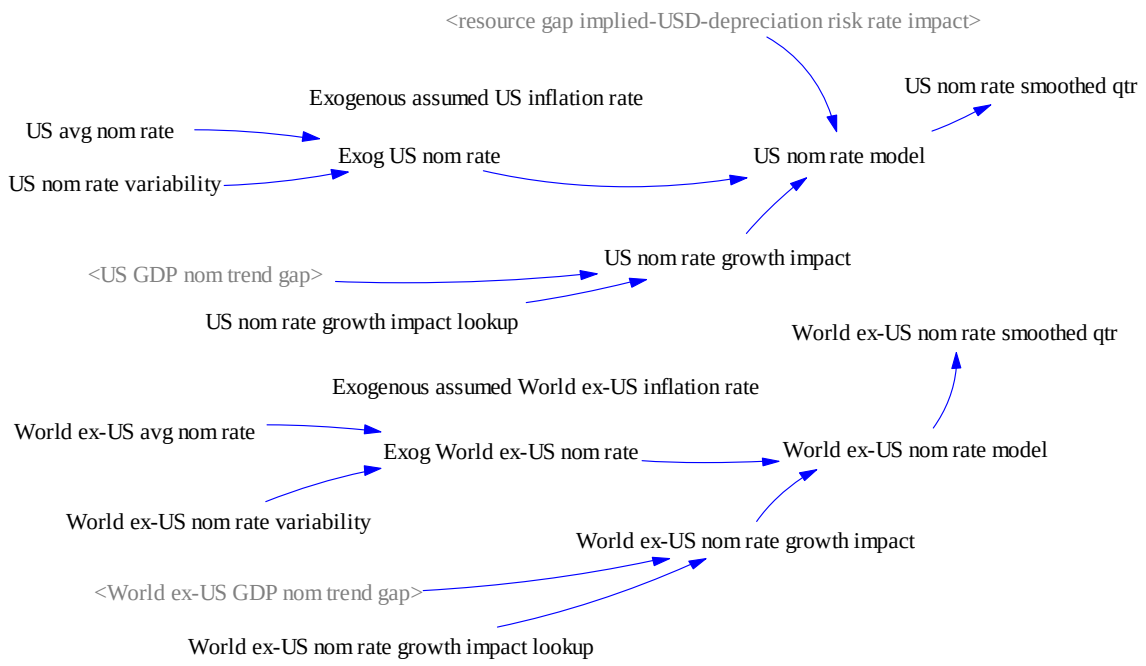
Appendix E: "Partially Endogenized" R-S Scenario Simulation Model (Causal Loops only)

from RSendogenousModel.mdl

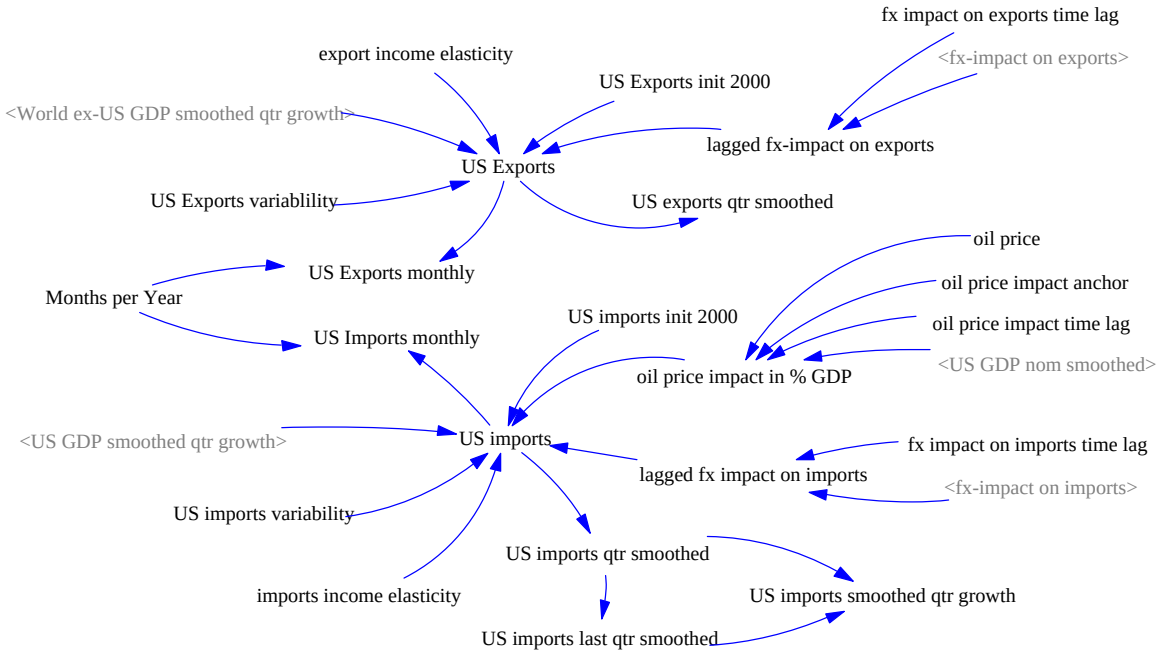
View 01: Exog US & World ex-US GDP



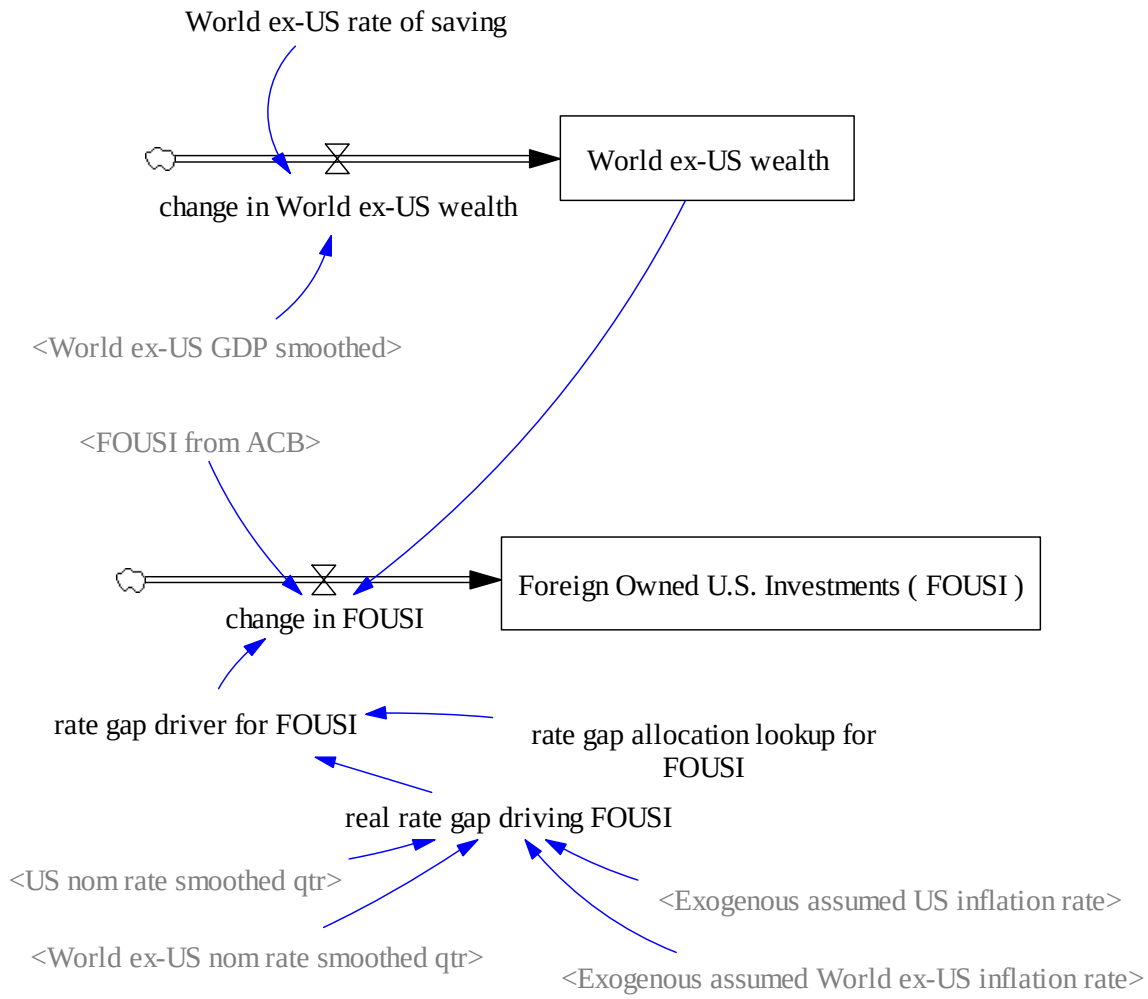
View 02: Exog US & World ex-US interest rates



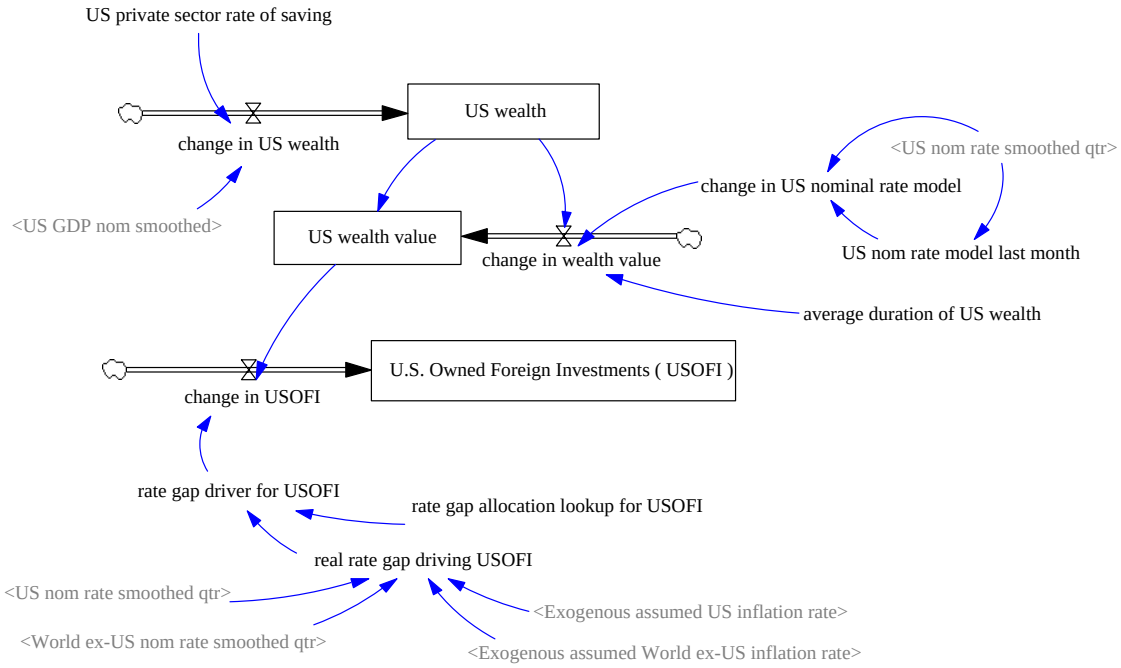
View 03: US Exports & Imports



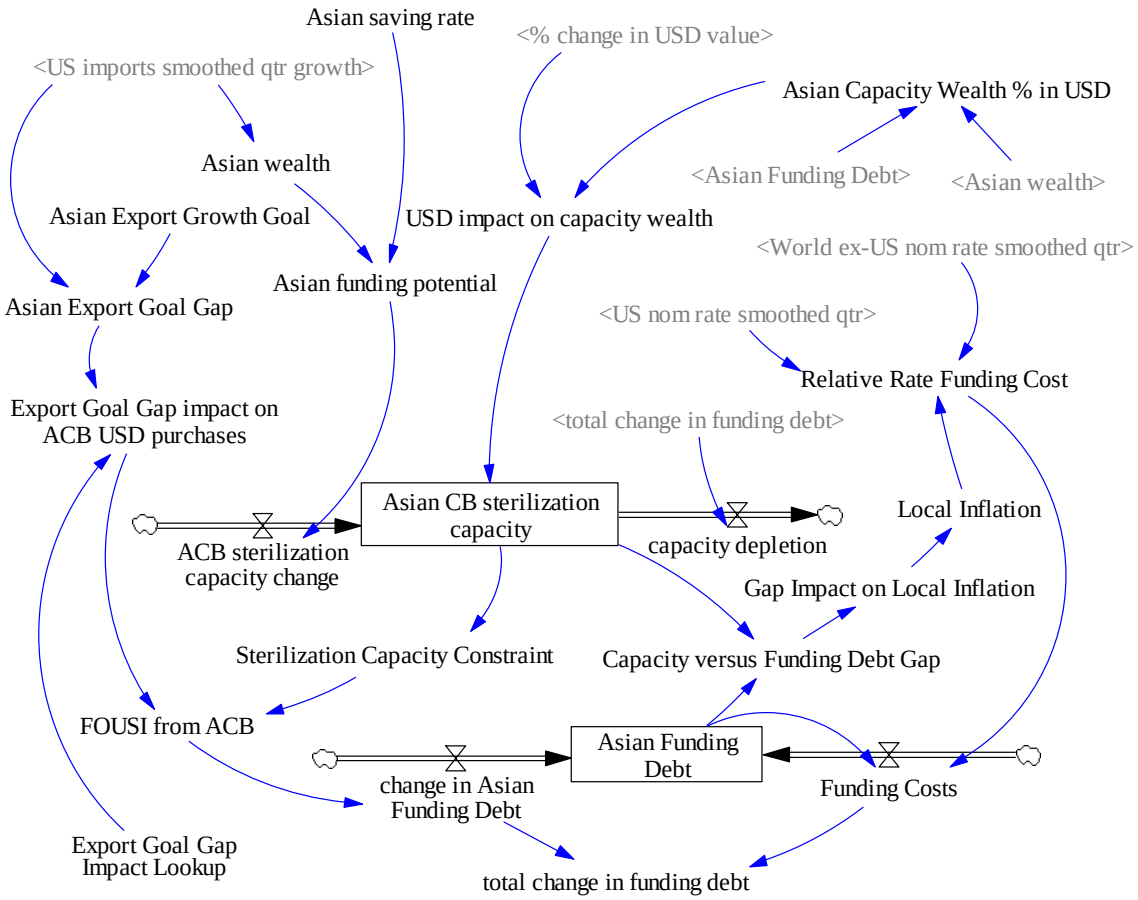
View 04: FOUSI



View 05: USOFI



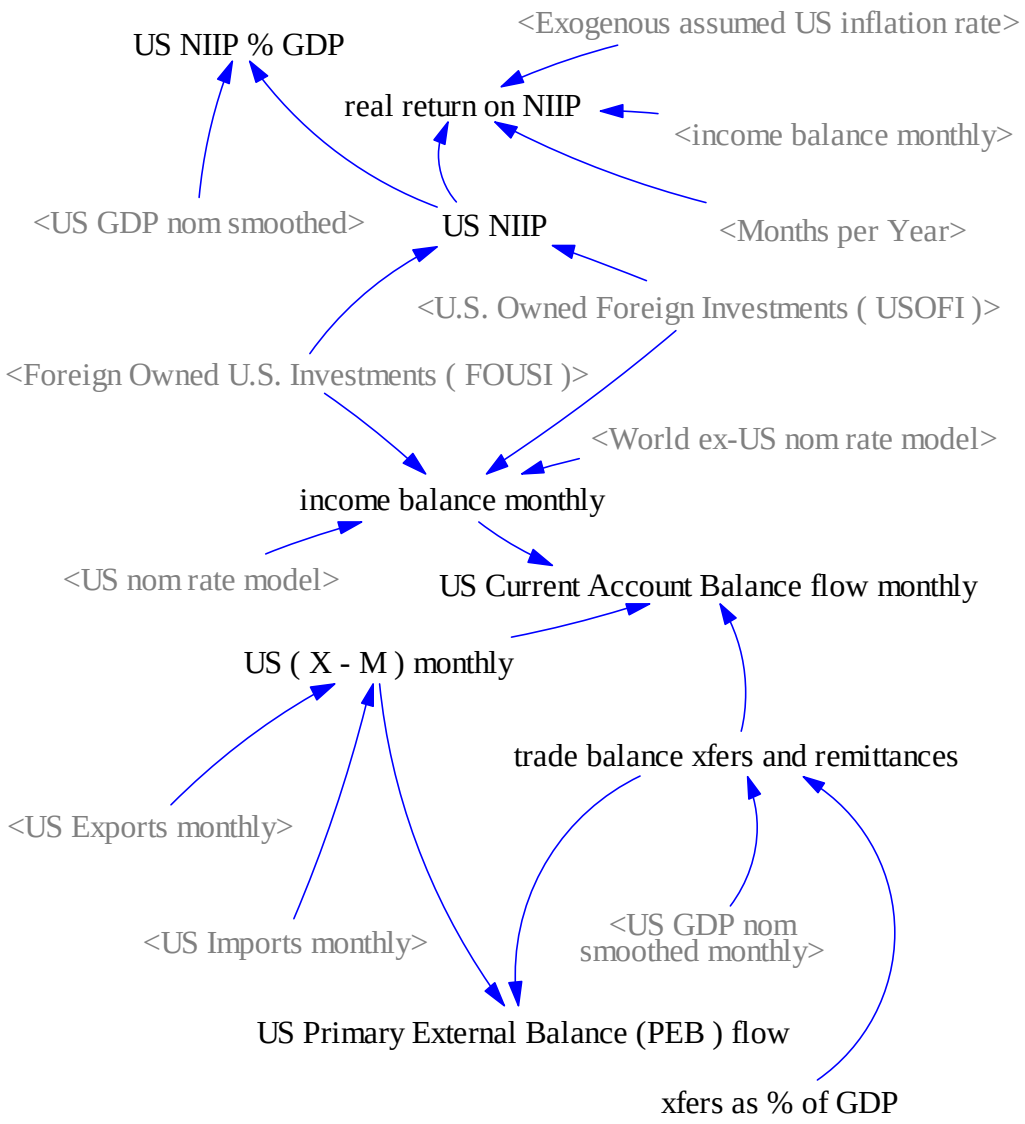
View 06: Asian CB FOUSI



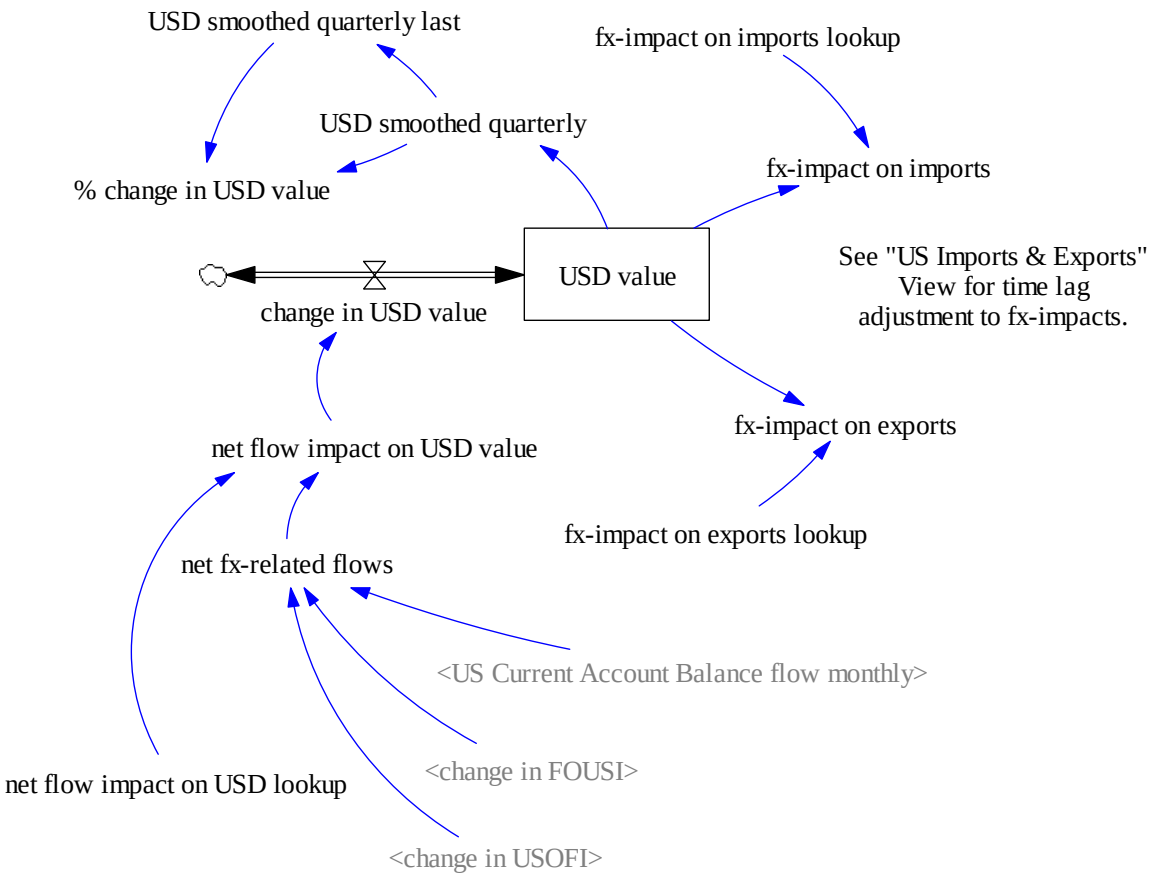
View 07: Current Account and Primary Balance

NIIP: Net International Investment Position

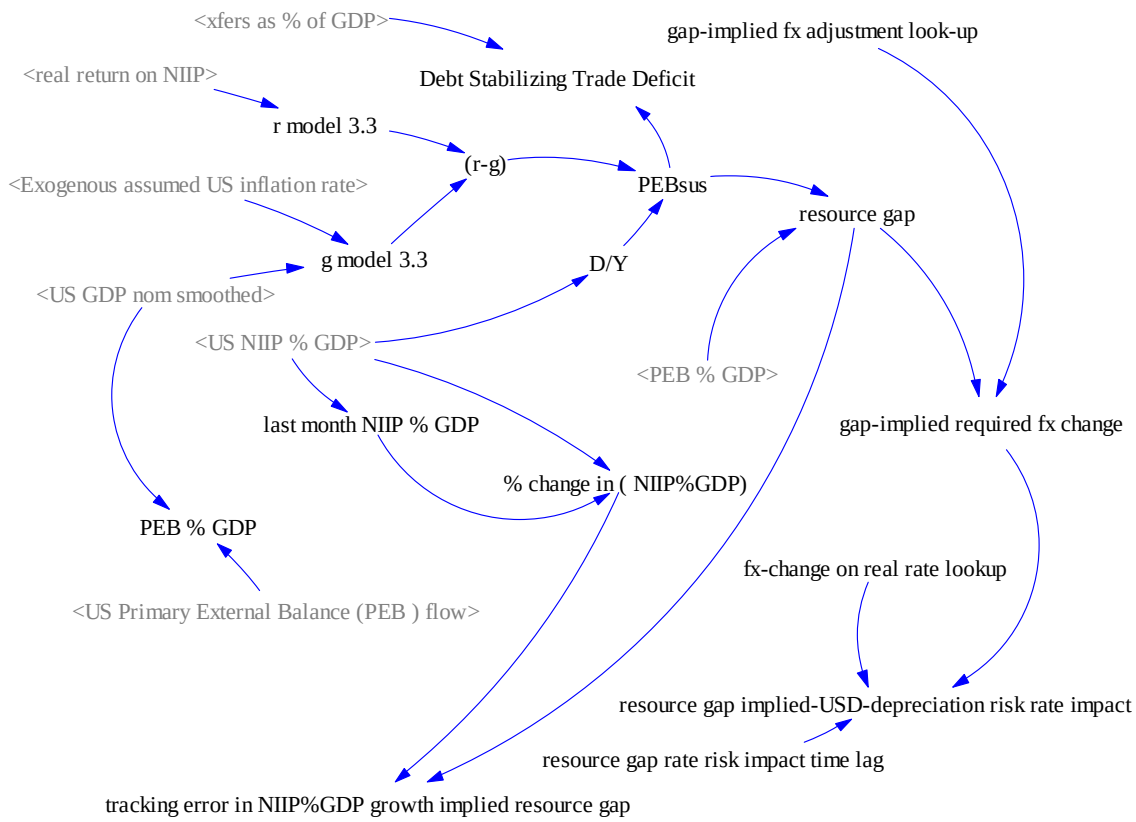
"income balance" = net investment return on US NIIP



View 08: FX Driven by Net Flows



View 09: R-S’s Resource Gap Concept



Appendix F: NIIP/GDP variable loops in endogenized model

Loop Number 1 of length 12
- US NIIP % GDP
  - D/Y
  - PEBsus
  - resource gap
  - gap-implied required fx change
  - resource gap implied-USD-depreciation risk rate impact
  - US nom rate model
  - US nom rate smoothed qtr
  - real rate gap driving FOUSI
  - rate gap driver for FOUSI
  - change in FOUSI
  - Foreign Owned US Investments (FOUSI)
  - US NIIP

Loop Number 2 of length 12
- US NIIP % GDP
  - D/Y
  - PEBsus
  - resource gap
  - gap-implied required fx change
  - resource gap implied-USD-depreciation risk rate impact
  - US nom rate model
  - US nom rate smoothed qtr
  - real rate gap driving USOFI
  - rate gap driver for USOFI
  - change in USOFI
  - US Owned Foreign Investments (USOFI)
  - US NIIP

Loop Number 3 of length 13
- US NIIP % GDP
  - D/Y
  - PEBsus
  - resource gap
  - gap-implied required fx change
  - resource gap implied-USD-depreciation risk rate impact
  - US nom rate model
  - US nom rate smoothed qtr
  - change in US nominal rate model
  - change in wealth value
  - US wealth value
  - change in USOFI
  - US Owned Foreign Investments (USOFI)
  - US NIIP

Loop Number 4 of length 14
US NIIP % GDP
D/Y
PEBsus
resource gap
gap-implied required fx change
resource gap implied-USD-depreciation risk rate impact
US nom rate model
US nom rate smoothed qtr
US nom rate model last month
change in US nominal rate model
change in wealth value
US wealth value
change in USOFI
US Owned Foreign Investments (USOFI)
US NIIP

Loop Number 5 of length 17
US NIIP % GDP
D/Y
PEBsus
resource gap
gap-implied required fx change
resource gap implied-USD-depreciation risk rate impact
US nom rate model
US nom rate smoothed qtr
Relative Rate Funding Cost
Funding Costs
total change in funding debt
capacity depletion
Asian CB sterilization capacity
Sterilization Capacity Constraint
FOUSI from ACB
change in FOUSI
Foreign Owned US Investments (FOUSI)
US NIIP

Loop Number 6 of length 18
US NIIP % GDP
D/Y
PEBsus
resource gap
gap-implied required fx change
resource gap implied-USD-depreciation risk rate impact
US nom rate model
US nom rate smoothed qtr
Relative Rate Funding Cost
Funding Costs
Asian Funding Debt
Asian Capacity Wealth % in USD
USD impact on capacity wealth
Asian CB sterilization capacity
Sterilization Capacity Constraint
FOUSI from ACB
change in FOUSI
Foreign Owned US Investments (FOUSI)
US NIIP

Loop Number 7 of length 21
US NIIP % GDP
D/Y
PEBsus
resource gap
gap-implied required fx change
resource gap implied-USD-depreciation risk rate impact
US nom rate model
income balance monthly
US Current Account Balance flow monthly
net fx-related flows
net flow impact on USD value
change in USD value
USD value
USD smoothed quarterly
% change in USD value
USD impact on capacity wealth
Asian CB sterilization capacity
Sterilization Capacity Constraint
FOUSI from ACB
change in FOUSI
Foreign Owned US Investments (FOUSI)
US NIIP

Loop Number 8 of length 23
US NIIP % GDP
D/Y
PEBsus
resource gap
gap-implied required fx change
resource gap implied-USD-depreciation risk rate impact
US nom rate model
income balance monthly
US Current Account Balance flow monthly
net fx-related flows
net flow impact on USD value
change in USD value
USD value
fx-impact on imports
lagged fx impact on imports
US imports
US imports qtr smoothed
US imports smoothed qtr growth
Asian Export Goal Gap
Export Goal Gap impact on ACB USD purchases
FOUSI from ACB
change in FOUSI
Foreign Owned US Investments (FOUSI)
US NIIP

Loop Number 9 of length 24

US NIIP % GDP

D/Y

PEBsus

resource gap

gap-implied required fx change

resource gap implied-USD-depreciation risk rate impact

US nom rate model

income balance monthly

US Current Account Balance flow monthly

net fx-related flows

net flow impact on USD value

change in USD value

USD value

fx-impact on imports

lagged fx impact on imports

US imports

US imports qtr smoothed

US imports last qtr smoothed

US imports smoothed qtr growth

Asian Export Goal Gap

Export Goal Gap impact on ACB USD purchases

FOUSI from ACB

change in FOUSI

Foreign Owned US Investments (FOUSI)

US NIIP

Loop Number 10 of length 27

US NIIP % GDP

D/Y

PEBsus

resource gap

gap-implied required fx change

resource gap implied-USD-depreciation risk rate impact

US nom rate model

income balance monthly

US Current Account Balance flow monthly

net fx-related flows

net flow impact on USD value

change in USD value

USD value

fx-impact on imports

lagged fx impact on imports

US imports

US imports qtr smoothed

US imports last qtr smoothed

US imports smoothed qtr growth

Asian wealth

Asian Capacity Wealth % in USD

USD impact on capacity wealth

Asian CB sterilization capacity

Sterilization Capacity Constraint

FOUSI from ACB

change in FOUSI

Foreign Owned US Investments (FOUSI)

US NIIP

Loop Number 11 of length 27
US NIIP % GDP
D/Y
PEBsus
resource gap
gap-implied required fx change
resource gap implied-USD-depreciation risk rate impact
US nom rate model
income balance monthly
US Current Account Balance flow monthly
net fx-related flows
net flow impact on USD value
change in USD value
USD value
fx-impact on imports
lagged fx impact on imports
US imports
US imports qtr smoothed
US imports last qtr smoothed
US imports smoothed qtr growth
Asian wealth
Asian funding potential
ACB sterilization capacity change
Asian CB sterilization capacity
Sterilization Capacity Constraint
FOUSI from ACB
change in FOUSI
Foreign Owned US Investments (FOUSI)
US NIIP