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Working Paper Series

#2022-013

Semi-endogenous growth in a non-Walrasian DSEM for Brazil: Estimation and simulation of changes in foreign income, human capital, R&D, and terms of trade

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Published 12 April 2022

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UNU-MERIT Working Papers
ISSN 1871-9872

Maastricht Economic and social Research Institute on Innovation and Technology
UNU-MERIT

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Abstract

In an empirical, dynamic simultaneous equation model (DSEM) for Brazil with 22 equations and variables, we show that foreign income is a driver of economic growth besides semi-endogenous technical change. With a balance-of-payments constraint and endogenous terms of trade, the major mechanism is (i) world GDP driving exports, (ii) exports paying for imported capital goods, which (iii) enter a production function increasing output and the foreign-debt/GDP ratio and (iv) increase the endogenous labour force, and (v) slightly reduce human capital growth. Permanent increases of human capital increase the R&D/GDP ratio, labour-augmenting productivity, and GDP. A policy to increase the R&D/GDP ratio leads to more human capital, labour productivity and GDP levels. Both knowledge policies reduce the debt/GDP ratio. A lasting shock on the terms of trade reveals that there is no Harberger-Laursen-Metzler effect. The results hold in the presence of endogenous terms of trade, foreign debt, net foreign income, and net current transfers from abroad, and non-Walrasian (dis-)equilibrium variables: inflation and changing inventories for the goods market, and unemployment in the labour market. Policy should strengthen the weak link from R&D to technical change and make education more attractive. Keywords: dynamic simultaneous equation model; balance-of-payments constrained growth; imported capital goods; foreign debt; human capital; R&D. JEL codes: F43, O11, O41, O47, O54.

1. Introduction

Growth accounting found a strong role for the productivity residual first in Cobb-Douglas functions (Tinbergen 1942; Solow 1957, Fagerberg 1994) and recently in more general CES functions (Ziesemer 2022a). Therefore, the neoclassical growth model of Solow (1956) has taken over the role of the leading growth model from Harrod-Domar, and technical change is seen as the leading driver of closed-economy growth. A second class of growth models considers world income growth as another driving force of growth. First, the World Bank's two-gap version of the Harrod-Domar model, based on Johnson (1953) and linear programming models (Basu 1984), and further developed during the 1960s, includes export growth (Feder 1981). Second, Bardhan and Lewis (1970) turned

[1] I am grateful to Danilo Spinola for inspiring discussions and useful comments. Comments from a seminar at the Department of Economics, Social Sciences University of Ankara (ASBU) are gratefully acknowledged.

the two-gap model into a neoclassical version by way of assuming that there is a domestic and a foreign capital stock; the investment of the latter is imported and paid for by exports. Both models have the assumption of exports depending on the terms of trade and an exogenous export growth rate. Ziesemer (1995a) assumes that their exogenous export growth rate is the product of that of world income growth and an income elasticity, as Thirlwall (1983) did, and links the model to the literature on the ideas of Prebisch (1950, 1959) and Singer (1999). Third, Thirlwall (1979) suggested balance-of-payments-constrained (BoPC) growth: If exports depend on world income and the terms-of-trade, and imports on domestic income and terms of trade, the equality of exports and imports on trade balance or their growth rates under constant terms of trade would imply domestic growth depending on foreign growth.[2] All these models have versions with international capital movements (see Feder 1981; Ziesemer 1995b, 1998; Thirlwall 2011).

There are strongly different ways to model the supply side and the terms of trade in the above mentioned literature. In the papers of the Harrod-Domar models with absent or fixed prices, the GDP growth rate consists of given parameters, mostly the savings ratio multiplied by the output-capital ratio. Export growth then affects only debt accumulation, the interest burden and the GNI (gross national income). The Bardhan-Lewis model has a neoclassical production function, in which technical change has been separated from efficient labour in the later literature. Terms of trade are driven by domestic supply and world income in the export function; all arguments are therefore ultimately driven by both foreign income and exogenous technical change, allowing the terms of trade to go either up or down or stay constant depending on the relative strength of these two forces. The missing link between productivity and constrained trade (Krugman 1989) is the effect of productivity increases on terms of trade reductions allowing for more exports and imported capital goods (Ziesemer 1995b). In the BoPC literature, terms of trade are exogenous and constant, and production, labour, investment, and savings are often ignored altogether.

Models differ in the way output reacts to foreign growth. The BoPC models are Keynesian in spirit and output is supposed to react with additional employment, although the latter never appears explicitly in the models. In extensions of Bardhan and Lewis (1970) with vertical or horizontal labour supply, output and employment react through additional capital goods imports. The question is whether employment reacts or only imported capital goods when foreign output increases. The evidence related to Thirlwall's law allows for both, because the evidence is derived without link to the factor markets. In order to allow for both, we use Okun's law, which allows for unemployment and has equilibrium unemployment as a special case, and we add an endogenous labour force

[2] Trade balance and BoPC are used as synonymous. But Kvedaras (2007) and Holland et al. (2004) point out clearly that the literature is about equality of exports and imports on trade balance for goods and services. This is also clear from the data used (Blecker 2021a,b). When foreign debt is introduced, it is either exogenous or other ratios of variables are fixed to determine debt in essentially only one (BoP) equation (Thirlwall 2011; Bhering et al. 2019) or two equations if the terms of trade growth is determined (Barbosa-Filho 2001).

function. We start the set-up of our model from exports, imports, and all balance of payments items. Then we add the goods market items investment, and savings, and the supply side with a production function and endogenous human capital, R&D, and technical change.

There is much empirical evidence supporting the impact of world income growth on domestic income growth or the impact of exports on growth in the single-equation regression mode. For the early approaches we refer to the well-structured survey in Dutt (2002; p. 372-374). For example, Perraton (2003) uses error-correction methods in the single equation form, but not the vector form leading to simultaneous equation systems. Alonso and Garcimartín (1998) use the vector-error-correction method to estimate the export and import functions and estimate other systems to get parameter estimates, but they do not use the power of estimation-based simulations to test the effects of world income growth and the growth reduction from the BoPC.[3] Jayme (2003) provides a VECM and analyzed shocks from exports on GDP but does not include the import and export functions or other variables. Conversely, Spinola (2020) estimates a vector-error-correction model and uses it for simulations but does not show the economic relations of BoPC models in the cointegrating equations.

López & Cruz (2000), Holland et al. (2004), Britto and McCombie (2009), Garcimartín et al. (2016), Lélis et al. (2018), Spinola (2020), and Birkan (2021) also analyze the related data in terms of VAR (vector-autoregressive) and VEC (vector-error-correction) models. These types of econometric models provide in principle a reliable data analysis for a small set of variables.[4] However, the way they are handled show several shortcomings.

First, some authors have separate VAR or VEC models for import and export functions although they share the terms of trade variables and therefore should be dealt with together because this goes against the lessons of cross-unit cointegration which holds across countries and across equations (Gonzalo and Granger 1995; Banerjee et al. 2004) and mean that sets of cointegrated variables should not be analyzed separately.

Second, they often do not use the model for simulations but only for the purpose of getting the long-term relations.

Third, their disadvantage in principle is that the more detailed mechanisms of the causality chain from world income to domestic GDP *via factor and goods markets* remains often unclear when only a slightly extended trade balance model is used.[5] Kennedy and Thirlwall (1979) and McCombie (1985) use only the goods market equation with exogenous exports or terms of trade and neglect of debt dynamics and interest payments. Palley (2003) suggests that capacity utilization adjusts imports or productivity growth to balance supply and demand growth. This leads to supply growth determining long-run

[3] Kvedaras (2007) formulates the condition of weak endogeneity as necessary for the BoPC model but does not carry out any empirical analysis.

[4] Pesaran (2015) suggests using not more than 10 variables when talking about $T \geq 100$.

[5] For a deeper discussion, see Fair (2018), chapter 4.6.3.

growth via Verdoorn's law. World GDP growth only affects capacity utilization when imports adjust, or productivity growth adjusts to world GDP growth. There is no link to labour markets and no goods market equilibrium condition. In Dávila-Fernández et al. (2018), there is a long-term ratio $I/Y = i*$ and deviations are assumed to be a function of capacity utilization. Assuming $Y = AK$ as from a limitational production function,[6] and $I \equiv \dot{K} + \delta K = i^{*}Y$, they get $\dot{K} = i^{*}AK - \delta K$as waekly exogenous capital accumulation process. The limitational production function then determines the output level. Investment is linked to the trade variables through an assumption regarding the adjustment of capacity utilization. The paper starts with Thirlwall's law in growth rates but it has no goods or factor market equilibrium. Dávila-Fernandez and Sordi (2019a) is the first paper since Kennedy and Thirlwall (1979) and McCombie (1985) that links the BoPC idea to a goods market equilibrium condition in a theoretical model. They impose that in the long run there is current-account equilibrium and therefore (i) there is no debt accumulation in the long run (and ignored in the short run), (ii) Thirlwall's law rules, and (iii) capital goods are not imported. We deviate in regard to these latter assumptions allowing for debt dynamics and imported capital goods, and in having an empirical model where all equations are estimated. We still allow for Thirlwall's law to work.

Razmi (2016) emphasizes the need for a dynamic simultaneous equation model (DSEM). The specific causal mechanism of imported capital goods and other factors of production also using the variables of BoPC models has been shown for an estimated reduced form of the Bardhan/Lewis model with imported capital goods by Mutz and Ziesemer (2008) for Brazil, by Habiyaremye and Ziesemer (2012) for Malaysia, by Ziesemer (2018) in a DSEM analysis for Croatia, and by Hallonsten and Ziesemer (2019) for Trinidad&Tobago, using simultaneous equation estimation, baseline simulation and shock analysis. In all cases we clearly see the effects of world income changes as expected in a Prebisch-Thirlwall perspective, increases in terms of trade and GDP.

As mechanisms in theoretical or empirical work, one either needs the constraint of BoPC models or imported capital goods suggested by Prebisch (1950) and included in World Bank. The heterodox model of Dutt (2002) and the neoclassical models based on Bardhan-Lewis (1970) have both, the BoP constraint without or with debt, and imported capital goods. When foreign debt is included, these models do not have a trade-balance constraint, or only a soft one with equal growth rates of exports and imports (Blecker 2021b). However, allowing for foreign debt does mean mainly that debt is used to pay for machines in the short run and that exports are used to pay debt service. In that sense, the balance of payments remains a constraint with debt allowing to postpone payment through exports (Ziesemer 1995b, 1998).

[6] *A* can be the product of capital productivity and capacity utilization. The dynamics of capacity utilization and unemployment rate open the link to business cycle research. Neoclassical economists can get a *Y/K* ratio from the marginal productivity condition of a CES function and use it in the perpetual accumulation of capital.

Our approach for Brazil does not impose balanced trade or current account or growth rate equality for exports and imports,[7] but a balance-of-payments identity including trade, net foreign debt flows, and interest payments on debt stocks, other net factor income and transfers from abroad, and puts emphasis on the impact of foreign debt on domestic interest rates. For all but one of these equations we formulate and estimate dynamic regression equations. In regard to trade, we use data on imported capital goods and distinguish them from domestic investment and imported consumption.

On the supply side we specify and estimate equations making technical change dependent on R&D, and R&D and human capital dependent on each other and on technical change, leading to semi-endogenous growth according to our estimates and simulations.

Changes of inventories are an important disequilibrium variable for the goods market besides unemployment for the labour market. Inventory changes as part of ex-post investment feed back into deposit rate determination, foreign debt accumulation and net secondary income from abroad, and unemployment feeds back into equations for (precautionary) savings and inflation. We estimate equation for all these variables without imposing perfect competition, constant terms of trade or other steady-state assumptions.

In section 2 we explain the data choice for all variables. In section 3 we briefly introduce the main aspects of econometric thinking in a non-technical manner. In section 4 we present the model with 22 variables and equations in estimated form and interpret the results in detail, especially the weaknesses in education and R&D policies. In section 5 we discuss the baseline simulation and show that the Brazilian economy has a long-run instability caused by its savings gap, which leads to increasing foreign debt, relative to GDP, driving up the interest rate. In section 6 we show the effects from simulations of permanent intercept changes of equations for world GDP, human capital, R&D, and terms of trade; we confirm Thirlwall's law and discuss the relation with the literature on (i) BoPC growth, (ii) growth with imported capital goods, and (iii) the reaction of unemployment, labour force, and human capital. In section 7 we summarize all major results as the basis of policy conclusions.

2. Data and definition of variables

The data for the variables mentioned above are taken from World Development Indicators (WDI) unless other sources are stated. Variables related to the current account and Thirlwall's law are as follows.

Z is world GDP in constant 2010 US$. Unlike Birkan (2021) we do not use US GDP to proxy for world GDP, because only 12% of Brazil's export go to the USA.

[7] VECMs are able to use weaker assumptions than equal growth rates. They have long run growth rates of exports and imports which can be different and are in line with the evidence (see references to VECMs above).

X is exports of goods and services in constant LCU (Local currency units). In spirit, this is the quantity of exports.

P is terms of trade calculated as 'exports as capacity to import', XP_X/P_M, divided by exports of goods and services in constant LCU, X, yields $p = P_X/P_M$. Net barter terms of trade are not used because they ignore services. REER data are not used because they use manufacturing weights, under-emphasizing agriculture, and services. REER is closely correlated with our terms-of-trade variable though.

M is imports of goods and services in constant local currency units.

mach is imported machinery and transport equipment in current 1000$ for the period 1989-2020 from the World Integrated Trade Solution, WITS, (at https://wits.worldbank.org) multiplied by 1000 and the official exchange rate, divided by the GDP deflator from WDI and multiplied by 100.

NPir is net primary income from abroad, real, (formerly *net factor income from abroad*) in constant LCU; (from current LCU using the GDP deflator).

NSir is net secondary income from abroad, real, (formerly *net current transfers from abroad*) in constant local currency unit (from current LCU using GDP deflator).

NLir is net labour income from abroad, calculated as net primary income from abroad plus interest paid, rF.

The second group of variables are related to investment, savings, and foreign debt, which related BoPC growth to the goods market.

GFCF is gross fixed capital formation, excluding changes in inventories, in constant local currency units.

dinv is the change of inventories.

S is savings in constant local currency units, from gross savings/GDP ratio, multiplied by GDP in constant LCU (WDI uses a different deflator for gross (fixed) capital formation in constant LCU, which is available only from 1970 onwards). Gross savings are calculated as gross national income less total consumption, plus net transfers.

dr is the deposit rate, not deflated obtained by saving households.

defl is the GDP deflator.

r is real interest rate (lending rate deflated by GDP deflator), available only from 1997 to 2019.

F is net foreign debt calculated as accumulated gross investment minus gross savings all in constant local currency units, using net foreign assets from abroad as initial value.

Variables related to production of GDP and knowledge are the following.

Y is domestic GDP in constant local currency units.

K_d is capital stock calculated by the perpetual inventory method from gfcf-mach defined above using a depreciation rate of 4.2547 percent, the average from PWT 9 for the period 1989-2017, and, to make initial capital stocks, an initial growth rate of 0.047 taken from Ziesemer (2022a).

K_f is capital stock calculated by perpetual inventory method from *mach* (imported machinery and transport equipment) with the same initial growth rate and depreciation rate as for K_d.

H is human capital index from PWT9.1 defined to be between one and five.

L is the labour force.

U is the unemployment rate. Gaps in the data are filled by estimating and forecasting Okun's law in equation (19) below and using the forecasted values to fill the gaps in the data.

Th099 is the labour augmenting technology level calculated for an elasticity of substitution of 0.99 in Ziesemer (2022a) with human capital in the production function.

rdy is R&D expenditure as a share of GDP, which generates technical change.

3. Econometric aspects

We specify the economic ideas in terms of the literature starting with trade variables and imported capital goods. Then we specify equations also for all explanatory variables that we use. By implication, unlike the early generations of DSEM models (see Kilian and Lütkepohl 2017 and Fair 2018), we do not include exogenous variables but rather have an equation for each variable as suggested by the VAR approaches; this allows to run simulations out of sample. We have too many variables for use of VECM or structural VAR models though, which are usable only for less than 10 variables (Pesaran 2015) and in practice limited to models with 2 to 8 variables (Kilian and Lütkepohl 2017). We always check the effect of statistically significant time trends in the spirit of detrending.

We test for the statistical significance of many lags of all variables. They are relevant because of habit persistence, estimated expectations, and adjustment processes (Pesaran 2015), which may be the implicit in the data. They also buy some insurance against (near) unit roots and contribute to cointegration (Maddala and Kim 1998). However, it may happen that many lags are significant, and we are left with too little degrees of freedom. Then we combine the economically essential variables with ar(p) processes (autoregressive processes of lag order p), and we test for remaining serial correlation. Adding an ar(p) process, $v = \sum_{i=1}^{p} \rho_i v_{-i} + \epsilon$, to a model $Y = X\beta + v$ yields a new dynamic model $Y = X\beta + \sum_{i=1}^{p} \rho_i (Y_{-i} - X_{-i}\beta) + \epsilon$ (see Wooldridge 2013). In the results section we report these dynamic models in the form $Y = X\beta + \Sigma_i \rho_i v_{-i} + \epsilon$.

We use the Three-Stage-Least-Squares (3SLS) method, which takes into account contemporaneous correlation of the residuals of all equations as the SUR (seemingly unrelated regression) method does, and we use instrumental variables to deal with endogeneity.[8] We drop the year 2020 in order to avoid end-of-sample bias from the COVID crisis.

Contemporaneous regressors and lagged dependent variables (the latter in case of non-negligible serial correlation when trying the lagged dependent as its own instrument) may be endogenous requiring instruments; we use lags of endogenous variables. This has several conditions (see Wooldridge 2013): 1. The instrument may not be a significant regressor in the equation where it serves as an instrument (order condition) because otherwise the first-stage regression would be regressing the variable on itself as instrument; using variables lagged once as instruments always ensures that the variable with the highest lag can be an instrument for the contemporaneous regressor, while the other lagged regressors serve as their own instruments. 2. As we use only endogenous variables, the lagged regressor must be significant in the equation for its own current variable because IVs must be correlated with the regressor (the rank order condition consists of the first and second condition together). Third, as the lagged regressor serving as IV depends on its lagged residual in its own equation, this residual should not be correlated with the residual of the equation where it serves as instrument, as IVs and regressors should not be correlated; this cannot be tested as IV estimation imposes $E(z'u)=0$ with instrument $z(u_z)$ and therefore we simply assume this or that the bias is small (see Nakamura and Nakamura 1998). More generally, correlation of residuals of one equation with lagged residuals of another equation should not bias the estimation much.

Simulation figures shown below are obtained by the Broyden algorithm using 1000 repetitions with random draws of residuals from a normal distribution as we have a too low number of observations for the use of the bootstrap method. Simulations start from initial values made from actual data. Models are solved forward and backward. Simulation with the estimated model requires that the (i) initial values are not too far away from a solution, and (ii) that there is no overflow through partial instabilities, and (iii) that no variable runs into negative values when it appears in log form elsewhere because logs of negative values do not exist. If overflow or negative values happen to appear, we have most probably an instability either because the economy is unstable or through a misspecification, which requires re-specification. In other words, problems with the solution of the model are an additional test for the economy or for mis-specification. One possible source of instability are unit roots of single variables or unit eigenvalues of systems. We therefore check that the sum of coefficients of lagged variables is between 1 and -1. Moreover, the simulations can show whether there are increasing amplitudes or exorbitant growth rates, both indicating instability in an intuitive manner. Instability will be explained economically in order to reduce the probability of mis-specification.

[8] GMM HAC method runs mostly into 'near singular matrix' problems during estimation.

4. The model and estimation results

We first explain the empirical model in the form of estimation results with p-values in parentheses except for identities. The results for baseline simulation and permanent changes of the intercept of the equations for world income, human capital, the R&D/GDP ratio and terms of trade are explained in section 5.

4.1 Exports, imports, investment, and savings

We start with the trade part and end with the knowledge part of the model. World GDP is one of the two driving forces of the model. It is estimated as an autoregressive process in equation (1), depending on its own lags and a time trend. Differentiating with respect to time and assuming constant growth rates we get a long-run growth rate of 2.83%. Therefore, the economy could grow also without technical change and human capital growth.

$$LOG(Z) = 3.628 + 1.12LOG(Z_{-1}) - 0.429LOG(Z_{-2}) + 0.187LOG(Z_{-3}) + 0.00336t \quad (1)$$
(0.0001) (0.00) (0.02) (0.103) (0.0004)

World GDP is the income term in the export demand function (2) with a short run income elasticity of 0.94, almost unity, and a short-run terms of trade elasticity of -0.32. Export price elasticities are low as usual in the literature. Because of the lagged dependent variable, the short run elasticities have to be divided by (1-0.665), making the long-run elasticities three times larger than the short-run elasticities, -0.95 for the terms of trade and 2.8 for world GDP. The export equation can be estimated in levels as the variables are cointegrated as in Birkan (2021).[9]

$$LOG(X) = -20.5 + 0.665LOG(X_{-1}) - 0.319LOG(P) + 0.94LOG(Z) - 0.0097t \quad (2)$$
(0.001) (0.0157) (0.0005) (0.00) (0.102)

Export revenues, *pX,* can be used to import machinery and consumption goods. The demand for imported machinery, *mach*, in equation (3) depends on the lagged dependent variable,[10] the previous value of the foreign capital stock, the interest rate (as in Fair 2018), the terms of trade as in Dutt (2002), world GDP, the lagged rate of inflation and two autoregressive terms. The long-run price elasticity is 1.232/1.234, close to unity.[11] The BoPC literature has an equation similar to (3) for intermediates (see Blecker 2021a; Blecker and Ibarra 2013; Ibarra and Blecker 2016). Technology

[9] Dávila-Fernandez and Sordi (2019b) add capital to the export equation. Pugno (1998) adds the level of prices to the growth rate version of (2). We hesitate to add these arguments and stick to the conventional version of the export equation.

[10] Subtracting the lagged dependent on the left in (3) changes the coefficient of the lagged dependent variable by (-1). We do this if this subtraction makes the coefficient significant while it is not otherwise in (3), (13), (17), and (20). In the case of equation (5) both versions are insignificant and therefore short and long run elasticities are identical.

[11] The sum of coefficients of log(mach) on the right-hand side after removing the difference on the left-hand side is -0.234 –0.433(1+0.234)-0.526(1+0.234). The sum of log(p) terms on the right-hand side is 1.232-0.433(-1.232) -0.526*(-1.232). The long-run elasticity terms-of-trade elasticity then is 1.232(1+0.433+0.526)/ [(1+0.234) (1+0.433+0.526)] = 1.232/1.234. This result is the same as obtained when ignoring the ar terms. This is the standard procedure; it is not meant to say that our model has a steady state.

effects do not enter here directly. Productivity effects come in indirectly from the production function (10) below into the supply increasing (or cost decreasing) argument of the terms of trade function (15); if they were included in (3), prices would capture only other aspects of price formation than technology, the major determinant of comparative advantage in trade theory. Average quality aspects go implicitly into the income elasticity and the intercept, and its change into prices and the time trend, which also has a detrending function for all variables (Wooldridge 2013).[12] Technology arguments can be inserted if the whole causality chain from several regressions would be inserted into a single equation regression, but then it would not represent the typical demand function but rather the explanatory variables of prices and income elasticities are included and lead to collinearity and a different interpretation.[13] We keep these arguments in separate equations. The inclusion of world GDP may reflect demand expectations or foreign exchange constraints.

$$D(LOG(MACH)) = \underset{(0.13)}{-17.34} - \underset{(0.00)}{1.234}LOG(MACH_{-1}) + \underset{(0.00)}{1.232}LOG(P_{-2}) - \underset{(0.00)}{1.5}LOG(1+R)$$

$$\underset{(0.00)}{3.05}LOG(Z) - \underset{(0.0001)}{1.7}LOG\left(K_{f,-1}\right) - \underset{(0.0044)}{1.1}DLOGDEFL_{-2} - \underset{(0.00)}{0.433}v_{-2} - \underset{(0.00)}{0.526}v_{-5} \qquad (3)$$

Imported consumption goods are total imports, M, minus imported machinery, $MACH$. They depend positively on income and terms of trade as usual, but here also on wealth, defined as the sum of domestic and foreign capital minus foreign debt. As the coefficient of the lagged dependent variable is 0.52, the long-run elasticities are about twice as high as the short-run elasticities.

$$LOG(M - MACH) = \underset{(0.0011)}{-32.24} + \underset{(0.0056)}{0.52}LOG(M_{-1} - MACH_{-1}) + \underset{(0.00)}{4.88}LOG(Y)$$

$$-\underset{(0.00)}{4.39}LOG(Y\_(-1)) + \underset{(0.0479)}{1.03}LOG(K_{d,-1} + K_{f-1} - F_{-1}) + \underset{(0.074)}{0.82}LOG(P_{-1}) \qquad (4)$$

Besides imported machinery we have investment of domestic goods, total gross fixed capital formation minus imported capital goods, in equation (5). It depends on the two lags of domestic capital,[14] lagged output[15] and two lags of the interest rate, where the first lag indicates the normal negative effect, and the second lag is an intertemporal

[12] Moreover, estimating the function in terms of growth rates is under suspicion of over differencing, requiring considering moving averages of the residuals, which are only imperfectly approximated by lags of all variables (Maddala and Kim 1998).

[13] Bottega and Romero (2021) discuss the related literature.

[14] Franke (2022) attributes the idea of negative effects of capital stocks on investment to Harrod an Kaldor and offers supporting evidence. They also appear in the neoclassical investment theory where investment is the difference between target and lagged value of capital. This effect therefore should not be controversial.

[15] Literature in the tradition of Keynes and Kalecki often uses capacity utilization (in the investment equation), for which data are pertinently hard to get. Capacity utilization is likely to be strongly correlated with unemployment rates. Output growth above trend is also strongly correlated with unemployment. Therefore, we would read investment functions with GDP as an argument analogous to having capacity utilization. When output is above (below) trend capacity utilization will also be above (below) normal.

substitution effect leading to higher investments when interest was high two periods ago. There is no lagged dependent variable here because capital stocks are included and make them statistically insignificant.

$$LOG(GFCF - MACH)$$
$$= \underset{(0.00)}{23.2} + \underset{(0.0045)}{4.43}LOG(K_{d,-1}) - \underset{(0.00)}{7.056}LOG(K_{d,-2}) + \underset{(0.00)}{2.96}LOG(Y_{-2}) -$$

$$\underset{(0.00)}{0.9}LOG(1 + R_{-1}) + \underset{(0.00)}{1.6}LOG(1 + R_{-2}) \quad (5)$$

Savings depend on their own lagged value. They have a high, positive income elasticity, react positively to deposit rates, inflation, and unemployment changes, negative to past inflation and wealth. High debt relative to domestic capital increase savings in the sense of a policy reaction function of the government. The lagged residual indicates the dependence on one additional lag for all variables. Short-run elasticities with or without lags have to be multiplied by roughly a factor three to get long-run elasticities.

$$LOG(S) = \underset{(0.00)}{38} + \underset{(0.00)}{0.354}LOG(S_{-1}) + \underset{(0.00)}{2.9}LOG(Y) + \underset{(0.00)}{0.19}DLOGDEFL$$

$$\underset{(0.00)}{- 0.06}DLOGDEFL_{-1} - \underset{(0.0009)}{3.53}\left(LOG\left(K_{d,-1}\right) + K_{f,-1} - F_{-1}\right) + \underset{(0.006)}{0.217}D\left(LOG(U_{-1})\right)$$

$$\underset{(0.00)}{+ 0.06}LOG(1 + DR_{-2}) + \underset{(0.00)}{33.3}(F_{-2}/K_{d,-2})^4 - \underset{(0.00)}{0.51}v_{-1} \quad (6)$$

As investment and savings are explained up to changes in inventories, we can now define their accumulation.

4.2 Perpetual inventory identities

For any given value of foreign debt, the difference between investment, the sum of gross fixed capital formation and changes of inventories, and savings (including net factor income and net current transfers from abroad) enhances foreign debt. Alternatively, we could use current account deficits. Data are made in the way indicated by equation (7) and therefore re-estimation confirms the unit coefficients and a constant for rounding errors, whereas t-values and p-values are irrelevant.

$$F = -16799751 + 1.00(GFCF + DINV - S) + 0.99999F_{-1} \quad (7)$$

Imported capital goods, *mach*, are accumulated to the foreign capital stock, where the lagged dependent variable has a coefficient of unity minus depreciation rate.

$$K_f = -198034.0 + 0.957K_{f,-1} + 0.999998MACH \quad (8)$$

Gross fixed capital formation minus imported capital goods builds the stock of domestic capital using the same rate of depreciation by lack of better information. The re-estimate yields

$$K_d = -419047.6 + 0.955K_{d,-1} + 0.999997(GFCF - MACH) (9)$$

The capital stocks enter the production function and together with debt they enter the definition of wealth introduced above.[16]

4.3 Production function, knowledge accumulation, and labour supply

A Cobb-Douglas production function seems to be realistic for Brazil according to Ziesemer (2022a,b). Elasticities of production for Brazil in equation (10) are near the standard values of 0.3 for domestic physical and human capital, and 0.6-0.7 for labour and technical change. The value for foreign capital is only 0.1. Moreover, we have autoregressive processes of order two and five, where the latter may reflect the business cycle length.

$$LOG(Y) = \underset{(0.044)}{4.625} + \underset{(0.0002)}{0.27}LOG(K_d) + \underset{(0.00)}{0.29}H + \underset{(0.00)}{0.69}LOG(TH099)$$

$$+\underset{(0.00)}{0.65}LOG(L(1-U)) + \underset{(0.002)}{0.1}LOG(K_{f,-2}) + \underset{(0.0003)}{0.34}v_{-2} - \underset{(0.022)}{0.2}v_{-5} \quad (10)$$

As the human capital variable *H* is defined in the range of one to five, we transform it to *4/(5-H)* in equation (11), which is between unity and infinity, in order to have a variable that is not limited in its value in the simulations. The change of this variable is driven by the rate of change of technology and by the demand for R&D purposes. When growth rates of GDP are larger, people go less for education rather than investing more in education. The unit coefficient reminds us of unit root problems, which are present in the dependent variable according to the ADF test, which has low power, but not according to the DF-GLS test, which has no low-power problem. Taking differences on the left-hand side and dropping the lagged dependent variable from (11) gives almost identical results and makes the instability of the model discussed below appear earlier. Moreover, after all, we could not find a better specification.

$$D(4/(5-H)) = \underset{(0.27)}{0.0044} + \underset{(0.00)}{1.02}D(4/(5-H_{-1})) \quad (11)$$

$$+ \underset{(0.0001)}{0.121}D(LOG(TH099_{-1})) + \underset{(0.11)}{0.0272}LOG(RDY_{-1}) - \underset{(0.0006)}{0.129}D(LOG(Y_{-2}))$$

The growth of the labour force in equation (12) is driven by its own five-year lag, encouraged by human capital growth, and growth of the GDP[17] with the same 2-year lag that discourages human capital formation. This may suggest the need for a policy

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[16] Our way to calculated capital, debt and wealth does not include revaluation as Fair (2018) does for the USA. The ups and downs from stock market valuation and de- or revaluation are not included here.

[17] Leon-Ledesma and Thirlwall (2000) explain this in detail.

reform to make education more attractive in Brazil. World income growth also has a positive effect, similar to the employment effects in traditional Keynesian models, but here coming from the labour force. Finally, there are autoregressive terms with lags four, five and one.

$$D(LOG(L)) = \underset{(0.00)}{-0.0173} + \underset{(0.00)}{0.583}D(LOG(L_{-5})) + \underset{(0.0009)}{0.68}D(LOG(H_{-1}))$$

$$+ \underset{(0.00)}{0.155}D(LOG(Y_{-2})) + \underset{(0.067)}{0.097}D(LOG(Z_{-1})) + \underset{(0.00)}{0.45}v_{-4} - \underset{(0.00)}{0.765}v_{-5} + \underset{(0.00)}{0.552}v_{-1} \quad (12)$$

Unlike Fair (2018) for the USA, we do not find a wealth effect or a discouraged worker effect from unemployment for Brazil. Technical change is enhanced by current and lagged R&D/GDP growth in equation (13) with positive effects from its own one-year lag (after correcting for its subtraction on both side for the estimation) [18] and negative effects from its five-year lag. If *R&D/Y* goes to a constant value, technical change goes to a slightly negative rate, perhaps through a bias from a low number of observations, or through loss of sectors with productivity growth abroad.

$$D(D(LOG(TH099))) = \underset{(0.006)}{-0.0268} - \underset{(0.002)}{0.689}D(LOG(TH099_{-1}))$$

$$+ \underset{(0.04)}{0.31}D(LOG(RDY)) + \underset{(0.006)}{0.585}D(LOG(RDY_{-3})) - \underset{(0.018)}{0.6}D(LOG(TH099_{-5})) \quad (13)$$

R&D is driven by its own lag, by past technical change and by a change in the growth rate of the human capital variable, which is stationary in the form used in (14).

$$LOG(RDY) = \underset{(0.07)}{0.034}$$

$$+ \underset{(0.00)}{0.83}LOG(RDY_{-1}) + \underset{(0.026)}{0.69}DLOG(TH099_{-3}) + \underset{(0.028)}{4.8}D(D(LOG(4/(5 - H_{-4})))) \quad (14)$$

If we assume that R&D goes to a constant share of GDP and technical change to a constant growth rate, (13) and (14) lead to a negative growth rate of technical change, and to *R&D/Y* = 1.07 in the long run. Improving the link from R&D to technical change is an important policy task for Brazilian business and its government.

4.4 Terms of trade, Interest, and Inflation

Theoretical and empirical results from models suggest that the terms of trade in (15) are driven by domestic and world GDP (derived from trade balance variables). They represent supply and demand growth where the latter is reflected by world income in the export demand function, which Prebisch (1950) and Singer (1999), Dutt (2002), Oreiro (2016) and Blecker (2021b), and Bardhan and Lewis (1970) have in common. In (15), the sum of coefficients for the world GDP variables is about the same as the

[18] Note the double difference of the dependent variable, which leads to statistical significance of the coefficient of the lagged dependent variable. World income growth would also be statistically significant here with the expected sign, but the model then cannot be solved.

coefficient for the lagged domestic GDP. Lags suggest that there are long-term contracts with prices changed only slowly when contracts expire successively.[19]

$$LOG(P) = \underset{(0.81)}{-0.24} + \underset{(0.00)}{0.79}LOG(P_{-1}) +$$
$$\underset{(0.006)}{1.94}LOG(Z) - \underset{(0.0047)}{3.15}LOG(Z_{-1})) + \underset{(0.07)}{1.38}LOG(Z_{-2}) - \underset{(0.018)}{0.19}LOG(Y_{-3}) \quad (15)$$

Interest rates have an impact on investment equations (3) and (5) and therefore should be explained as well. They can be seen as a return for banks who have a cost from deposit rates *dr*, which affect interest rates positively with a lag of three years. Two lags of the interest variable matter in equation (16). The foreign debt/GDP ratio increases interest rates in cubic form, which we plot in Figure 1. Deviations from output trend, which is similar to the output gap variable used by Fair (2018), and the lagged dependent variable enhance interest rates.[20] An autoregressive term of order five with roughly a unit coefficient appears again.

$$LOG(1+R) = \underset{(0.0032)}{-22.5} + \underset{(0.00)}{0.77}LOG(1+R_{-1}) - \underset{(0.00)}{0.975}LOG(1+R_{-2})$$

$$+ \underset{(0.00)}{53.34}F/Y - \underset{(0.00)}{99.48}(F/Y)^2 + \underset{(0.00)}{61.8}(F/Y)^3$$

$$+ \underset{(0.0337)}{0.51}LOG(Y_{-1}) - \underset{(0.0003)}{0.032}t + \underset{(0.01)}{0.54}LOG(1+DR_{-3}) - \underset{(0.00)}{1.063}v_{-5} \quad (16)$$

The deposit rate, log *dr,* reacts, according to (17), slightly positively to its own lag, to higher current interest and inflation rates as incentives to offers savers more, negatively to lagged interest rates (offering less if banks had higher interest and offered more in the past), and almost not to past inflation rates, which outweigh each other. Capital inflows in the form of investment minus savings decrease the deposit rate. Changes from five years ago have a slightly positive effect through an ar(5) process. This equation is similar to the Dewald-Johnson-Taylor rules for discount rates (Fair 2018).

$$D(LOG(1+DR)) = \underset{(0.003)}{0.09} - \underset{(0.00)}{0.86}LOG(1+DR_{-1}) + \underset{(0.00)}{0.25}LOG(1+R)$$

$$+ \underset{(0.00)}{0.52}DLOGDEFL - \underset{(0.00)}{0.138}(GFCF + DINV - S)/S - \underset{(0.00)}{0.34}LOG(1+R_{-1})$$

$$- \underset{(0.034)}{0.32}DLOGDEFL_{-1} - \underset{(0.0003)}{0.012}LOG(1+R_{-2}) + \underset{(0.01)}{0.34}DLOGDEFL_{-2} + \underset{(0.00)}{0.15}v_{-5} (17)$$

[19] A time trend here has a very small coefficient and is statistically highly insignificant. Equation (1) suggests that the current and two lags of world GDP could be replaced by the third lag and a time trend. Therefore, a time trend should not be added here.

[20] We could also add the inflation rate, but then the model is solved only within sample and with too many failures.

The change of the inflation rate in (18) is reduced by its own lags and also by increasing interest rates beyond 27% because of its inverted u-shape form, and by the unemployment rate squared. (18) is a Phillips curve augmented with its own lags and interest policy and four ar(i) terms. All coefficients in (18) have p-value = 0.0000.

$$D(DLOGDEFL) = -0.126 - 0.48D(DLOGDEFL_{-1}) + 1.054(LOG(1+R))$$

$$-1.94\big(LOG(1+R)\big)^2 - 1.97(U_{-1})^2 - 0.075D(DLOGDEFL_{-6}) - 0.832v_{-2}$$

$$-0.916v_{-1} - 0.36v_{-3} - 0.219v_{-4} \qquad (18)$$

The presence of lagged dependent variables in equations (15)-(18) show that all price adjustments are sluggish.

4.5 Disequilibrium adjustment and income from abroad

Labour markets may not clear immediately, and we leave it open whether Keynesian or neoclassical assumptions[21] are more realistic. Okun's law as formulated in (19) can capture both cases. The unemployment rate depends on its own lag[22] and on the GDP growth rate and thereby varies over business cycle periods. For a hypothetical long-run growth rate of two or three percent the coefficients imply a long-run unemployment rate of 10.8% or 7.8%.

$$U = 0.0168 + 0.9U_{-1} - 0.3D(LOG(Y)) \qquad (19)$$
$$(0.01) \quad (0.00) \quad (0.023)$$

Adding the growth rate of labour supply or of technical change (in the spirit of linking the BoPC growth rate to the natural rate) does not lead to statistically significant results, implying that there is no tension between the actual and the natural rate of growth for Brazil.[23] When goods markets do not clear perfectly excess supply must go into inventories and excess demand can be served by reducing inventories (Harrod 1939; Fair 2018). However, this happens here only with coefficient 0.62, indicating together with the lagged dependent variable that this mechanism is also imperfect. The change of inventories, *dinv*, is modeled in equation (20). To get intuitively plausible coefficients, we take the change of inventories as percentage of the domestic capital stock, which avoids introducing additional volatility when dividing by GDP instead. It depends on its own first lag with coefficient -0.1 and with -0.218 on its own second lag. It is reduced by excess demand. A time trend corrects for trending of all variables. All variables have an additional effect when lagged by four periods.

$$D\left(\frac{DINV}{KD}\right) = -0.775 - 1.1\frac{DINV_{-1}}{KD_{-1}} - 0.218\left(\frac{DINV_{-2}}{KD_{-2}}\right) + 0.0279LOG(Y)$$

[21] Assumptions about the wage elasticity of labour supply have moved from zero to three in the recent literature (see Ziesemer and von Gässler 2021) and those for labour demand would depend on the constant or variable elasticities of substitution.
[22] Leon-Ledesma and Thirlwall (2000) estimate a special case of this where our coefficient of 0.9 is forced to be unity.
[23] For other cases Palley (2003) suggests adjustment of capacity utilization leading to growth in line with Verdoorn's law.

(0.00) (0.00) (0.0002) (0.00)

$$-0.62\frac{(GFCF - S + PX - M - RF + NLIR + NSIR)}{KD} – 0.00065t \ - 0.617v_{-4} (20)$$

(0.00) (0.00) (0.00)

In the formulation of excess demand in (20), savings are diminished by net factor income from abroad, $-RF + NLIR$, for capital and labour services – and by net secondary income (transfers) from abroad, $NSIR$. Net labour income from abroad depends on growth at home and abroad and its own lags in (21).

$$LOG(NLIR) =$$

$$45.8 – 0.378LOG(NLIR - 3) + 4.15LOG(Z) - 4.39LOG(Y) - 0.5LOG(NLIR_{-5}) \quad (21)$$

(0.0024) (0.0085) (0.00) (0.00) (0.0226)

Net secondary income from abroad, in (22), is calculated as a residual from the balance of payments identity, which has net labour income from abroad with a unit coefficient and the sum of debt reduction, $(-GFCF - DINV + S)$, and the interest-augmented trade balance of goods and services, $(-PX + M + RF)$, also with a unit coefficient.[24]

$$NSIR =$$

$$6.83E + 08 - 0.99999NLIR + 0.99((-GFCF - DINV + S - PX + M + RF))(22)$$

This residual determination of secondary income may look like another possibility to escape from the balance of trade constraint. However, in all our simulations below secondary income does not react in an economically or statistically significant way.

The combination of data and the dynamic specification and estimation methods leads to 58 included observations for the period 1962 to 2019. The total system (unbalanced) observations are 622, resulting in an average across the 22 equations of 28 yearly observations. The appendix lists the observations per equation. The chosen method iterates coefficients after estimation of a one-step weighting matrix. Convergence is achieved after after finding 1 weight matrix, 23 total coefficient iterations. We present the number of observations, adjusted R^2, and the Durbin-Watson statistic for serial correlation for the 22 equations in Table A.1.

From the coefficients of the debt/GDP ratio in (16), using an intuitively chosen part of the constant, we get Figure 1. The data for the F/Y are in the range from zero to 0.7 (70%). For debt ratios between 45% and 60% the interest rate is constant, but then it increases strongly.

[24] The deviation from unity and the intercept stem from errors and omissions. Errors and omissions are about 0.1119%, a ninth of a percent, of the GDP, which is about 4000 billion LCU or $700 billion. The intercept then is 0.68 billion comparing to the GDP of 4000 billion LCU. LCU, a Brazilian Real, is currently about 0.2 Euro or 0.21 US dollar.

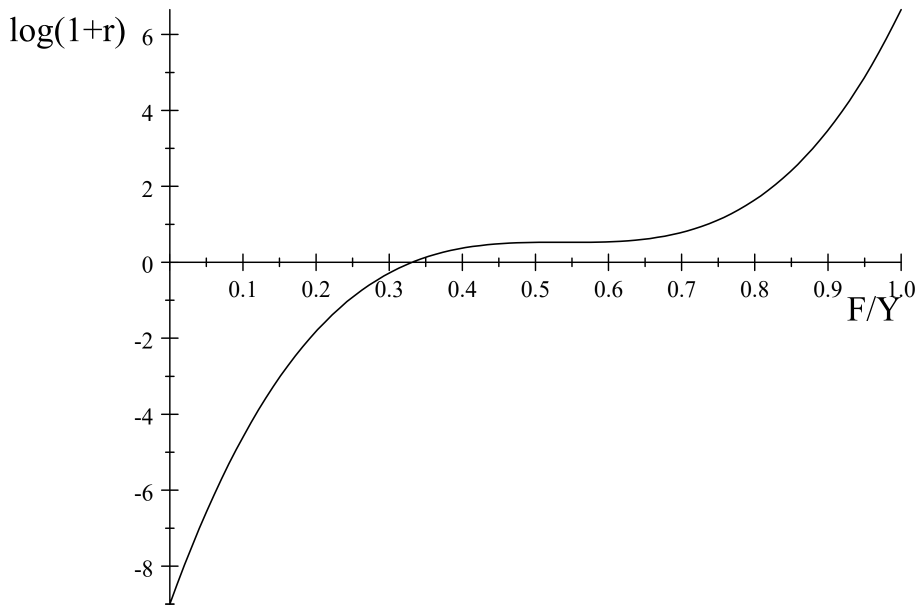

Figure 1 The empirical relation between debt/GDP ratio, F/Y, and the interest rate.

5 Baseline simulation and instability

We can solve the model for the periods for which all equations have estimated residuals, which is the later part 2004-2019 of the estimation period, and beyond until 2032. Going beyond 2032 the solutions generate more than the standard value of two percent failures. This is probably caused by an instability in the model. The reason for the instability is that investments are mostly larger than savings shown in Figure 2. This difference accumulates to foreign debt in (7), shown as share of GDP in Figure 3. According to Figure 1 this drives up the interest rate, which drastically brings inflation down and even to negative rates in forward simulations until 2032. The policy reaction to increases of debt in the savings equation (6) when taken relative to domestic capital, $33.3(F_{-2}/KD_{-2})^4$ or $0.54(F_{-2}/Y_{-2})^4$, is too weak to avoid the instability. Hopefully, Brazil will strengthen savings policies in the next ten years.[25]

The baseline simulation in Figure A.1 shows that actual data are above baseline for some data series from 2006 to 2014. For 2006 to 2008 this is a global bubble. Brazil does not suffer much from the financial crisis, except in 2009, and interest rates go down from 2009 to 2013. Then the Brazilian political crisis brings the economy down from 2015-2017.[26] The COVID crisis brings the economy down below baseline again in 2020. Data remain in the confidence intervals before 2007. The baseline solution of the model is also obtained backward and built into the graphs of Figure A.1 for the period of data availability of each equation.

[25] Singh (2022) finds a low regression slope coefficient of $I/Y = \alpha + \beta S/Y$. The ratio of new debt to GDP, $I/Y - S/Y = \alpha + (\beta - 1)S/Y$, indicates a correspondingly strong reduction of new debt to an increase of savings.

[26] See Arestis et al. (2022) for a detailed discussion.

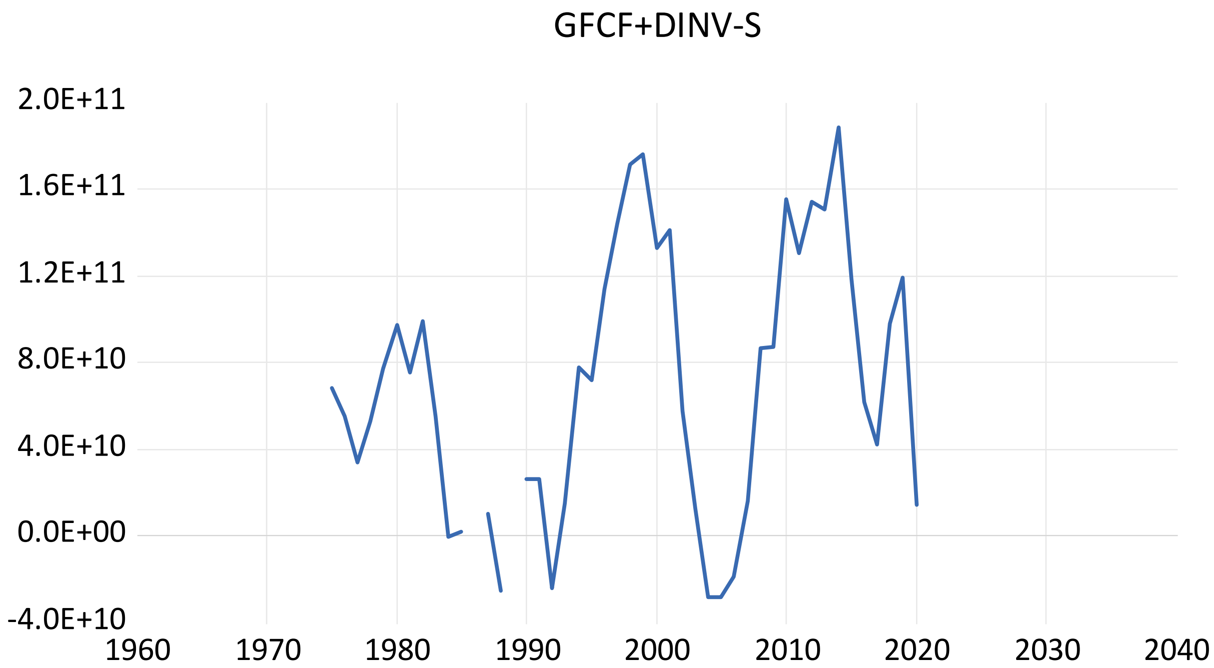

Figure 2: Investment minus savings data generating changes of foreign debt.

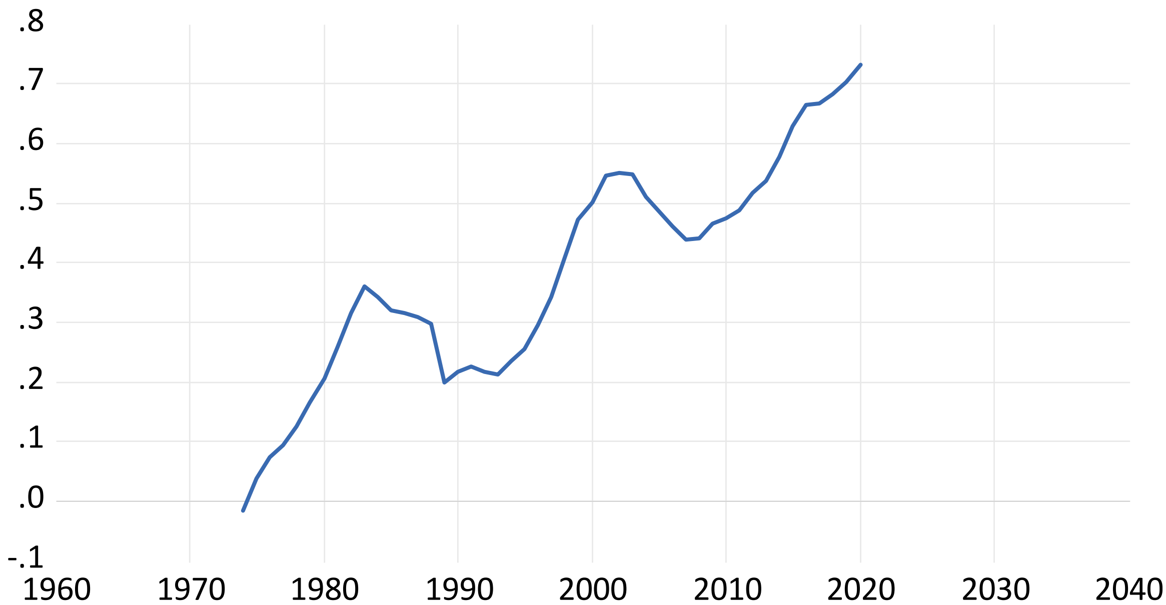

Figure 3 The foreign debt to GDP ratio, *F/Y*, accumulates over time in the data to 70%.

6 Simulation of permanent changes

6.1 Consequences of a world GDP shock

In order to analyze the ideas of Thirlwall and Prebisch we now impose a permanent increase on the intercept of the world income equation by a half percent, 0.005. This effect plays through the whole system of equations. Figure 4 shows the major effects for the period 1960-2030. The higher set of curves with units on the right vertical axis show the baseline mean, the scenario means, and the actuals. The difference between baseline and actuals is shown in the lower curve with units on the left vertical axis. In percentages, the calculated growth rate of world income goes from 0.005 to 4.2% above the baseline simulation. Export quantities show a high increase as expected from the income elasticity of exports of 0.94 in equation (2). After all feedback effects through output changes, terms of trade are up to three percent higher than baseline as expected from the Prebisch-Singer perspective. Output also shows positive changes as expected by the Thirlwall perspective. The effects are statistically significant except for periods around the crisis years 2009 and 2020.

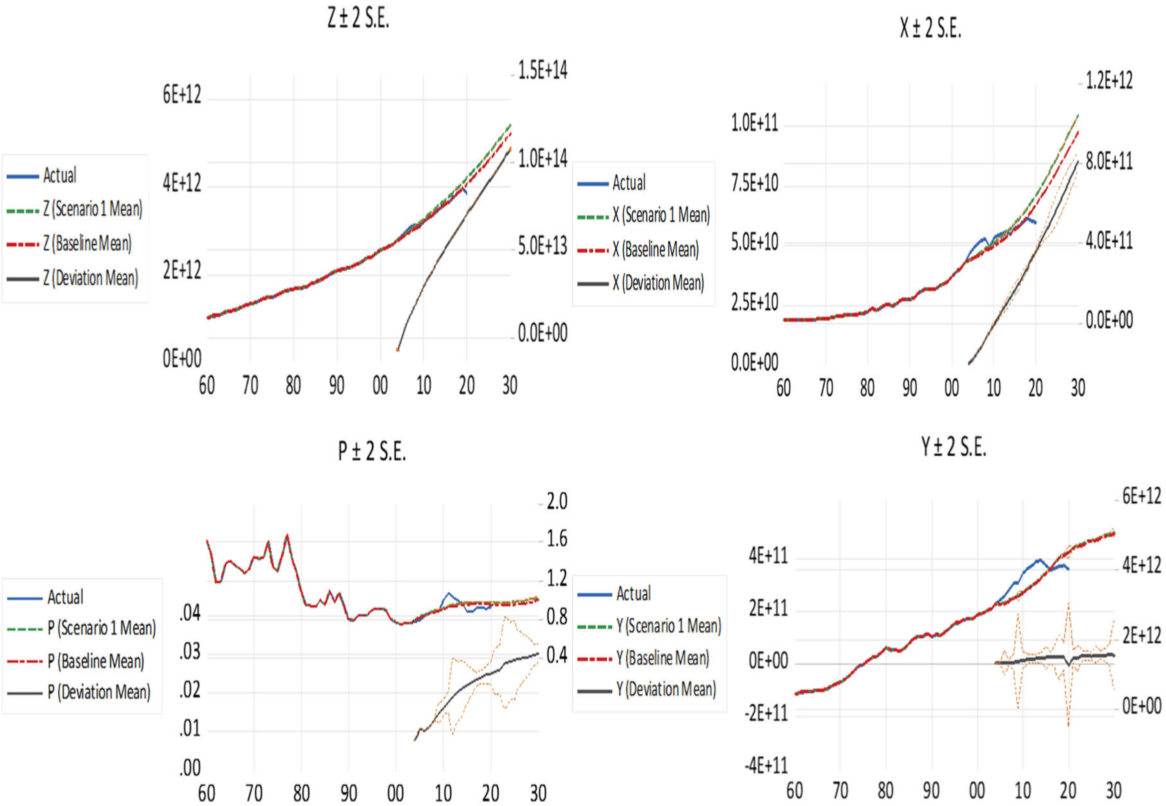

Figure 4 Simulations of world GDP change compared to baseline show Prebisch and Thirlwall effects. The right vertical axis measures baseline means, the scenario means, and the actuals shown as higher set of curves. Left vertical axis measures the difference between baseline and actuals shown as the lower curve.

This raises the question, which factors of production are increasing how much. Figure 5 shows the results. The Keynesian expectation that unemployment falls comes out here as *du=-0.1%* but the effect is statistically insignificant and small compared to an unemployment rate of 13% in 2020. The labour force reacts with going from between zero and 0.74% beyond baseline and this is statistically significant for most periods. Foreign capital is between 0.13% and 3.5% above baseline and significantly so until 2025. Domestic capital is between zero and 2.7% above baseline, which is statistically significant mostly in the later periods. The effect on imported capital expected on the basis of the Bardhan-Lewis model is the strongest effect of the factor input changes.

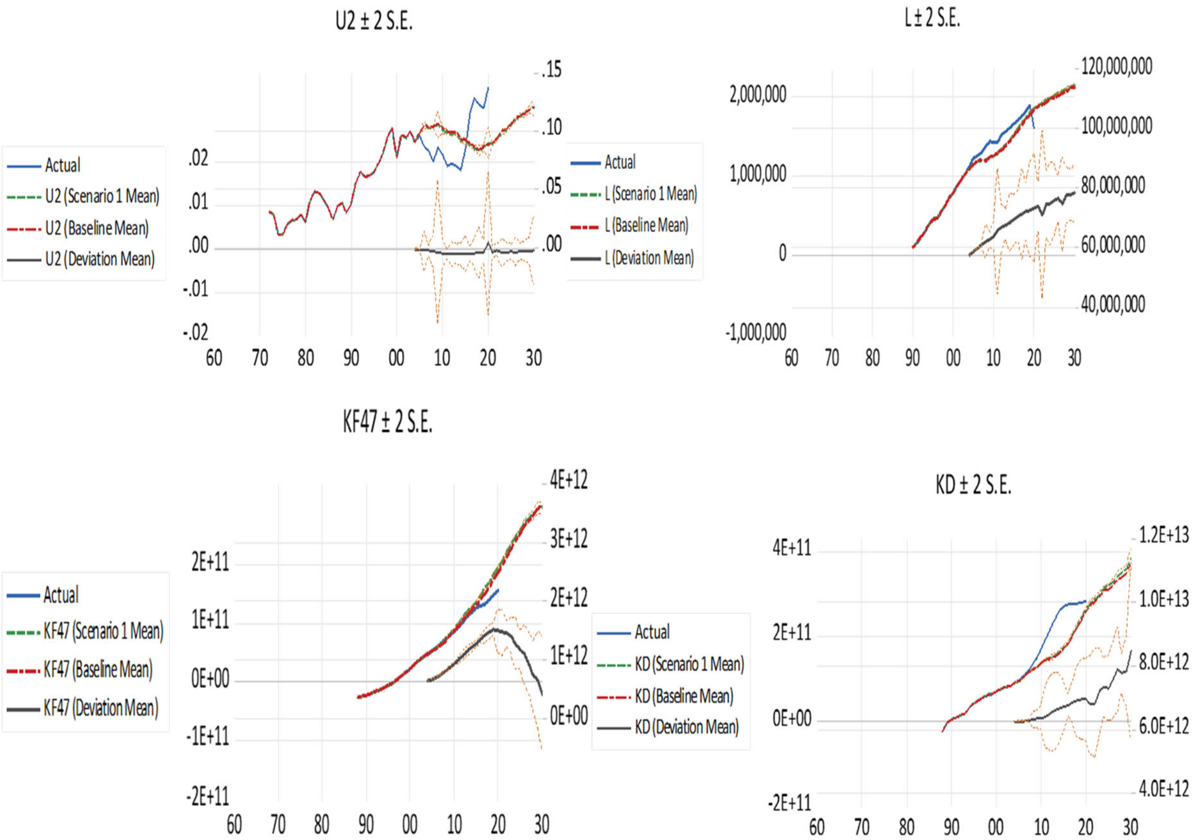

Figure 5 Production factor enhancements from a change in world GDP. Axes and curves are explained in Figure 4.

Figure A.2 shows all results from this world growth scenario confirming that all equations are interacting. Among these effects, the increase in output has unpleasant but small consequences: human capital decreases by 0.09%, which is statistically significant only in the later periods; R&D and technical change fall but in a statistically insignificant way. The residual determination of net secondary income from abroad does not play a role in determining the results: their change is negative until 2022 and later changes to being positive are first small and later statistically insignificant.

6.2 Human capital and R&D changes

World GDP growth is a driving force that allows the economy to grow even without technical change if export revenues are used to buy machinery. This comes with the disadvantage that the economies cannot change world income growth. However, domestic growth can be strengthened through human capital and R&D leading to more technical change. In Figure 6 we show the main effects of human capital changes by an enhancement of the intercept by 0.001. Human capital increases R&D, which increases technical change. Together they enhance human capital again. All effects are statistically significant, but those for R&D and technical change phase out before 2030. Output effects remain high because human capital stays high. Figure A.3 shows all effects of this human capital policy scenario.

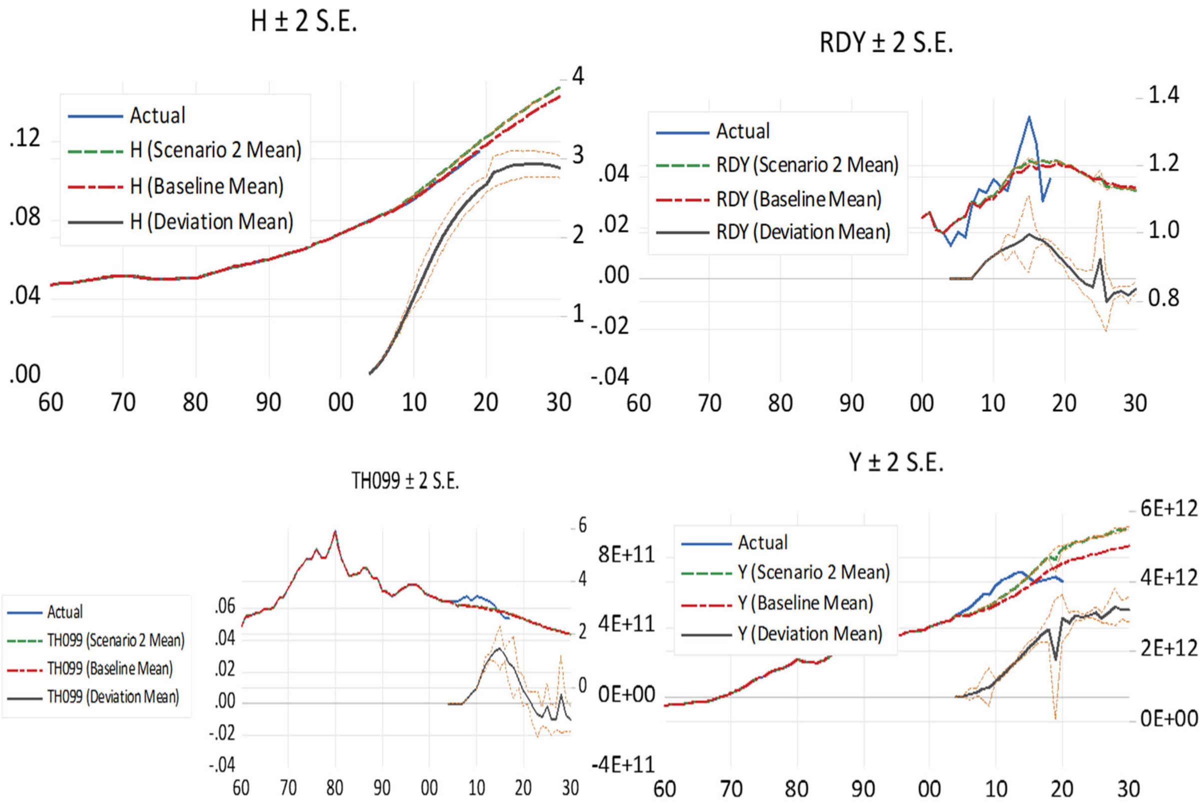

Figure 6 The main effects of a permanent change of human capital policy. Axes and curves are explained in Figure 4.

R&D policies have more persistent effects in Figure 7 than human capital policy in Figure 6. We enhance the intercept of the R&D equation by 0.001. Additional R&D enhances technical change and together they trigger more human capital. Technical change and human capital then enhance output. After ten years the level effects on R&D and technical change get lower. Growth rate differences can be shown for the period 2001 to 2021. This may justify speaking of semi-endogenous growth. Figure A.4 shows all effects of this R&D policy scenario.

The human capital and R&D policies decrease the terms of trade and foreign capital is replaced by domestic capital. Savings increase less than investment and foreign debt grows, but less so then GDP. The size of the shocks is not comparable as *H* and R&D have different dimensions. Therefore, the size of the results is also not comparable.

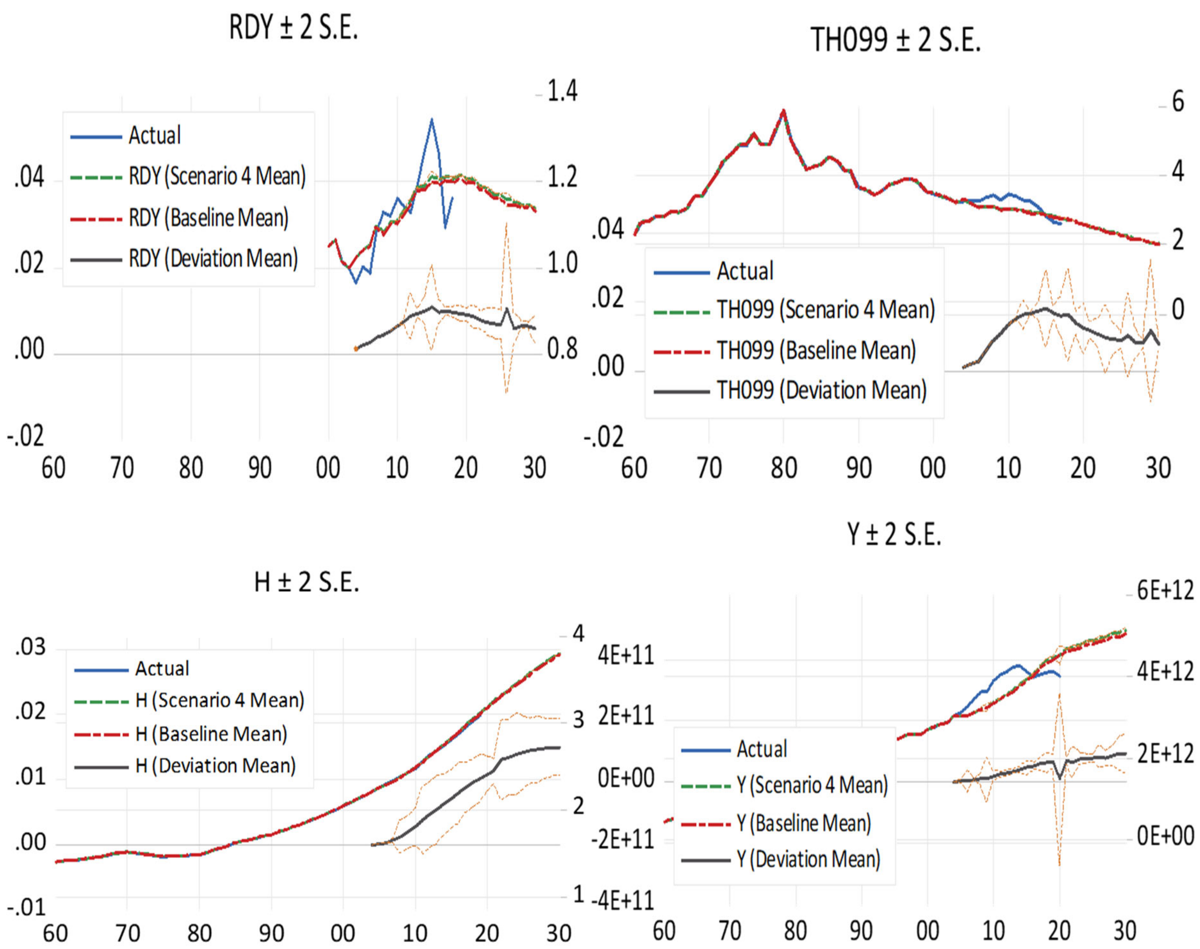

Figure 7 Simulation of R&D/GDP policy changes.

6.3 Marshall-Lerner condition and the Harberger-Laursen-Metzler effect

Finally, our model is able to look at the Harberger-Laursen-Metzler effect (HLME): A change in the terms of trade may have short run effects in line with the Marshall-Lerner conditions, but through dynamic effects the accumulation of foreign debt may go into the opposite direction, $HLME \equiv DF<0$ for a positive terms of trade shock. Figure 8 shows the main effects of increasing the intercept of the terms-of-trade equation. The terms of trade go up by zero to 0.5% compared to baseline. Through the long-term price elasticity of exports of almost unity, the value of exports hardly changes in the upper left part of Figure 8, but the import functions have price elasticities summing up to 2, ignoring additional dynamic effects in (3) and (4), thereby fulfilling the Marshall-Lerner condition with a lag of two years. One would therefore expect higher debt, $dF>0$, as shown in the lower right part of Figure 8. The *HLME* would suggest that dynamic effects could overrule this result, but this is not the outcome here. Figure A.5 shows all effects of this terms-of-trade shock scenario.

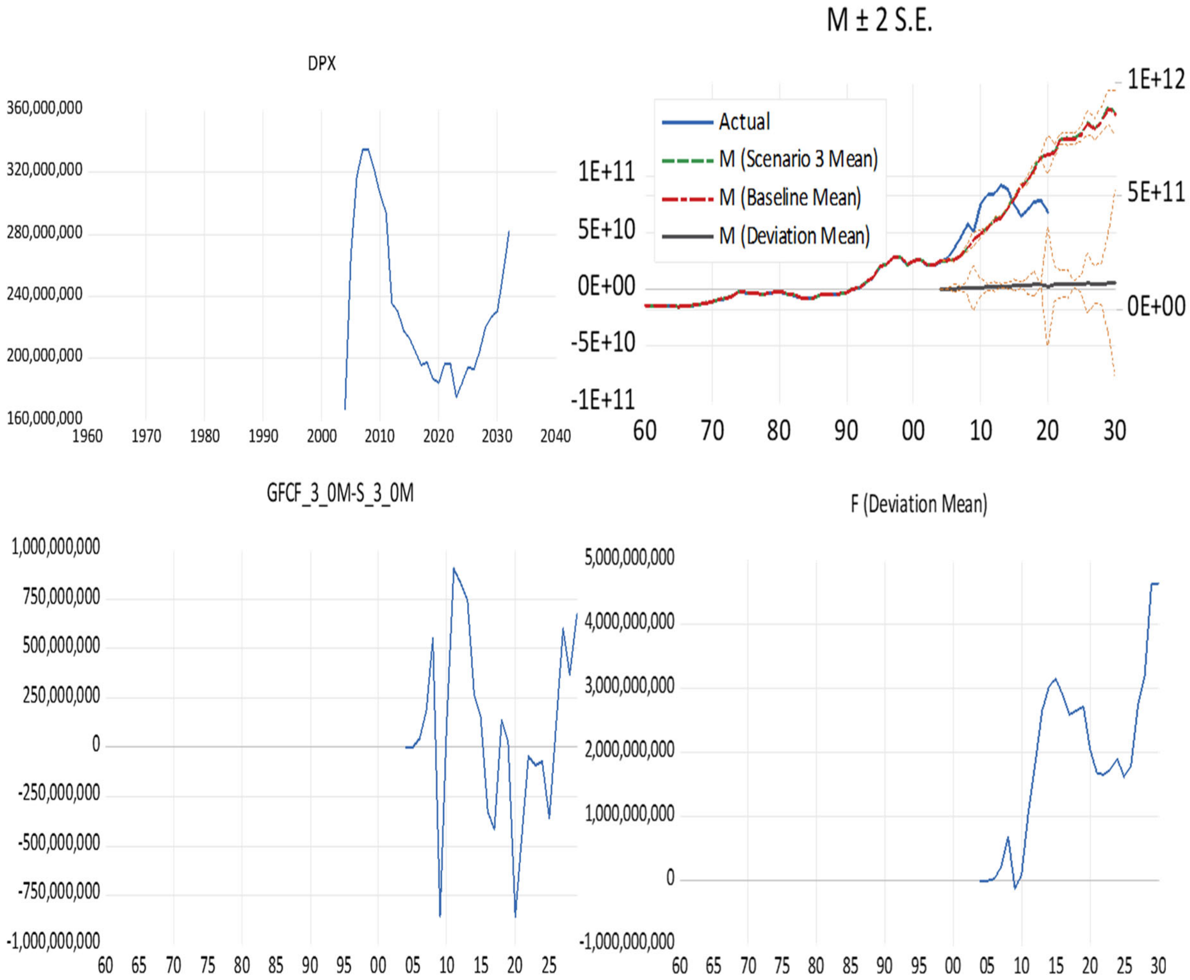

Figure 8: Simulation of terms-of-trade change: no Harberger-Laursen-Metzler effect. Axes and curves are explained in Figure 4.

7 Summary and conclusion

Our regressions reveal that human capital is currently reduced by higher GDP growth. Education should be made more attractive compared to earning money, especially in boom periods. Another important regression result is that R&D weakly affects technical change, which may go to zero in spite of the presence of R&D and calls for a policy linking R&D and technical change more closely.

The baseline simulation shows that Brazil is an unstable economy in the sense that investment is larger than savings leading to increased debt. The private sector raises the interest rate, but the savings-investment difference, although interest elastic, and debt formation do not strongly react to this. Also, policy reactions of savings to high and increasing debt do not stop the development of this problem. The policy reaction function needs to be strengthened and should generate more savings. This does not necessarily mean that government should do this through reduction of budget deficits. Tax and subsidy measures providing incentives for savings of households may also be useful.

Permanent changes of world GDP have level effects as suspected by Thirlwall and Prebisch, and only temporary growth rate effects in Brazil. Additional world income growth triggers importing capital goods and more labour supply and only little other input growth from unemployment or domestic investment. This supports the relevance of models with imported capital goods more than the traditional Keynesian background of BoPC growth models in the case of Brazil for the period under consideration. This conclusion follows under the assumption that unemployment rates capture unemployment correctly. If, in contrast, unemployment statistics are administratively biased, the unemployed may actually not be well captured and the labour supply reaction may actually be an unemployment reaction. Moreover, if unemployment continues running up to higher levels, effects of growth on unemployment may also become stronger.

Permanent enhancements of human capital and R&D increase also technical change and output but decrease the terms of trade leading to the use of more domestic instead of imported capital goods.

The Marshall-Lerner condition holds when looking at prices with lags up to two years mainly because of high price elasticities of imported machinery, whereas other imports and exports have a low price elasticity, which are in sum still large enough to satisfy the ML condition though. Increasing terms of trade lead to higher imports and marginally positive effects on exports because of a unit long-run price elasticity. This leads to increased foreign debt and not to dominant dynamic counter-acting effects on savings or investments as suspected by the Harberger-Laursen-Metzler idea.

Foreign debt increases more strongly than domestic GDP under a world GDP enhancement and less strongly under a human capital or R&D expansion. Human capital and R&D are therefore not only growth policies but also would help stabilizing the Brazilian economy in regard to foreign debt dynamics.

Overall, all results are based on a model that has two driving forces, growth of productivity and world GDP, which the BoPC and the neoclassical two-gap models have in common. Both these growth rates are important and should not be neglected because we show that they are empirically important.

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Appendix

Instrumental variables

Instruments of eq. (1): C LOG(Z(-1)) LOG(Z(-2)) LOG(Z(-3)) @TREND
Instruments of (2): C LOG(P(-1)) LOG(Z) LOG(X(-2)) @TREND
Instruments of (3): C LOG(MACH(-2)) LOG(P(-2)) LOG(1+R(-1)) LOG(Z) LOG(KF (-1)) DLOGDEFL(-2)
Instruments of (4): C LOG(M(-2)-MACH(-2)) LOG(Y) LOG(Y(-1)) LOG(KD(-1)+KF (-1)-F(-1)) LOG(P(-1))
Instruments of (5): C LOG(KD(-1)) LOG(Y(-2)) LOG(1+R(-1)) LOG(KD(-2)) LOG(1+R(-2))
Instruments of (6): C LOG(S(-2)) LOG(Y(-1)) DLOGDEFL(-1) LOG(KD(-1)+KF (-1)-F(-1)) D(LOG(U(-1))) DLOGDEFL(-2) LOG(1+DR(-2)) $(F(-2)/KD(-2))^4$
Instruments of (7): C (GFCF+DINV-S) F(-1)
Instruments of (8): C KF (-1) MACH.

Instruments of (9): C KD(-1) GFCF-MACH

Instruments of (10): C LOG(KD(-1)) H LOG(TH099) LOG(L(-1)(1-U(-1))) LOG(KF (-2))
Instruments of (11): C D(4/(5-H(-2))) D(LOG(TH099(-1))) LOG(RDY(-1)) D(LOG(Y(-2)))

Instruments of (12): C D(LOG(L(-5))) D(LOG(H(-1))) D(LOG(Y(-2))) D(LOG(Z(-1)))

Instruments of (13): C D(LOG(TH099(-1))) D(LOG(RDY)) D(LOG(RDY(-3))) D(LOG(TH099(-5)))

Instruments of (14): C (LOG(RDY(-2))) D(LOG(TH099(-3))) D(D(LOG(4/(5-H(-4)))))

Instruments of (15): C LOG(P(-2)) LOG(Z) LOG(Z(-1)) LOG(Z(-2)) LOG(Y(-3))
Instruments of (16): C LOG(1+R(-2)) F(-1)/Y(-1) $(F(-1)/Y(-1))^2$ $(F(-1)/Y(-1))^3$ LOG(1+R(-3)) LOG(Y(-1)) @TREND LOG(1+DR(-3))
Instruments of (17): C LOG(1+DR(-2)) LOG(1+R) DLOGDEFL (GFCF+DINV-S)/S LOG(1+R(-1)) DLOGDEFL(-1) LOG(1+R(-2)) DLOGDEFL(-2)

Instruments of (18): C D((DLOGDEFL(-2))) (LOG(1+R(-1))) $(LOG(1+R(-1)))^2$ $(U(-1))^2$ D((DLOGDEFL(-6))) (GFCF(-1)-S(-1)+P(-1)X(-1)-M(-1)-R(-1)F(-1)+NLIR(-1)+NSIR(-1))/KD(-1)
Instruments of (19): C U(-2) D(LOG(Y(-1)))

Instruments of (20): C (DINV(-2))/KD(-2) (LOG(Y(-1))) (GFCF(-1)-S(-1)+P(-1)X(-1)-M(-1)-R(-1)F(-1) +NLIR(-1)+NSIR(-1))/KD(-1) @TREND (DINV(-3)/KD(-3))

Instruments of (21): C LOG(NLIR(-3)) LOG(NLIR(-5)) LOG(Z) LOG(Y(-1))
Instruments of (22): C NLIR ((-GFCF - DINV + S -PX + M + RF))

Table A.1 Observations, adj R2, Durbin-Watson statistic

Equation no.	*Obs.*	*Adj. R-sq.*	*DW stat*
(1)	57	0.9995	1.996
(2)	58	0.996	2.12
(3)	18	0.846	2.00
(4)	29	0.97	2.10
(5)	21	0.967	1.887
(6)	29	0.974	2.06
(7)	43	1.00	Identity reproduct.
(8)	31	1.00	Identity reproduct.
(9)	31	1.00	Identity reproduct.
(10)	23	0.9995	2.15
(11)	18	0.869	2.56
(12)	19	0.73	1.77
(13)	14	0.346	1.84
(14)	17	0.70	2.286
(15)	57	0.90	1.897
(16)	16	0.846	2.40
(17)	16	0.978	2.24
(18)	19	0.835	1.987
(19)	46	0.9167	1.97
(20)	19	0.9165	2.17
(21)	18	0.80	1.825
(22)	23	identity	-

The Doornik-Hansen test for multivariate normality returns message 'log of non-positive number'. Portmanteau autocorrelation tests returns message 'near singular matrix'.

Figures with all effects from shocks (not for publication)

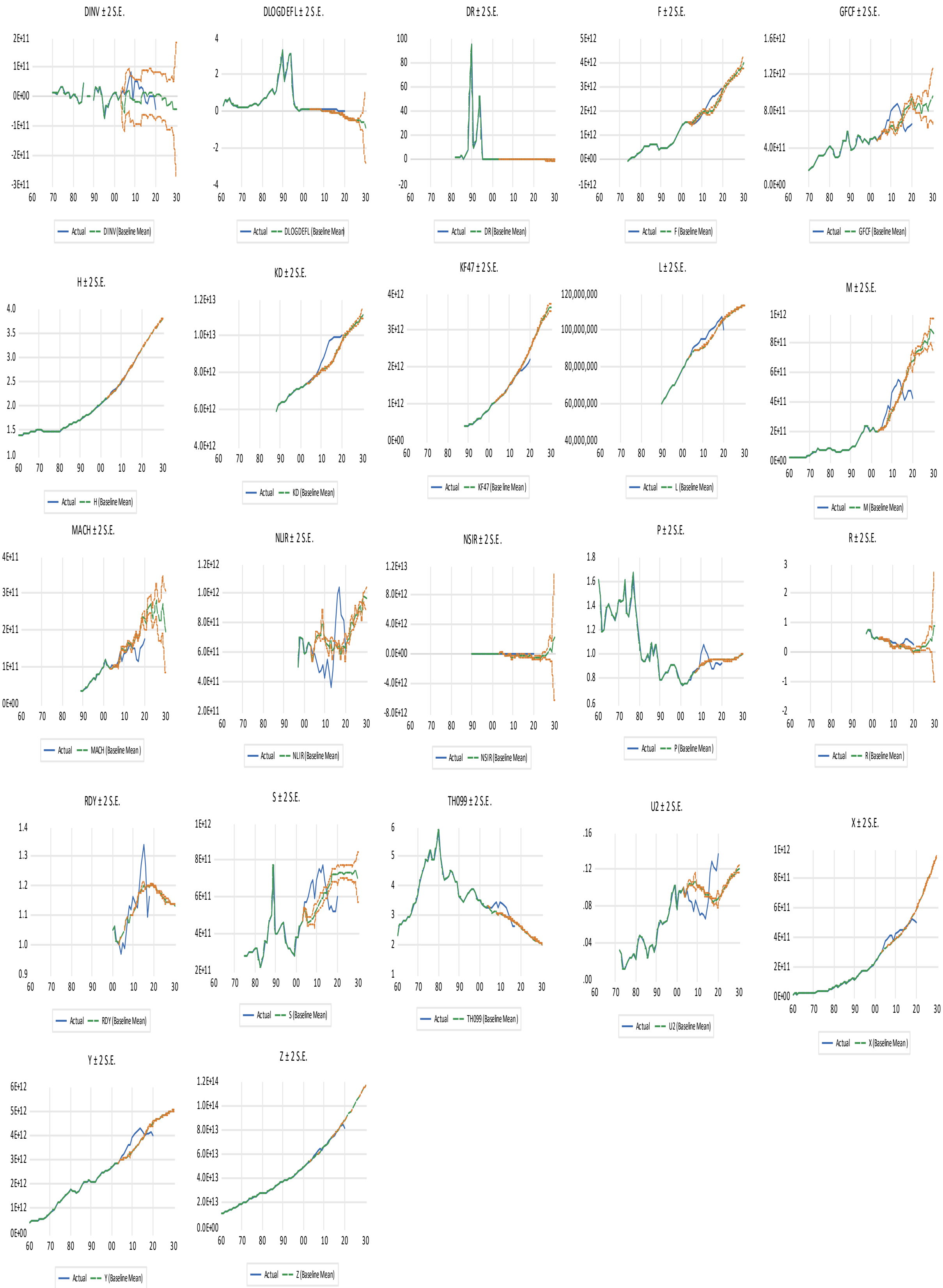

Figure A.1 Baseline simulation and actual data. Axes and curves are explained in Figure 4.

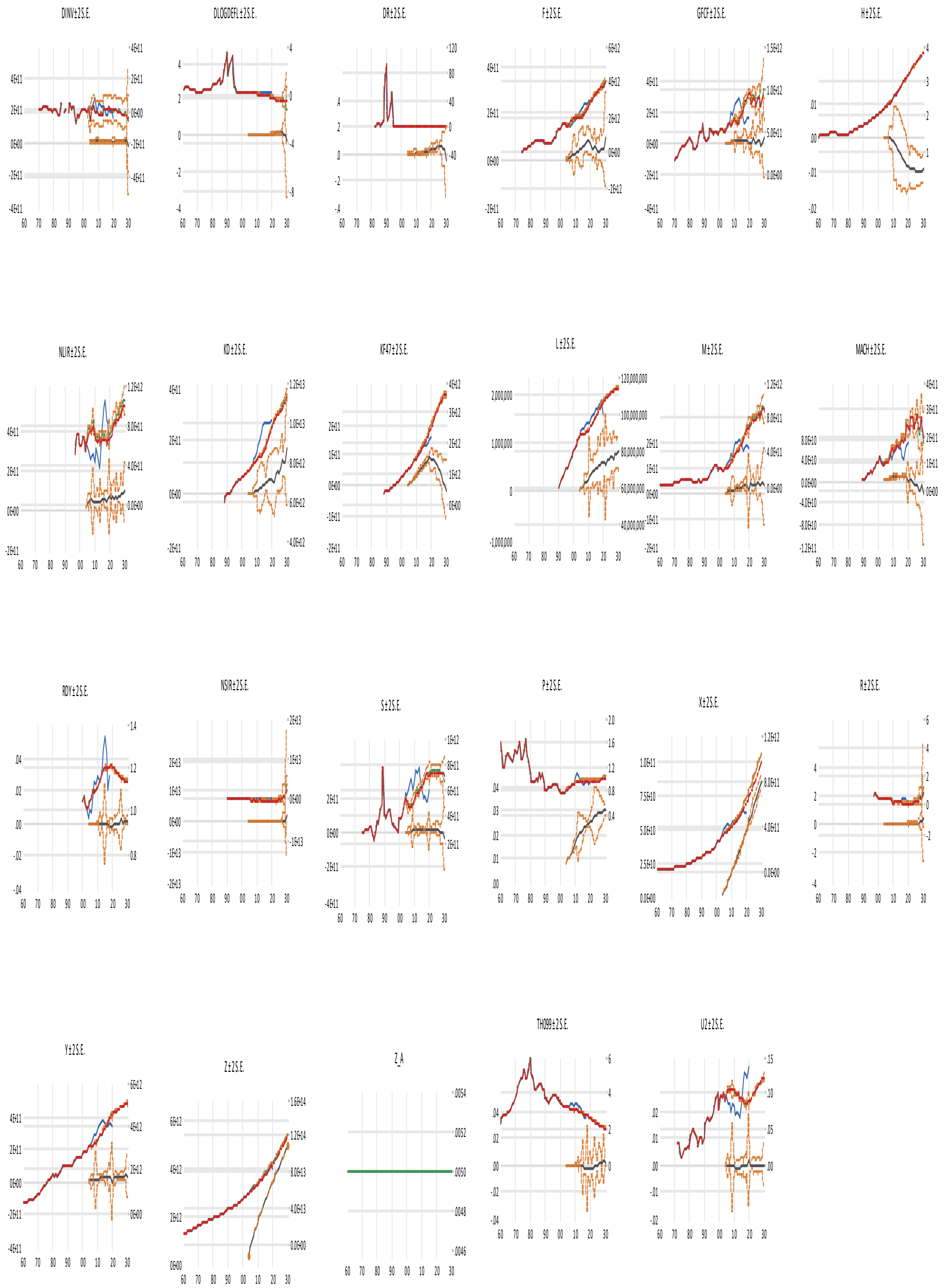

Figure A.2 Effects of world income changes running up from 0.5 percent (intercept change) running up to 4.2 percent. Axes and curves are explained in Figure 4.

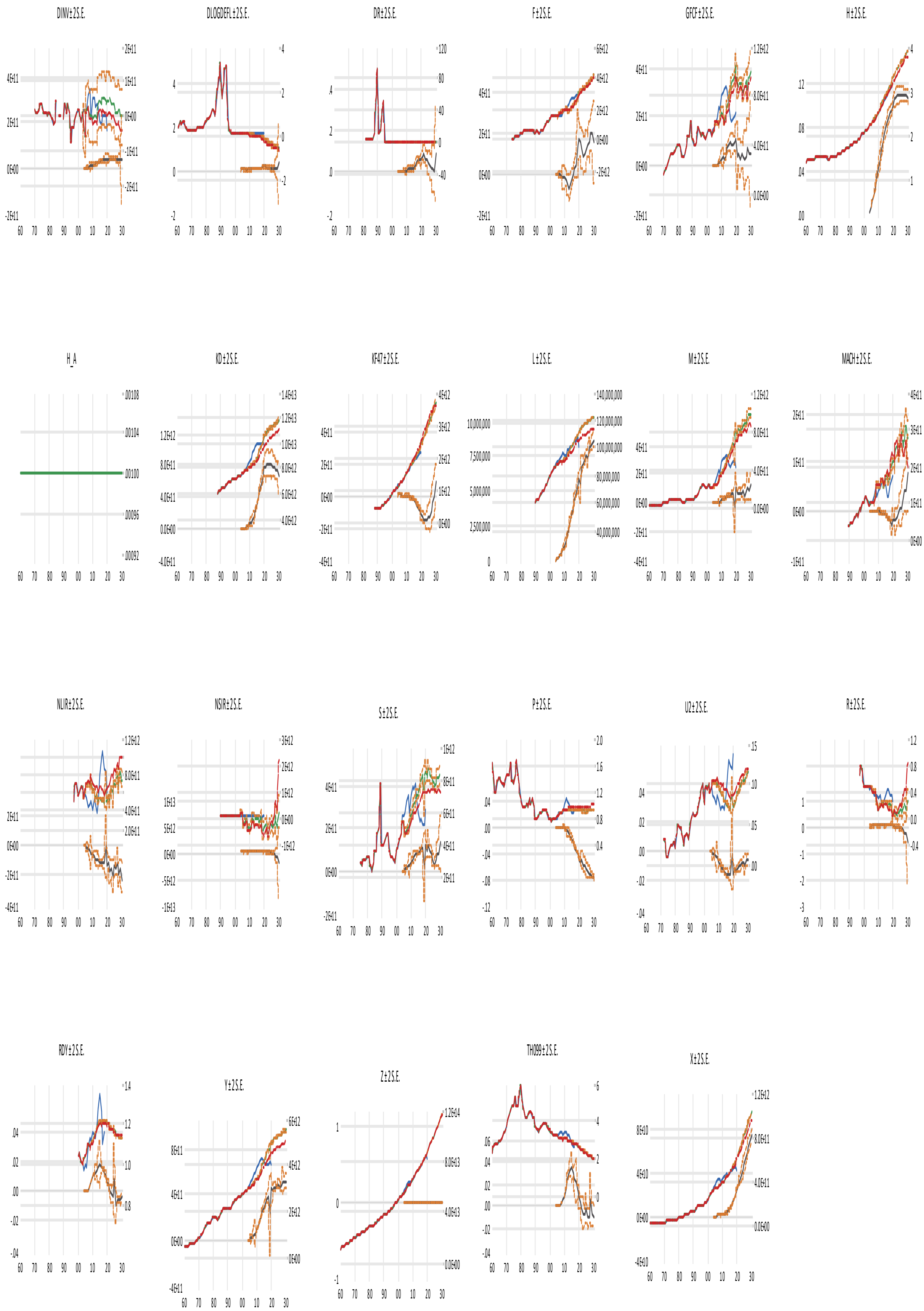

Figure A.3 Effects of human capital intercept changes of 0.001. Axes and curves are explained in Figure 4.

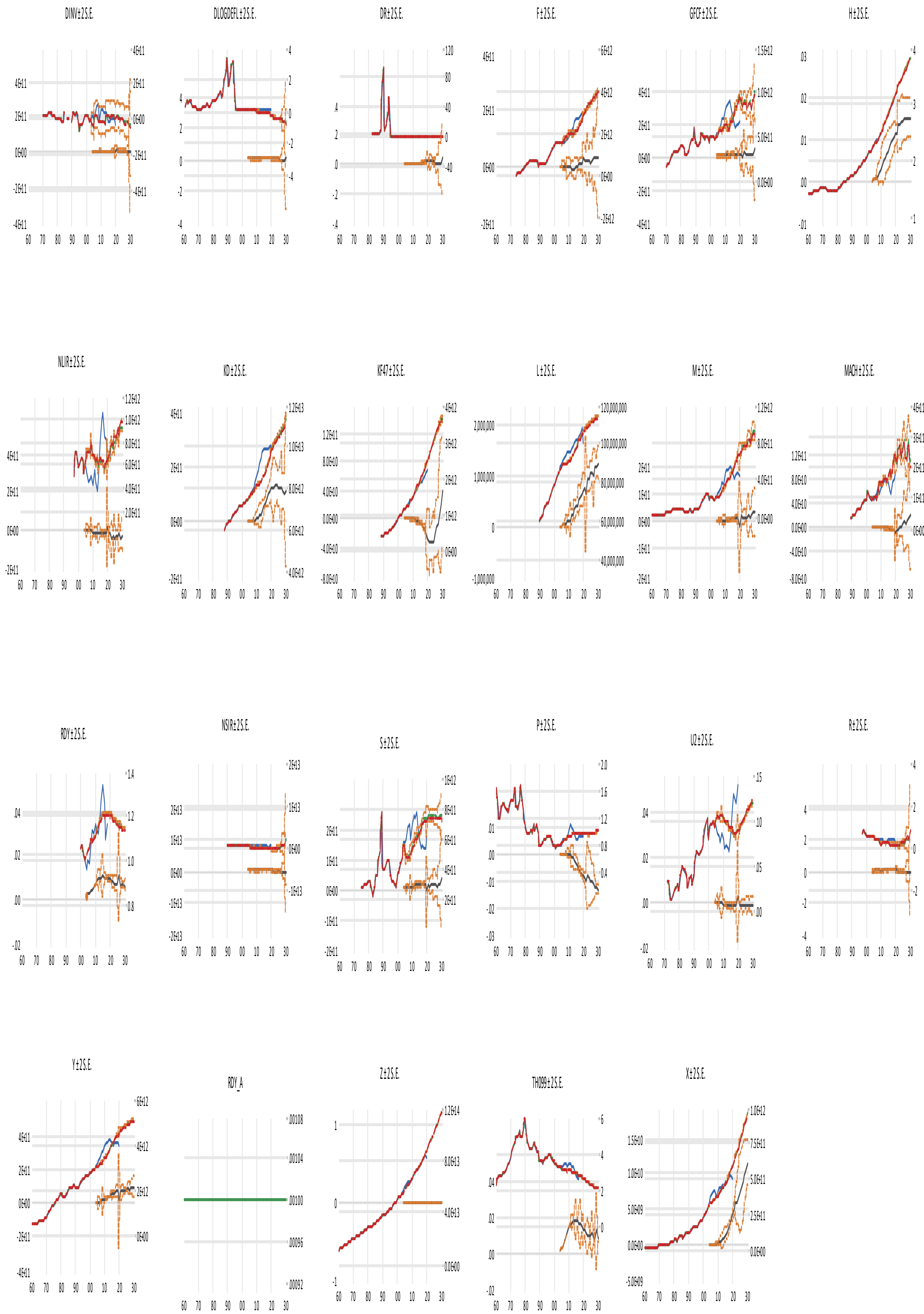

Figure A.4 Effects of R&D intercept changes of 0.001. Axes and curves are explained in Figure 4.

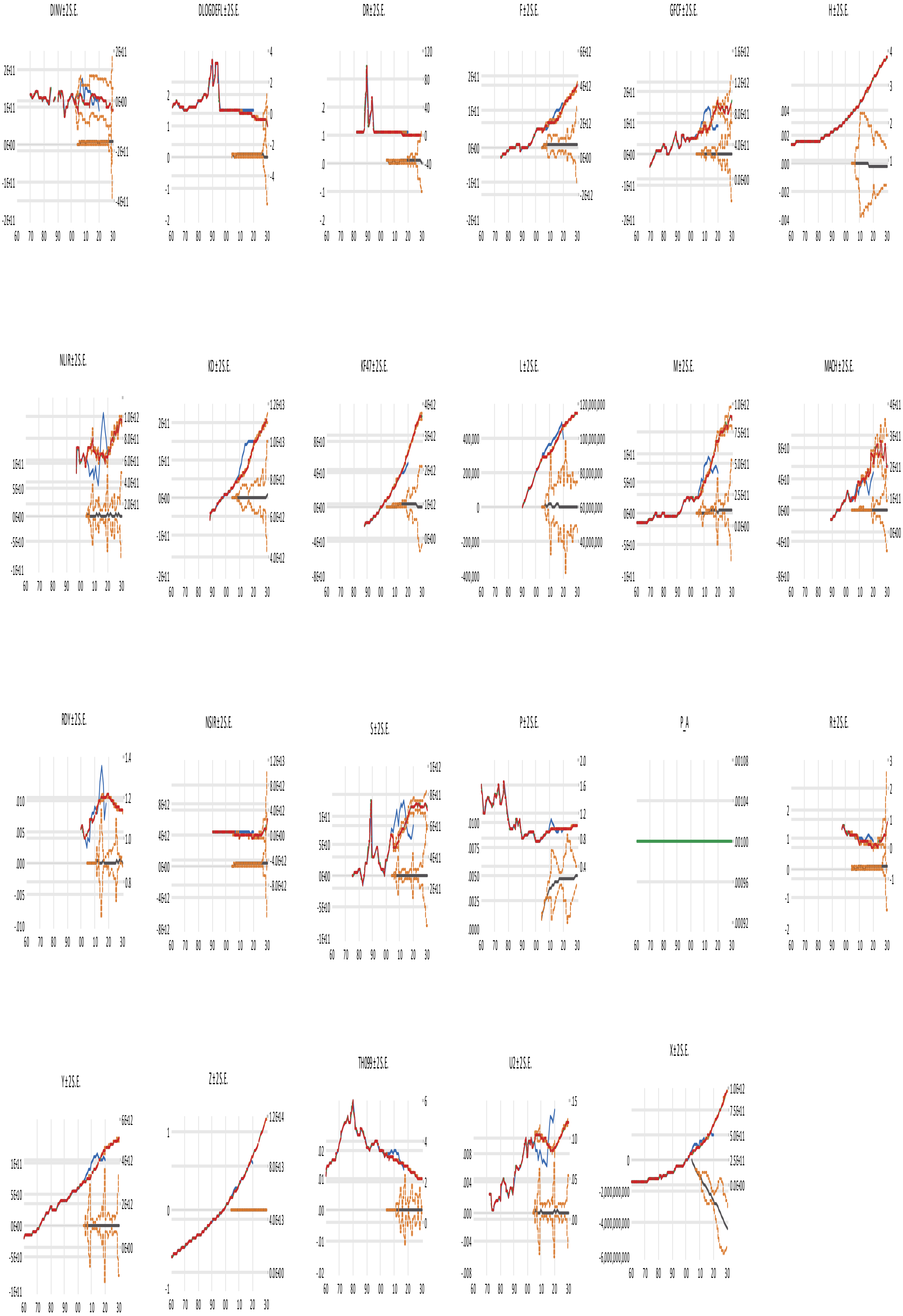

Figure A.5 Effects of terms of trade intercept changes. Axes and curves are explained in Figure 4.

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