A two-region model of economic growth and trade

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Abstract

Trade protectionist tendencies are visible in a few countries around the world due to their increasing current account deficit and their public and household debt. However, the long-term effect of such a policy is quite unclear especially considering the feedback from the Rest of the World (ROW). In this paper, using the US economy as a case, we present our two-region model of economic growth and trade which uses Vensim's subscripting language to depict the two regions: the USA and the ROW. The model contains three major reinforcing loops responsible for endogenous economic growth. It also outlines the mechanisms that explain the emergence of debt and its negative impact on economic development. In order to model foreign trade, we introduce a factor FTE (foreign trade effectiveness) to describe the extent to which one economy has market access to another economy. The model is parameterized using historical statistic data of the US economy and the World. On the whole, there is a fair match between the calibrated model outputs and historical data. Our scenario simulations demonstrate that a higher share of non-investors' income in the US economy may help to reduce the debt-to-GDP ratio and accelerate the growth in the long run. Import tariffs on foreign products may also have such positive effects if the tariff revenue is distributed to the non-investors.

Keywords: foreign trade effectiveness, import tariff, capital share, indebtedness, endogenous growth

1. Introduction

The US American economy and its trade relations to the Rest of the World (ROW) are – not only in recent years – one of the main areas of interest in the public and in the economic research. Figure 1 shows the statistical data regarding GDP, non-investor debt, and investment (GCF, gross capital formation) of the USA and the ROW as well as the import and export share on GDP of the USA from 1970 to 2015 [8, 12, 15, 25]. The World is concerned about the increasing current account deficit and the public and household debt of the USA, and in particular, about the consequences of possible US policy changes regarding its international trade relations. Among others, two key questions arise: What are the essential causes of the high debt ratio in the US economy? What is the long-term impact of a possible US trade protectionism policy?

The development of a national economy is one of the major application areas of system dynamics. A model for the national economy should, according to Forrester et al., include the following sectors: production, labor, demography, household, finance, government, and foreign trade, in particular, because (in the 1980s) "there are signs emerging that the United States is in the transition stage. The transition stage is consistent with the social, environmental, and inflationary forces that are developing." [7]. In Saeed's stock-and-flow structure representing Schumpeter's concept of creative destruction [20], the "capital" stock (and the investment into it) takes a central place in a collection of "technology", "unspent savings" and other three stocks reflecting workforce. Nathan B. Forrester [5] translates, among others, Hicks' IS-LM model [10] into a system dynamics model with stocks "permanent income", "employment", "short-run expected demand", "long-run

expected demand", "capital" and "averaged output". Weber presents a number of endogenous growth models, including the Romer model [23, 19], as stock-and-flow diagrams with stock-variables "capital stock", "technical progress", and "labor forces" resp. "human capital" [28]. Wheat [29] describes a feedback method of teaching macroeconomics. Based on a model with stock variables including "savings", "homes", "govts", "firms" and "inventories", the wages are identified as a key factor for consumption-driven economic growth. In Utama's financial sector sub model [26] five stocks namely "bank reserve", "bank deposit", "firm loan", "firm deposit" and "worker deposit" are included. A study by Kunte and Damani [14] uses three stocks "firm capital", "household capital" and "population" to model the growth of a national economy. Randers' concept [17] provides further extensions in the area of social friction and environmental issues.



Figure 1: GDP, non-investor debt and GCF of the USA and the ROW (B\$, logarithmic scale on the left); import and export share on GDP of the USA (%, right scale) [8, 12, 15, 25]

Translating (and improving if necessary) existing economic models or creating models from scratch are principle ways that system dynamics is used for economic modeling [16]. Some of the modeling works focus on specific national economies or specific policy issues. A modified Harrod-Domar model of growth by Rego & Vega [18] uses stock variables "capital" and "debt" for scenario analyses of Argentina's economy. Skribans [24] uses stock variables like "labor force", "average wage", "average output", "average consumption", "inventories" and "debt capital" to show that the European Union needs changes in its internal migratory policy. Yamaguchi shows in [30] that under the current monetary system in the United States a significant debt reduction "inevitably triggers economic recessions and unemployment" of American and foreign economies. Ansah addresses the impact of fiscal policy on socio-economic development and fiscal sustainability of Ghana [1]. Block et al. [4] address the debt crises in the euro-zone using stock variables including "capacity", "investor money", "non-investor money" and "consumer debt" and find out that

achieving more income equality seems to be a better strategy meeting the challenge of the debt crisis than a policy of austerity. However, this strategy may be undermined by free international trade, as demonstrated by Arto et al. [2] using a two-country model containing stock variables "capacity", "non-investor money" and "consumer debt" for each of the countries. The higher the degree of free movement of goods, the more likely the two countries will, as in a Prisoners' Dilemma, choose the policy of austerity – the worse option. A small model [see, e.g., 6, 9] of the dynamics of economic growth, foreign trading and indebtedness is presented in [11] and uses an additional stock "offshore (capacity)" to model the development of the import into the USA.

In this paper, we present a two-region model of economic growth and trade for the USA and the ROW. The model focuses on the development of and the relationship between the GDP, the level of public and private debt, the import and export volumes, the income distribution, and the investment propensity. The purpose of this model which we developed based on the models presented in [2, 11], is to find out (1) whether a higher share of non-investors' income in the US economy may help to reduce the debt-to-GDP ratio and accelerate the growth in the long run, and especially (2) what effects and side effects US tariffs on foreign products may have to the US and World economy.

In the following, we describe our model in Section 2. In Section 3 we use statistical data of the US and World economy to parameterize the model. In Section 4 we discuss several scenarios regarding their possible effects to the US and World economy. Section 5 concludes this paper.

2. A two-region model of economic growth and trade

The system dynamics model which we present in this section uses Vensim's subscripting language [27] to depict two regions. All variables (but time, INITIAL TIME and FINAL TIME) in the model are subscripted having subscript Region with the subscript elements USA and ROW.



Figure 2: Two connected stock-and-flow structures as a starting point of a two-region model.

The model is focused on the relations and driving forces between GDP and non-investor debt which is the sum of government and household debt of a national economy and is equal in magnitude to the stock variable non-investor money if the latter is negative (Figure 2). One basic idea of the model is the division of economic actors into two categories: investors and non-investors. One key difference between these two groups is that the members of the first group never need to adjust their consumption level because of lack of money while the members of the second group have to do that if necessary. The parameter capital share describes the share of the GDP which the members of the first group receive while the rest of GDP is considered the (sum of working resp. tax) income of non-investors.

Notice that in this work we use a blue and opaque arrow in the figures resp. a \nearrow sign in the text (f. i. from non-investor debt to interest) for positive influence, whilst a red and transparent arrow resp. a \searrow sign (f. i. from non-investor money to non-investor debt) depicts a negative effect.

Seeking to develop their businesses investors put a certain share (reinvest share) of their last (year's) return as the investment in the production, service, and innovation capacity [13]. Notice that the production into inventory [see, e.g., 21] is also included in the term investment. Increasing capacity pushes increasing consumption. In our model, the supply-side economic effects caused by increasing capacity can be parameterized by the lookup function consumption add-on. The total consumption is the sum of investor consumption and non-investor consumption. Considering that GDP is essentially made up of consumption and investment we identify three reinforcing loops (Figure 3) which are the engines of endogenous growth:

- R4.1: GDP ≯ return ≯ return last (year in next year) ≯ investment (in next year) ≯ GDP (in next year)
- R4.2: GDP ≯ return ≯ investment ≯ capacity ≯ consumption add-on ≯ non-investor consumption ≯ GDP
- R4.3: GDP ≯ return ≯ investment ≯ capacity ≯ consumption add-on ≯ investor consumption ≯ GDP



Figure 3: Three reinforcing loops as engines of economic growth

Since the relation from GDP to return is a part of all three reinforcing loops, a high level of capital share can obviously accelerate the growth of a national economy significantly.



Figure 4: Adding debt/GDP, population and further variables to the model

At the same time, a high level of capital share means a low level of non-investors' income which can lead to indebtedness. The level of indebtedness of a national economy is characterized by debt/GDP, as shown in Figure 4. Two lookup variables austerity and reinvest share determine the strength of the negative impact of an increasing debt-to-GDP ratio on investment and on non-investor consumption. CPI, interest rate, and population are added to the model as exogenous time profiles. The dynamics of indebtedness is given by five additional feedback loops among which one is balancing and four are reinforcing loops (Figure 5):

- B6.1 debt/GDP
 non-investor consumption
 non-investor money
 non-investor debt
 debt/GDP
- R6.2 debt/GDP \> reinvest share ∧ investment ∧ GDP \> debt/GDP
- R6.3 debt/GDP \searrow non-investor consumption \nearrow GDP \searrow debt/GDP
- R6.4 debt/GDP
 reinvest share
 investment
 GDP
 income
 non-investor money
 non-investor debt
 debt/GDP
- R6.5 debt/GDP
 non-investor consumption
 GDP
 income
 non-investor money
 non-investor debt
 debt/GDP



Figure 5: Five feedback loops in conjunction with non-investor debt

Notice that the relationship from GDP to income is contained in both reinforcing loops R6.4 and R6.5. A lower capital share enhances the effect of these loops: pushing economic growth, reducing non-investor debt and even increasing investment (see Section 3). In this way, R6.4 and R6.5 counteract the loops R4.1–R4.3. Furthermore, the balancing loop B6.1 has the stock variable non-investor money as a part.



Figure 6: Foreign trade and tariff

As shown in Figure 6, we calculate the import into a region from the ratio between foreign and domestic capacity. This ratio is multiplied by a certain factor which we introduce as FTE (foreign trade effectiveness) to reflect that the foreign capacity does not have full access to a domestic market because of diverse objective (f.i. habit, distance) and subjective (f.i. regulations) reasons. Import tariffs are treated in our model separately.



Figure 7: A two-region causal loop diagram (partial)

The import and export links between the two regions make the model very complex in terms of feedback loops. Vensim counts several hundreds of them. In Figures 6 and 7 we can only specify some of them:

- R7.1 import \searrow GDP \nearrow return \nearrow investment \checkmark capacity \searrow import
- B7.2 import \searrow GDP \nearrow return \nearrow investment \nearrow demand \nearrow import
- R8.1 export ∧ GDP ∧ return ∧ investment ∧ capacity ∧ export
- B9.1 tariff ∧ income ∧ non-investor money \ non-investor debt ∧ debt/GDP \ reinvest share ∧ investment ∧ capacity \ import ∧ tariff
- B9.2 tariff[USA] \> export[ROW] / GDP[ROW] / return[ROW] / investment[ROW] / capacity[ROW] / import[USA] / tariff[USA]

It is obvious that there are more loops and side effects which make numeric simulations necessary.

3. Parameterization

Our model has a total of 36 essential variables, as listed in Table 1. These variables all have the subscript Region with the subscript elements USA and ROW. Datasets from [8, 12, 15, 25] are used directly as exogenous parameters or for the parameterization. To do this we modify the values of the lookup tables and constants marked "fitting" in Table 1 to match the simulation results of the model to the values marked "data to match". During the parameterization, some or all these variables can be replaced temporarily by the corresponding datasets.

		lookup	exogen. Param.	data to match	fitting	scenario			lookup	exogen. Param.	data to match	fitting	scenario
1	austerity						19	import					
2	capacity						20	income					
3	capacity start						21	interest					
4	capital share						22	interest rate	M			M	
5	consumption add-on						23	investment			M		
6	consumption pc start						24	investor consumption					
7	consumption share start						25	investor income					
8	CPI						26	non-investor consumption					
9	debt/GDP						27	non-investor debt			M		
10	demand						28	non-investor money					
11	depreciation						29	non-investor money start					
12	exchange rate						30	period				Μ	
13	export						31	population					
14	FTE						32	reinvest share	M			M	
15	FTE profile						33	return					
16	FTE start						34	return last					
17	GDP						35	tariff					
18	GDP start						36	tariff rate					

Table 1: Essential variables of the model of economic growth and trade

We calculate the datasets for the ROW as the difference between the World and the USA [12, 15]. One of these datasets – non-investor debt of the ROW – attracts our special attention: Being a stock variable, debt development can hardly be as volatile as the data (blue curve in Figure 8). The reason for this is that the figures are in US dollar and thus include currency fluctuations. To model the economic development of the ROW properly we introduce a virtual currency for the World (WCU) of which the exchange rate to US dollar (violet curve in Figure 8) is defined in such a way that the development of the ROW is smoothed (red curve in Figure 8).



Figure 8: Smoothing the development of debt stock using virtual currency for the ROW (WCU)

As shown in Figure 9 there is a fair match between the calibrated model outputs and historical data in the cases of GDP, debt and GCF. The divergence between the model and data in the cases of import and export is within a 30% range and can be seen as acceptable.



Figure 9: Fair consistency between the data (see Section 1) and the model simulations

Figure 10 shows the results of a sensitivity analysis using scatterplots [22, 3]. All three inputs of interest – $FTE_{ROW to USA}$, $FTE_{USA to ROW}$ and capital share – are implemented as lookup tables in our model. For the sake of clarity, we choose three input variables: a shift in the percentage of capital share from 1970 to 2015 and two multiplicative factors of both FTEs. Two output metrics are non-investor debt at the end of 2015 and the GDP of 2015 since our focus is on economic growth without indebtedness. The model's behavior is apparently quite sensitive to both FTEs. This requires closer investigation and the development of tool-based parameterization techniques to improve the simulation results.



Figure 10: Scatterplots of GDP and non-investor debt versus FTE of both the USA and the ROW as well as versus shift of capital share of the USA

4. Scenario simulations

In this section, we present the results of two scenario analyses of the US economy using the model described in Sections 2 and 3.

The first scenario analysis deals with the question about whether a change towards more distributive equality in the US economy may help to reduce the debt level while keeping economic growth. Specifically, in this scenario analysis, the non-investor income should increase and the capital share should decrease by 5% resp. 10% from 2018 to 2020. In fact, our simulations show that compared to the scenario, where no decrease (0%) takes place, such a change may reduce the debt-to-GDP ratio significantly (Figure 11, top left). Regarding the development of the GDP, we see a worse-before-better pattern in the long run (Figure 11, top right). There is a counterintuitive behavior of the system as well: a lower capital share may help to reduce the debt level and in this way keep the investment propensity at an acceptable level (Figure 11, bottom left). A very small advantage for the ROW economy, regarding both the debt-to-GDP ratio and the GDP, comes from the reduced GCF on the side of the USA, which in turn leads to a reduced export and an increased import of the USA (Figure 11, bottom right).



Figure 11: More distributive equality may help to reduce the debt level while keeping economic growth

In the second scenario analysis, we consider the effects of import tariffs for the economies of the USA and the ROW. We compare five scenarios:

- 1. No (additional) import tariff is imposed.
- 2. An (additional) import tariff will be imposed by the USA and the tariff rate will increase from 0% to 20% from 2018 to 2020 and then be kept at 20%. No reaction from the ROW.
- 3. The ROW reacts with a tariff rate which will increase from 0% to 10% from 2018 to 2020.
- 4. The ROW's tariff rate will increase from 0% to 20% from 2018 to 2020.
- 5. The ROW's tariff rate will increase from 0% to 30% from 2018 to 2020.
- 6. Our model outputs show that the 2nd scenario, in comparison to the 1st, baseline scenario, will reduce the debt-to-GDP ratio significantly while accelerating economic growth (Figure 12, left side). Notice that the tariff revenue flows completely into the US treasury according to our model. Even the 3rd scenario still brings some advantages for the US economy. However, the advantage turns to a disadvantage if the ROW should respond with an equally high or even higher tariff to the American import, as in the 4th and 5th scenarios. Expressed as a percentage, the effect of such a change on the ROW is noticeably smaller than that on the US, as shown in Figure 12 (right side).



Figure 12: import tariffs and their impacts on the economic development

5. Conclusion and outlook on future research

In this paper, we presented a two-region model of economic growth and trade which uses Vensim's subscripting language to depict the two regions: the USA and the Rest of the World (ROW). The model basically contains three reinforcing loops responsible for endogenous growth. It also outlines the mechanisms that explain the emergence of debt and its negative impact on economic development. In order to model foreign trade, we introduced a factor FTE (foreign trade effectiveness) to describe the extent to which one economy has market access to another economy (Section 2).

The model was parameterized using historical statistic data of the US economy and the World. In total there was a fair match between the calibrated model outputs and historical data. The sensitivity analyses showed that the behavior of our model is quite sensitive to FTE (Section 3). Our scenario simulations demonstrated that a higher share of non-investors' income in the US economy may help to reduce the debt-to-GDP ratio and accelerate the growth in the long run. Import tariffs on foreign products may also have such positive effects if the tariff revenue is distributed to the non-investors (Section 4).

Despite the rather simple division of the world into only two regions, the present model seems to provide some interesting insights into the US economy and its trade relations to the ROW. Future research could take the next step by having a closer investigation of the factors FTE and developing tool-based parameterization techniques. Based on this, we will then face the challenge of creating

a three-region model to look at the development of two economies with their bilateral trade relationship in the context of world trade.

References

- John Pastor Ansah: Negotiating Fiscal Sustainability against Socio-Economic Development: A Model-Based Policy Analysis. *The 2010 International Conference of the System Dynamics Society, Proceedings,* Seoul, Korea, July 25 – 29, 2010
- [2] Klaus Arto, Joachim Block, Bo Hu, Armin Leopold, Stefan Pickl: Inclusive growth and sustainable finance in connected national economies. *The 2014 International Conference of the System Dynamics Society, Proceedings*, Delft, Netherlands, 2014, July 20 24
- [3] Asmeret Bier: Sensitivity Analysis Techniques for System Dynamics Models of Human Behavior. *The 29th International Conference of the System Dynamics Society*, Washington, D.C., July 24th – 28th, 2011
- [4] Joachim Block, Bo Hu, Armin Leopold, and Stefan Pickl: Inclusive growth and sustainable finance - a system dynamics model. *The 2013 International Conference of the System Dynamics Society, Proceedings*, Cambridge, MA, USA, July 21-25 2013
- [5] Nathan B. Forrester: A dynamic synthesis of basic macroeconomic theory: implication for stabilization policy analysis. *Diss.*, Massachusetts Institute of Technology, 1982
- [6] Jay W. Forrester: System Dynamics and the Lessons of 35 Years. *Kenyon B. De Greene Editor: The Systemic Basis of Policy Making in the 1990s*, April 29, 1991
- [7] Jay W. Forrester, Nathaniel J. Mass and Charles J. Ryan: The system dynamics national model: understanding socio-economic behavior and policy alternatives. *Technology Forecasting and Social Change, 9: 51–68, 1980*
- [8] Federal Reserve Economic Data. Federal Reserve Bank of St. Louis, 2019, https://fred.stlouisfed.org/ (24.02.2019)
- [9] Navid Ghaffarzadegan, John Lyneis and George P. Richardson: How small system dynamics models can help the public policy process. *System Dynamics Review*, 27: 22–44, 2011
- [10] J. R. Hicks: Mr. Keynes and the "Classics"; A Suggested Interpretation. Econometrica, Vol. 5, No. 2: 147-159, Apr., 1937
- [11] Bo Hu, Pascual Cravaack, Martin Gawliczek: Drawing Insights from a Small Model and Statistical Data of the US Economy. *The 2018 International Conference of the System Dynamics Society, Proceedings,* Reykjavík, Iceland, August 6-10, 2018
- [12] A History of World Debt How public debt has changed since 1880. IMF, 2011, https://www.imf.org/external/pubs/ft/fandd/ 2011/03/pdf/picture.pdf (10.02.2019)
- [13] Bradford C. Johnson, James M. Manyika, Lareina A. Yee: The Next Revolution in Interactions. *The McKinsey Quarterly, Number 4: 20-33, 2005*
- [14] Shreenivas Kunte, Om Damani: Exploring Harrod Domar and Solow Models of Economic Growth. The 2016 International Conference of the System Dynamics Society, Proceedings, 2016

- [15] Visualizing global debt. *mckinsey.com*, June 2018, https://www.mckinsey.com/businessfunctions/strategy-and-corporate-finance/our-insights/visualizing-global-debt (09.02.2019)
- [16] Michael J. Radzicki: System dynamics and its contribution to economics and economic modeling. *Complex Systems in Finance and Econometrics*, 727-737, 2011
- [17] Jorgen Randers: 2052 A Global Forecast for the Next Forty Years using a mix of models. *The 2013 International Conference of the System Dynamics Society, Proceedings*, July 22, 2013
- [18] Juan Rego and Juan A. Vega: Probabilistic Generation of Scenarios for Argentina, Using an Elemental Harrod-Domar Model of Growth. *The 1987 International Conference of the System Dynamics Socity, Proceedings,* China, 1987
- [19] Paul M. Romer: Increasing returns and long-run growth. *Journal of political economy*, 94.5: 1002-1037, 1986
- [20] Khalid Saeed: Economic Development, Creative Destruction and Urban Dynamics A Proposal for Rethinking Developmental Agendas. *The 28th International System Dynamics Conference*, Seoul, Korea, July 25 - 29, 2010
- [21] Khalid Saeed: Jay Forrester's operational approach to economics. *System Dynamics Review*, 30.4: 233-261, 2014
- [22] Andrea Saltelli, Marco Ratto, Terry Andres, Francesca Campolongo, Jessica Cariboni, Debora Gatelli, Michaela Saisana, Stefano Tarantola: Global Sensitivity Analysis: The Primer. John Wiley & Sons, Ltd., 2008
- [23] Joseph Alois Schumpeter: The Theory of Economic Development. Jürgen Backhaus Editor: Joseph Alois Schumpeter - Entrepreneurship, Style and Vision, 61-116, ISBN 978-0-306-48082-9, Springer, Boston, MA, 2003
- [24] Valerijs Skribans: European Union Economy System Dynamic Model Development. *The* 2012 International Conference of the System Dynamics Society, Proceedings, 2012
- [25] DataBank. The World Bank, 2019, https://databank.worldbank.org/data/indicator/ NY.GDP.MKTP.KD.ZG/1ff4a498/Popular-Indicators# (16.01.2019)
- [26] Ginanjar Utama: On Component Based Modeling Approach for the Financial System: with a Case Study of Keen-Minsky Model. the 31st International Conference of the System Dynamics Society, Proceedings, 2013
- [27] Subscripting. *vensim.com*, Ventana Systems, 2015, https://vensim.com/subscripting/ (01.03.2019)
- [28] Lars Weber: Understanding Recent Developments in Growth Theory. *The 2007 International Conference of the System Dynamics Society, Proceedings, 2007*
- [29] David Wheat Jr.: The feedback method of teaching macroeconomics: is it effective? System Dynamics Review, Vol 23 No. 4: 391-413, ISBN Hoboken, NJ, USA, John Wiley & Sons, Ltd., 25 August 2007
- [30] Kaoru Yamaguchi: Workings of A Public Money System of Open Macroeconomies Modeling the American Monetary Act Completed –. *The 2011 International Conference of the System Dynamics Society, Proceedings,* Washington, DC, July 24 – 28, 2011