The nonlinear nature of country risk*

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Abstract

Country risk premia can substantially affect macroeconomic dynamics. We concentrate on one of their most important determinants - a country's net foreign asset position and - in contrast to the existing research - investigate its nonlinear link to risk premia. The importance of this particular nonlinearity is twofold. First, it allows to identify the NFA level above which the elasticity becomes much (possibly dangerously) higher. Second, such a nonlinear relationship is a standard ingredient of DSGE models, but its proper calibration/ estimation is missing. Our estimation shows that indeed the link is highly nonlinear and helps to identify the NFA position where the nonlinearity kicks in at -70% to -80% of GDP. We also provide a proper calibration of the risk premium - foreign debt relationship applicable to DSGE models and demonstrate that the steady state NFA position matters for economic dynamics in such a model.

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1 Introduction

Country risk premia have the ability to substantially affect macroeconomic dynamics in open economies. This is particularly the case when spreads shoot up (as they did for instance in Greece in 2010(?)) effectively cutting the economy off from borrowing. What stands out in this context is the potential of risk premia to generate a debt spiral. If a country is highly indebted investors may fear about its solvency. As a consequence risk premia could rise, increasing debt servicing costs and, as a consequence, possibly further increasing foreign debt. This mutual relationship may not only have bearing consequences for indebted countries, but also make the relationship between foreign debt and risk premia highly nonlinear.

Given their importance, risk premia have received substantial attention in the literature, both empirical and structural (DSGE). Empirical papers concentrate on finding the determinants of country risk. The list of related papers is long and includes i.a. Ferrucci (2003); Ciocchini et al. (2003); Baldacci and Kumar (2010) and Bellas et al. (2010). Fouejieu and Roger (2013) provide an extensive literature review on the topic. These studies point at a number of important risk premium determinants, including the fiscal balance and debt, foreign debt or net foreign assets, political stability, exchange rate volatility, financial sector characteristics, the ability to borrow in domestic currency or external liquidity conditions. Several papers point out the crucial role of foreign debt, however it usually enters the estimated equations in a linear fashion. To motivate our case we present on Figure 1 the scatterplot of our two main data series - the interest rate differential between a country's and the United States' long term bonds and its net foreign asset position. The non-linear relationship is evident, although one should remember that this picture does not control for other, possibly important factors.

In the DSGE literature risk premia play a very important role - following Schmitt-Grohe and Uribe (2003) endogeneous risk premia, driven by a country's net foreign asset (NFA) position are used to pin-down foreign debt and allow for solving DSGE models of small, open economies (e.g. Adolfson et al. 2007; Christoffel et al. 2008; Justiniano and Preston 2010). The source of the problem is that without an endogeneous premium a small, open economy could borrow any amount at the world interest rate.

As already explained, the NFA position plays a crucial role in both streams of the literature. However, both streams miss something important. The empirical literature has so far concentrated on modeling a linear relationship between the risk premium and NFA (or gross foreign debt) position. This misses the crucial problem of debt traps. The DSGE literature in contrast, usualy focuses on a nonlinear (e.g. exponential) relationship, however it neglects its calibration. This may bias the models dynamics.

In this paper we focus our attention on the nonlinear relationship between the risk premium and the NFA position of a country. We see two important contributions, one for policy and one for modeling. Both are not offered by linear models. First, from the policy perspective our estimates help to determine the regions where the premium becomes particularly elastic to debt and - as a consequence - the economy risks falling into a debt spiral. From the modeling perspective, we offer a ready-to-use calibration of the risk premium - NFA relationship that can be applied in DSGE models. Of course one has to bear in mind that the relationship offers rather a shortcut than a structural linkage. From this perspective our results could also be considered as motivation to provide a structural derivation of this link in the DSGE literature. Our results could then serve as a check whether the derived link is in line with empirics.

The paper consists of two parts. In the first we estimate a nonlinear model of the risk premium, focusing primarily on its relationship with the NFA. We collect data for 41 advanced and emerging economies and show that indeed the link is highly nonlinear. For positive and mildly negative NFA positions the risk premium to NFA elasticity is slightly negative. However, once NFA worsens further the elasticity decreases substantially. We identify the level at which strongest nonlinearities kick in at approximately -70% to -80% NFA to GDP ratio. At this level of foreign debt the semi-elaticity of spreads with respect to NFA increases more than twentyfold compared to normal times. As a consequence a country can be cought in a debt trap.

The second part adapts the estimated relationship to the structure of a typical DSGE model. Such relationships have for a long time constituted an important ingredient of small open economy DSGE models. However, their calibration was supposed to provide model stability rather than reflect the elasticities found in the data. We fill this gap. Moreover, we show on the basis of a standard two-economy DSGE model that taking into account the nonlinear risk premium - NFA relationship has important consequences. First, it allows to take into account diverging rates of time preference in a way that is consistent with a well parametrized steady state. Second, we show that model dynamics differ significantly depending on the steady state NFA position.

The rest of the paper is organized as follows. Section 2 discusses the data and Section 3 our econometric procedure and results. Section 4 discusses the application of our results for DSGE modeling. Section 5 concludes.

2 Data

We collect annual data for 41 advanced and emerging economies (see Table 1 for a list). Our panel extends from 1991 to 2014, is however unbalanced due to limited availability of data on long-term interest rates. Our dependent variable is defined as the difference between a country's long-term ineterest rate and the rate for United States. The data comes from International Financial Statistics and Bloomberg and in most cases represents the yield on 10-year government bonds. For a few countries, where 10-year bonds were missing we approximate the spread using 5-year bonds.

Following the literature we use the following set of explanatory variables:

- Net foreign asset to GDP ratio - the data is drawn from the IMF's database constructed for the External Balance Assesment exercise (IMF, 2013). The series is and update on the NFA statistics provided by Lane and Milesi-Ferretti (2001).
- General government gross debt to GDP ratio (source: World Economic Outlook)
- General government net lending to GDP ratio (source: World Economic Outlook)
- VXO (source: Chicago Board of Trade)
- Foreign exchange reserves to GDP ratio (source: World Development Indicators)
- CPI inflation (differential to US inflation) (source: World Development Indicators)
- Current account balance to GDP ratio (source: World Economic Outlook)
- GDP per capita (at purchasing power parity) relative to the US (source: World Economic Outlook)
- Exchange rate volatility (unconditional volatility based on monthly data) (source: Bank for International Settlements and International Financial Statistics)

3 Model and estimation

3.1 Econometric approach

We assume the non-linear relationship between a country's risk premium and the value of its net foreign assets. In particular we expect that the semi-elasticity of the risk premium with respect to its NFA position increases as the latter variables approaches on negative values. We capture this non-linear relationship using panel smooth transition regression (PSTR) model as proposed initially by Granger and Teräsvirta (1993) and Teräsvirta (1994) for time series and cross sectional data and extended by González et al. (2005) for panel data. We differentiate between two regimes, which depend on the level of the country's external indebtedness.

González et al. (2005) propose a model, for which the transition function has been defined ex ante as a logistic function. In contrast we start from a more general form of non-linearity and test for the distribution of the transition function. Therefore we formulate a fixed effects PSTR model which takes a general form:

$$y_{it} = \mu_i + \delta_1 NFA_{it} + G\left(s_{it}; \gamma, c\right) \cdot \delta_2 NFA_{it} + \beta' x_{it} + u_{it}, \tag{1}$$

where $G(s_{it}; \gamma, c)$ is a transition function allowing for the non-linear relationship between the country's risk premium y_{it} and the net foreign assets position (NFA_{it}). Moreover x_{it} stands for the vector of other variables affecting the risk premium (as listed in Section 2), μ_i express the fixed individual effects while u_{it} are the error terms. We investigate two alternative transition functions usually proposed in the literature, the logistic function:

$$G(s_{it}; \gamma, c) = (1 + \exp\{-\gamma(s_{it} - c)\})^{-1}; \quad \gamma > 0 \tag{2}$$

and the exponential function:

$$G(s_{it}; \gamma, c) = 1 - \exp\{-\gamma(s_{it} - c)^2\}; \quad \gamma > 0. \tag{3}$$

The variable s_{it} in (2) and (3) is the transition variable, c is a threshold parameter, while γ is a transition parameter, which measures the speed of transition from one regime to another. The restriction $\gamma > 0$ is an identifying restriction.

The transition functions described by (2) and (3) are bounded between 0 and 1. It means that the parameter measuring the semi-elasticity of the risk premium with respect to net foreign assets position may vary between δ_1 and $\delta_1 + \delta_2$ along with the transition variable s_{it}. The logistic function (2) approaches zero for very large negative values of the transition variable and approaches one for very large positive values. The exponential function (3) approaches unity for very large both positive and negative values of the transition variable s_t and is close to zero when s_t is equal to the value of the threshold parameter c.

We assume that the semi-elasticity of the risk premium with respect to the country's NFA position depends on its NFA stock. Therefore the transition variable s_{it} in equation (1) reflects the net foreign assets position and the PSTR model boils down to:

$$y_{it} = \mu_i + \delta_1 NFA_{it} + G\left(NFA_{it}; \gamma, c\right) \cdot \delta_2 NFA_{it} + \beta' x_{it} + u_{it}, \tag{4}$$

If the PSTR model with the logistic transition function (2) is true, it implies that the changes in external debt influence the risk premium to a different extent when the debt is low and when it is high. On the other hand, when the exponential transition function (3) is validated the semi-elasticity of the risk premium with respect to external debt changes (probably rises) as debt increases but after exceeding a certain debt level it goes back to the initial level.

We proceed in two steps. First we test for the presence of general PSTR non-linearity in the form proposed by the model (4) against the linear panel model. The model (4) is linear if $\gamma = 0$ or $\delta_1 = \delta_2$. However under both hypothesis the PSTR model contains unidentified parameters and the respective tests are non-standard (see Hansen, 1996 and Luukkonen et al., 1988 for discussion). Therefore we adopt the method proposed by Escribano and Jordá (2001), which allows to distinguish between two alternative transition functions: the logistic and the exponential one.[1] Following this approach we approximate the non-linearity in model (1) by the second order Taylor series expansion of the PSTR model with exponential transition function around $\gamma = 0$, which is the auxiliary regression for this test:

$$\begin{array}{c} y_{it} = u_i + \delta NFA_{it} + \beta' x_{it} + \lambda_1 NFA_{it} s_{it} + \lambda_2 NFA_{it} s_{it}^2 + \\ + \lambda_3 NFA_{it} s_{it}^3 + \lambda_4 NFA_{it} s_{it}^4 + u_{it} \end{array}, \tag{5}$$

After substituting NFA_{it} into (5) as the transition variable s_{it} we get the test regression in the following form:

$$y_{it} = u_i + \delta NFA_{it} + \beta' x_{it} + \lambda_1 NFA_{it}^2 + \lambda_2 NFA_{it}^3 + \lambda_3 NFA_{it}^4 + \lambda_4 NFA_{it}^5 + u_{it}, \tag{6}$$

The null hypothesis of linearity is:

$$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$$

and may be tested using LM type statistic.

Once the linearity is rejected the next step is to select between the PSTR model with the logistic or exponential transition functions. Therefore following Escribano and Jordá (2001) we test two hypotheses:

$$H_{0L} : \lambda_1 = \lambda_3 = 0$$

and

$$H_{0E} : \lambda_2 = \lambda_4 = 0$$

We choose the PSTR model with logistic (exponential) transition function if the minimum p-value is obtained for H_{0L} (H_{0E}), conditionally on rejecting linearity.

After the transition function has been selected we estimate the parameters of the non-linear model (4). For the smooth transition regression model with fixed effects González

[1] González et al. (2005) propose the testing procedure where the non-linear (logistic) transition function in equation (1) is approximated by the first order Taylor series expansion. Since we would like to test the general non-linearity first and then select between the transition functions we do not follow this procedure, which implies ex ante the logistic distribution of the transition function.

et al. (2005) propose the application of the within estimator and non-linear least squares (NLS). As for the linear within estimator we remove first the fixed effects from the model by subtracting the individual specific means from the data. Then we apply the non-linear least squares estimator to the transformed variables.

The algorithm which allows to compute the within estimator for the panel STR model differs slightly as compared to the linear case. Since the model is non-linear the values of some explanatory variables in (4) depend on the parameters of the transition function c and γ. Therefore respective explanatory variables and their individual specific means are varying with the iterative estimation of the parameters of the transition function. For that reasons they have to be recomputed at each iteration (see González et al., 2005 for details).

3.2 Estimation results

We start the analysis by specifying the linear model first. We relate the risk premium to country's net foreign assets position as well other variables which may potentially affect the risk premium: the general government debt level, the fiscal balance, the inflation differential, the ratio of FX reserves to GDP, the C/A balance and GDP per capita.

We estimate a static fixed effects model with the standard errors corrected for the presence of autocorrelation and remaining heteroscedasticity. The estimation results for the linear model with country fixed effects have been collected in Table 2. In the first column we present the risk premium model including the whole initial set of potential explanatory variables. Some of them prove to be statistically insignificant. In particular we find the risk premium not to be affected by the value of foreign exchange reserves as related to country's GDP. Moreover the yield differential is not influenced by the changes in the current account balance.

This latter result combined with the statistical significance of the net foreign assets position allow concluding that the investors in the assessment of the country's risk premium pay more attention to the stock of the external indebtness rather than to its changes. All other explanatory variables included initially in the risk premium model prove to have a statistically significant impact on the yields differential.

Our estimates seem consistent with economic intuition. The risk premium depends positively on the general government debt and on the inflation differential, which partially captures the difference in the short term nominal interest rates. We also observe a positive relationship with exchange rate volatility. Furthermore the estimation outcome shows that the yields differential decreases as the real convergence process occurs. We evidence that the progress in the stage of convergence expressed by the relative GDP per capita limits a country's risk premium. The premium is also negatively affected by the general government balance. It is worthy to note that the risk premium is influenced by both the government debt and the fiscal deficit. Interestingly in contrast to the external indebtness the investors account for the stock but also the flow fiscal variables.

In the second column of Table 2 we show the final specification of the linear fixed effects model with statistically significant explanatory variables only. The semi-elasticity of the risk premium with respect to inflation differential amounts to 0.54 which means that the increase of country's inflation as compared to US inflation transmit to the long term yields differential only by a half. The semi-elasticity of the public debt is relatively low and equals 0.023 – the growth of general government debt to GDP ratio by 1 p.p. raises the yields differential by 2.3 bps. The reaction of the investors to changes in the general government balance is stronger. The improvement of the fiscal balance by 1 p.p. reduces the yields differential by ca. 6 bps. However it is worth to note that both fiscal variables are correlated with each other because the improvement of the fiscal balance might lead to the reduction of the borrowing needs and furthermore to decrease of public debt. Hence the isolated impact of each of these variables may be stronger.

The net foreign assets position is statistically significant - its improvement by 10 p.p. shrinks the yields differential by slightly more than 10 bps.

At this point the issue of potential endogeneity of the explanatory variables has to be raised. As far as the fiscal variables are concerned this problem seems to be negligible since the change in long-term yields differential affects the current level of debt and fiscal deficit only to minor extent. That is because the change in long-term yields influences only the costs of the debt service for the new issuance of the long-term sovereign bonds, which constitutes usually only a small part of the whole debt service costs. We also do not expect the endogeneity problem in case of the net foreign assets position since we use the NFA stock measured at the end of the preceding year. We believe that the only explanatory variable which may be endogenous in our model is the variable representing the exchange rate volatility. To address the problem of potential endogeneity we instrument this variable by its first differences, its squares as well as by the VXO index measuring the level of risk aversion on the global financial markets

The results for the model with instrumented exchange rate volatility variable have been collected in the third column of Table 2. The Sargent J-test fails to reject the hypothesis about the proper choice of instruments at the 5% significance level. The results achieved for the model with instrumental variables do not differ substantially as compared with the estimation results for the model estimated with the OLS presented in column 2. Only the coefficient estimate for exchange rate volatility is slightly smaller. The choice of the estimation method does not alter the coefficient estimates for other variables. Additionally as a robustness check we estimate the fixed effects model with time (year) dummies to capture the potential commons trends. These results are presented in the fourth and fifth columns of Table 2. The findings are similiar to the basic model with the exception of the variable reflecting the fiscal balance, which proves to be statistically insignificant in this model.

As a next step we test for the potential non-linearity in the relationship between the net foreign assets position and the country's risk premium using the algorithm proposed by Escribano and Jordá (2001) described in more details in Section 3. First we estimate the second order Taylor series expansion for the PSTR model with exponential transition function, which is the auxiliary regression for this test. We verify the joint statistical significance of the variables being the subsequent powers of NFA from the second to the fifth power in equation (6). We collect the outcomes of this test in Table 3. We follow this testing procedure for the model estimated with OLS (columns 1 and 2 in Table 3) and for the alternative model, in which the exchange rate volatility has been instrumented (columns 3 and 4). The appropriate test statistics allow rejecting the null hypothesis of linearity in favour of general STR type non-linearity at any conventional significance level for both investigated models.

Once the linearity has been rejected we select further between the logistic and exponential transition function in the PSTR model as described in Section 2. The outcome of this test for our basic fixed effects model estimated with OLS (columns 1 and 2 in Table 3) as well as with IV method (columns 3 and 4 in Table 3) clearly suggests the choice of the logistic function as the appropriate transition function. The p-values for the respective hypotheses are significantly lower than for the hypotheses implying the validity of the exponential function.

For the alternative specification of the PSTR model including the year dummies and being estimated for the robustness check (columns 5-8 in Table 3) the appropriate test statistics also imply the rejection of the linearity.However once the choice of the transition function is concerned the employed selection procedure leads to inconclusive results, which differ in respect to the estimation method. While for the model estimated with OLS the outcome of the Escribano and Jorda procedure implies the selection of the exponential transition function (with lower p-values), for the model estimated with IV method the logistic tranistion function is preferred. All in all we select the transition function relying on the results achieved for our basic fixed effects model as well as for the alternative model estimated with the IV method and we finally choose the logistic function as the transition function in the PSTR model.

Thus we estimate the non-linear PSTR model with the logistic transition function. Accordingly we derive the coefficients of the model with OLS and with the IV method to check for the potential endogeneity of the exchange rate volatility. We use the same instruments as in the previous steps: first differences of the exchange rate volatility, its squares and VXO index. The estimation results for both models are presented in Table 4

In the first column we present the fixed effects model estimated with non-linear OLS while in the second column we show the fixed effects model estimated with non-linear LS with instrumental variables. Moreover in the third and fourth columns we show the results for the model including the year dummies. The results validate the choice of the PSTR model with the logistic transition function. The parameter reflecting the non-linear impact of the NFA position on the risk premium is statistically significant at 5% significance level.

As pointed out in Section 3 the choice of the logistic transition function implies that the (negative) parameter measuring the influence of the net foreign assets stock on the yields differential decreases as the NFA declines values. The results for the fixed effects model estimated with non-linear OLS (column 1 in Table 4) show that the impact of the changes in NFA stock on the country's risk premium increases significantly (in modulus) as NFA approaches ca -74% of the country's GDP. For NFA values larger than this threshold level the worsening in the NFA position by 10 p.p. results in the increase of the risk premium by ca. 19 bps. It is worth to remind that this effect is almost twice as large as for the linear model discussed previously. For very large positive values of NFA the semi-elasticity of risk premium in respect to NFA stock is only negligible. The improvement in NFA stock by 10 p.p. results in the decrease of risk premium by only 0.7 bps. (the sum of coefficients $\delta_1 + \delta_2$ equals -0.07 – see Table 4). As mentioned above the threshold level at which the impact of changes in NFA position on the yields differential starts to be substantial has been estimated at ca. -74% of GDP. This threshold proves to be statistically significant at the 5% significance level. The semi-elasticities are presented as function of the NFA position on Figure 2.

It is worth to note that the results for the fixed effects model estimated with instrumental variables are very close to the OLS estimates. The only difference concerns the parameter estimate related to exchange rate volatility being instrumented in the second model.

The results achieved for the alternative model including the year dummies (columns 3 i 4 in Table 4) estimated for the robustness check do not differ signifcantly from the outcomes obtained for our basic models. The semi-elasticities of the risk premium in respect to the NFA position are only about 10% larger than in the basic models and statistically significant. The only difference as compared with the models presented in columns 1 and 2 is that the variable reflecting the fiscal balance proves to be statistically insignificant as in the linear case.

Finally if we compare the parameter estimates for other control variables in the PSTR models with the respective estimates for the linear models presented in Table 2 we conclude that they do not differ much. The only but still very little discrepancy concerns the parameter estimates related to the level of public debt. In the non-linear models the respective coefficients are about 20 per cent smaller than in the linear case.

4 Consequences for DSGE models

4.1 A simple rule

The relationship on which our study focuses - between the country risk premium and its net foreign asset position plays an imporant role in constructing and solving DSGE models. As explained in detail by Schmitt-Grohe and Uribe (2003), models of small open economies may suffer from indeterminancy. This is because in a standard framework nothing pins down the small open economy's foreign debt level. Schmitt-Grohe and Uribe (2003) offer a number of solutions to this problem, i.a. endogenous discount factors, convex portflio adjustment costs or a debt elastic country interest rate premium.

The last solution has been found particularly popular, several small open economy DSGE models have been solved by adding this feature (e.g. Adolfson et al. 2007; Christoffel et al. 2008; Justiniano and Preston 2010). The original specification, from which most future studies borrow is as follows:

$$\rho_t = \psi \left(exp(d_t - d) - 1 \right)$$

where ρ_t denotes the risk premium as specified in DSGE models (details below), d_t is the net foreign debt to GDP ratio, d its steady state level and ψ a positive parameter.

Under such a function foreign debt is pinned down in steady state and the positive slope of the function guarantees its stability around this level. What is problematic is the calibration. While the steady state debt can be usualy recovered from the country's data, things are more complicated when it comes to the debt elasticity. For many countries there may not be enough volatility in the data to allow for a succesful time series estimation. Even less promising seems finding the parameter via system estimation of the whole DSGE model. First, such estimation does not usualy feature control variables which, as we show, are important determinants of the premium. Second, for technical reasons estimation of DSGE models is conducted for their linearized version. However, we have shown, that the relationship is strongly nonlinear.

In what follows we transform the estimated nonlinear OLS relationship so that it can be directly applied in DSGE models. The transformation takes into account the following issues.

- In contrast to our econometric specification, DSGE models usualy do not feature control variables like exchange rate volatility. We keep them in the estimation to avoid biased parameters, but ignore them in the final specification.

- Most of the DSGE models under consideration are of quarterly frequency. We adjust the parameters accordingly to make it compatible with models where for instance $\rho_t = 0.025$ is a 25 basis point premium expressed on quarterly basis.

- DSGE models usualy contain a net foreign debt variable instead of net foreign assets. The variable is expressed relative to quarterly GDP.
- In the presented estimations NFA was measured at the end of the previous period. Accordingly d_t will denote foreign debt at the end of period $t-1$.

Then our relationship is:

$$\rho_t = d_t \left\{ \psi_1 + \psi_2 \left[1 + exp \left(\psi_3 \left(d_t - \psi_4 \right) \right) \right]^{-1} \right\} \tag{7}$$

The parameters of equation (7) afer being slightly rounded are given in Table 5. It should be noted, that given the relatively fast transition between the two regimes (see Figure ...) for stochastic purposes the relationship can be linearized around the appropriate steady state without much loss of accuracy. The only problematic area is the viscinity of our threshold debt ratio (300 % of quartelrly GDP). Otherwise, the nonlinear function can be used directly for studying deterministic dynamics.

4.2 The model

A natural question emerges, whether and how these estimates matter for DSGE modeling. This will be analysed on the basis of a standard two economy new Keynesian model. The model consists of two symmetric economies, both populated by households, intermediate and final good producers and a central bank. Households derive utility from leisure and consumption, can save in domestic and foreign bonds and accumulate capital. Producers use labor and capital rented from households to produce differentiated intermediate goods. These are exported or sent to the domestic market. At this stage prices are sticky a la Calvo in local (consumer) currency. Final goods are aggregated from domestic and imported goods and used for consumption purposes. The central bank follows a Taylor rule. Below we present only problems of the domestic agents, problems of foreign agents are symmetric. Foreign variables are denoted with an asterix.

Households

Households work n_t, consume c_t and accumulate domestic B_t and foreign B_t^* bonds remunerated at the central bank interest rates R_t and R_t^* respectively. Moreover, they own the capital stock K_t which is rented to firms at the rate R_t^K and depreciates at the rate δ. A representative household ι maximizes lifetime utility:

$$maxU_t = E_t \sum_{i=0}^{\infty} \beta^i e^{\varepsilon_{u,t+i}} \left[\frac{(c_{t+i}(\iota) - hc_{t+i-1})^{1-\sigma}}{1-\sigma} - A_n \frac{(n_{t+i}(\iota))^{1+\varphi}}{1+\varphi} \right] \tag{8}$$

subject to a sequence of budget constraints:

$$P_t c_t(\iota) + \frac{1}{R_t} B_{t+1}(\iota) + \frac{S_t}{\rho_t R_t^*} B_{t+1}^*(\iota) = W_t n_t(\iota) + R_t^K K_t(\iota) + B_t(\iota) + S_t B_t^*(\iota) + \Pi_t \tag{9}$$

and the law for capital accumulation

$$K_{t+1} = (1-\delta) K_t + \left[1 - \Gamma \left(\frac{i_t}{i_{t-1}} \right) \right] i_t \tag{10}$$

where P_t, W_t, S_t, Π_t are, respectively the price of consumption goods, the nominal wage, the nominal exchange rate and dividends paid by imperfectly competitive intermediate goods producers. Further, i_t denotes investments and $\Gamma(\bullet)$ denoes a quadratic investment adjustment cost. Moreover, β denotes the agents' discount rate and A_n is the weight of labor in utility. The inverse of the intertemporal elasticity of substitution in consumption is denoted by σ and φ is the inverse Frisch elasticity of labor supply. Consumption is subject to external habit persistence h. We assume that the intertemporal preference shock $\varepsilon_{u,t}$ follows an AR(1) process with persistence ρ_u and standard deviation of innovations σ_u. The international risk premium ρ_t is assumed to follow (7).

We will not present all equilibrium conditions, only those refered to below. The first is the Euler consuption equation:

$$\frac{\lambda_t}{P_t} = \beta E_t \frac{\lambda_{t+1}}{P_{t+1}} R_t \tag{11}$$

and the second the uncovered interest rate parity condition:

$$E_t \frac{\lambda_{t+1}}{\pi_{t+1}} R_t = E_t \frac{q_{t+1} \lambda_{t+1} \rho_t R_t^*}{\pi_{t+1}^* q_t} \tag{12}$$

where λ_t denotes the marginal utility of household's consumption, $\pi_t \equiv \frac{P_t}{P_{t-1}}$ is inflation and $q_t \equiv \frac{S_t P_t^*}{P_t}$ the real exchange rate.

Producers

There are two types of firms: intermediate goods producers and final good producers. Perfectly competitive final good producers purchase intermediate domestic and foreign goods and produce a final good $\tilde{y}_t$ using the following technology

$$\tilde{y}_t = \left[\eta^{\frac{\mu-1}{\mu}} \left(y_{H,t}\right)^{\frac{1}{\mu}} + (1-\eta)^{\frac{\mu-1}{\mu}} \left(y_{F,t}\right)^{\frac{1}{\mu}}\right]^{\mu} \tag{13}$$

where η is the home bias in consumption and μ determines the elasticity of substitution between domestic and foreign goods while $y_{H,t} = \left(\int_0^1 y_{H,t}\left(j\right)^{\frac{1}{\mu_H}} dj\right)^{\mu_H}$ and $y_{F,t} = \left(\int_0^1 y_{F,t}\left(j\right)^{\frac{1}{\mu_F}} dj\right)^{\mu_F}$ are aggregates of domestic and foreign intermediate goods respectively. Parameters μ_H and μ_F determine the elasticities of substitution between their varieties.

Producers of intermediate goods act under monopolistic competition. They produce specific (differentiated) goods and sell them to final good producers at home and abroad. They solve the same cost minimization problem, however, have different pricing strategies for the domestic and foreign market. Local currency pricing is assumed, i.e. prices are sticky in the buyers currency. They produce using the following technology

$$y_{H,t}\left(j\right) + y^*_{H,t}\left(j\right) = z_t k_t^{\alpha}(j) n_t^{1-\alpha}\left(j\right) \tag{14}$$

where z_t denotes a productivity shock that follows an AR(1) process with persistence ρ_z and standard deviation of innovations σ_z. Intermediate goods producers set their prices according to the Calvo scheme. In each period, each producer j receives with probability $1-\theta_H$ or $1-\theta^*_H$ a signal to reoptimize her price on the domestic or foreign market respectively. She then maximizes:

$$\max_{\tilde{P}_{H,t}(j),\left\{y_{H,t}(j)\right\}_{s=0}^{\infty}} E_t \sum_s \left(\beta\theta_H\right)^s \Lambda_{t+s} \left(\frac{\tilde{P}_{H,t}\left(j\right)}{P_{t+s}} - mc_{t+s}\right) y_{H,t+s}(j) \tag{15}$$

when producing for the domestic market, or

$$\max_{\tilde{P}^*_{H,t}(j),\left\{y^*_{H,t}(j)\right\}_{s=0}^{\infty}} E_t \sum_s \left(\beta\theta^*_H\right)^s \lambda_{t+s} \left(\frac{\tilde{P}^*_{H,t}\left(j\right) S_{t+s}}{P_{t+s}} - mc_{t+s}\right) y^*_{H,t+s}(j) \tag{16}$$

when producing for the export market. When setting prices she faces downward sloping demand curves, that solve the problems of domestic and foreign final goods producers. In the equations above profits are evaluated according to the households (i.e. the owners) marginal utility of consumption, $\tilde{P}_{H,t}\left(j\right)$ and $\tilde{P}^*_{H,t}\left(j\right)$ are the new prices set on the domestic and foreign market by those firms that are allowed to change their price and mc_t is the real marginal cost.

Monetary policy and market clearing

The central bank follows a standard Taylor rule (variables without time indices denote steady state levels)

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\gamma_R} \left[\left(\frac{\pi_t}{\pi}\right)^{\gamma_\pi} \left(\frac{y_t}{y}\right)^{\gamma_y}\right]^{1-\gamma_R} \tag{17}$$

where γ_R, γ_π and γ_y are parameters and y_t denotes real GDP. The model is closed with a balance of payments equation and standard market clearing conditions.

Calibration

The calibration strategy is subordinated to the main goal of this section, to document the working of the nonlinear risk premium function in a small open economy. Given this goal the calibration of structural parameters is fully symmetric, the only difference being the size of the two economies (so that one is large and closed and the other small and open). Consequently the calibration reflects rather a generic than a specific small and large economy. In particular Calvo probabilities and habits are set to .75, the intertemporal elasticity of substitution is 2, the smoothing parameter in the Taylor rule is .75, the response to inflation 2 and the response to output .125, roughly in line with much of the empirical DSGE literature Smets and Wouters (2005); Adolfson et al. (2007). The elasticity of substitution between home and imported goods in the final aggregate is set to 2.5 (which implies $\mu = 1.66$). The small economy is assumed to produce 1% of world GDP and its openness (share of imports in final good) is calibrated at .5. Calibrated parameters are presented in Table 6.

4.3 Steady state issues

Let us start with the steady state. To better understand what the relationship between the risk premium and the NFA position impies for the model let us consider the UIP condition and risk premium equation in the steady state. The former boils down to (non-indexed variables denote steady state levels)

$$\frac{R}{\pi} = \rho\frac{R^*}{\pi^*}$$

Substituting for R and R^* from the steady state consumption Euler equations at home and abroad yields the relationship between the risk premium and rates of time preference:

$$\rho = \frac{\beta^*}{\beta}$$

Given the link between the NFA position and the risk premium a balanced steady state

NFA position is consistent only with equal rates of time preference. On the other hand non-zero debt is compatible only with diverging levels of patience. Importantly, with a reasonably parametrized risk premium function diverging time preference rates imply a non-degenarate steady state with a plausible NFA position. For instance assuming $\beta^* = .99$ and $\beta = .985$ (i.e. an annualized two precent premium) implies an annualized steady state debt-to-GDP ratio of roughly 100%.

Diverging rates of time preference have not received much attention in the literature yet. However, as shown by Falk et al. (2015) time preferences differ substantially between countries. This may have important consequences for a broad range of macroeconomic issues, including economic growth (Dohmen et al., 2015), monetary policy (Fagan and Gaspar, 2007) or external imbalances. A simple but well parametrized link can offer a useful shortcut to analyse such problems.

4.4 Model dynamics

The previous section explained how to generate a non-zero steady state NFA position. In the current section we check how this affects the model dynamics. As is clear from equation (7), the risk premium elasticity depends on debt. As a consequence responses to shocks will depend on the debt level as well. The goal of this section is to understand the mechanism and to verify whether the differences are significant. Before we proceed, one thing needs to be clarified, however. Different debt levels have two implications for model dynamics. First, as explained before, the premium elasticity differs. Second, debt reacts to the premium because of interest payments. In what follows we separate out the first effect in order to explain it better. We consider two shocks - a standard supply shock to productivity, and a standard demand shock to preferences.

Figure 3 presents the reaction of the small economy to a negative productivity shock that generates a 2% decline in output. Since households smooth consumption and adjusting investments is costly both these variables decline by less than output. The impact is smoothed out thanks to net exports which decline, as a consequence foreign debt increases. Here the stories begin to differ depending on the premium elasticity. In the zero-debt economy ($\beta = \beta^*$) the premium increases only slightly. As a result the economy is not prevented to take more debt - net exports and NFA decline strongly and consumption and investments decline much less than for the indebted economy. Interstingly, for the productivity shock the domestic demand vs. net exports effect cancel out so that the impact of the shock on output is similar in both cases.

After the demand (preference) shock (Figure 4) consumption rises, one of the consequences being higher imports and rising foreign debt. In the zero-debt economy this generates only a moderate increase of the risk premium. In the indebted economy the risk premium rises more sharply. As a consequence the interest rate (not shown) increases by more in the latter economy, crowding out investments. In contrast to the productivity shock, now domestic demand and net exports do not cancel out, so that also GDP reacts differently for the two economies.

While the specific patterns clearly depend on the shock, two common conclusions can be drawn. First, the reactions may differ substantially, dependening on the country's initial NFA position. The differences for national account components are, however more prononced than for GDP. In general, the higher steady state debt, the stronger the impact of shocks on the domestic economy and the weaker on net exports.

5 Conclusions

This paper explores the nonlinear relationship between the country risk premium and its net foreign asset position. This nonlinearity is of particular importance since it may lead countries into debt traps. If risk premia initially increase slowly with worsening NFA positions and then suddenly jump the country may not be able to serve its foreign debt anymore. Moreover, the resulting sharp increase in financing costs may cause an economic recession. Greece could serve as a recent example of such unpleasant developments.

We estimate a nonlinear panel model based on data from 41 advanced and emerging economies. Our specification is flexible enough to allow for a wide range of nonlinearities. The data favors a nonlinear relationship with a relatively fast transition between low and high elasticity regimes. For positive and mildly negative NFA positions the risk premium elasticity is only slightly negative. However, once NFA worsens further the elasticity decreases substantially. The strongest impact is experienced for NFA starting from -74 % of GDP.

As an important by-product of our estimation is a risk premium - foreign debt relationships that can be applied in DSGE models. Such a relationship has for a long time constituted an important ingredient of small open economy DSGE models. However, its calibation was supposed to provide model stability rather than reflect the elasticities found in the data. Our paper offers an appropriate calibration.

Moreover, we show on the basis of a standard two-economy DSGE model that taking into account the nonlinear risk premium - NFA relationship has important consequences for such models. First, it allows to take into account diverging rates of time preference in a way that is consistent with a well parametrized steady state. Second, we show that model dynamics differ significantly depending on the steady state NFA position. In particular, the higher steady state debt the stronger the impact of shocks on the domestic economy and the weaker on net exports.

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Tables and Figures

Table 1: List of countries included

Country	Sample	Country	Sample
Australia	1991-2014	Korea	1995-2014
Austria	1991-2013	Malaysia	1994-2014
Belgium	1991-2014	Mexico	1997-2014
Brazil	2011-2014	Morocco	1999-2012
Canada	1991-2014	Netherlands	1991-2014
Chile	2006-2013	New Zealand	1991-2013
China	2007-2014	Norway	1991-2013
Colombia	2003-2013	Pakistan	1995-2013
Costa Rica	2013-2014	Philippines	1995-2007
Czech Republic	2001-2013	Poland	2002-2014
Denmark	1993-2013	Portugal	1991-2013
Finland	1991-2013	Russia	2006-2011
France	1991-2014	South Africa	2001-2014
Germany	1993-2014	Spain	1991-2014
Greece	1994-2013	Sweden	1994-2014
Hungary	2002-2013	Switzerland	1991-2014
India	2000-2014	Thailand	1997-2014
Indonesia	2004-2014	Turkey	2007-2014
Ireland	1996-2013	United Kingdom	1991-2014
Italy	1991-2014	Uruguay	2004-2013
Japan	1991-2014		

Table 2: Estimation results - linear model.

	(1)	(2)	(3)	(4)	(5)
	FE-OLS	FE-OLS	FE-IV	FE-TD-OLS	FE-TD-IV
NFA	-1.200**	-1.029**	-1.033**	-1.087**	-1.077**
	(0.491)	(0.511)	(0.509)	(0.493)	(0.490)
INF DIF	0.546***	0.538***	0.541***	0.504***	0.508***
	(0.085)	(0.084)	(0.083)	(0.078)	(0.077)
EXRATE VOL	0.159***	0.152***	0.129***	0.133**	0.065
	(0.053)	(0.051)	(0.037)	(0.039)	(0.042)
GG DEBT	0.020*	0.023*	0.022*	0.019**	0.019**
	(0.011)	(0.013)	(0.013)	(0.009)	(0.009)
GG BALANCE	-0.077***	-0.063*	-0.063*	-0.004	-0.004
	(0.028)	(0.033)	(0.034)	(0.052)	(0.052)
GDP PER CAP	-6.543	-7.017	-7.032	-11.10*	-11.13*
	(4.347)	(4.535)	(4.547)	(5.706)	(5.754)
FX RESERVES	-0.815	-	-	-	-
	(2.094)				
CA BALANCE	0.071*	-	-	-	-
	(0.043)				
const	3.584	3.737	3.803	6.543**	6.722
	(2.660)	(2.692)	(2.670)	(3.590)	(3.605)
R2	0.749	0.745	0.745	0.801	0.800
Adj R2	0.730	0.727	0.727	0.779	0.778
Obs	691	693	693	693	693
J-test (p-value)	-	-	0.249	-	0.012

Note: The models in columns (1) and (2) are the fixed effects models estimated with OLS. The model in column (3) has been estimated using IV estimator. The numbers in columns (4) and (5) stand for parameter estimates for the models with period dummies estimated respecitvelly with OLS and IV method. We instrumented variable EXRATE VOL with its first differences and the squares of the first differences as well as VXO variable. The detailed description of control variables: see Section 2. White period standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Linearity tests.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	FE-OLS		FE-IV		FE-TD-OLS		FE-TD-IV	
Test	LM	LMF	Wald	WaldF	LM	LMF	Wald	WaldF
$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$	12.184**	2.847**	11.391**	2.848**	18.395***	4.163***	16.26***	4.066***
	(0.0160)	(0.0233)	(0.0225)	(0.0233)	(0.0010)	(0.0025)	(0.0029)	(0.0027)
$H_{0L} : \lambda_1 = \lambda_3 = 0$	5.549*	2.580*	5.149*	2.574*	2.195	4.898*	3.088	1.544
	(0.0624)	(0.0765)	(0.0762)	(0.0770)	(0.1122)	(0.0864)	(0.2135)	(0.2143)
$H_{0E} : \lambda_2 = \lambda_4 = 0$	3.165	1.469	2.920	1.460	5.935*	2.662*	1.876	0.936
	(0.2055)	(0.2309)	(0.2322)	(0.2330)	(0.0514)	(0.0706)	(0.3921)	(0.3926)

Note: The numbers in the table are the values of the test statistics to verify the following hypotheses: the hypothesis of linearity against the general PSTR non-linearity (H_0), the hypothesis of linearity against the PSTR model with logistic transition function (H_{0L}), the hypothesis of linearity against the PSTR model with exponential transition function (H_{0E}). The auxiliary regression is the equation (6). The numbers in columns (1) and (2) refer to the fixed effects model estimated with OLS while the numbers in columns (3) and (4) refer to fixed effects model estimated with IV estimator. The numbers in columns (5)-(8) stand for parameter estimates for the models with period dummies estimated respecitvelly with OLS and IV method. We instrumented variable EXRATE VOL with its first differences, the squares of the first differences and VXO variable. For FE model we used likelihood ratio *Chi*2- and *F*-type test statistics while for FE-IV model we applied Wald *Chi*2- and *F*-type test statistics. The detailed description of control variables: see Section 2. Likelihood and Wald test p-values in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Estimation results - PSTR model with exponential transition function.

	(1)	(2)	(3)	(4)
	FE-OLS	FE-IV	FE-TD-OLS	FE-TD-IV
NFA (δ_1) - regime I	-1.916***	-1.911***	-2.134***	-2.122***
	(0.722)	(0.728)	(0.614)	(0.624)
NFA (δ_2)	1.850**	1.828**	2.248***	2.232***
	(0.735)	(0.739)	(0.640)	(0.657)
NFA ($\delta_1 + \delta_2$) - regime II	-0.066	-0.082	0.114	0.110
	-	-	-	-
Transition parameter (γ)	205.49	208.80	236.19	178.81
	(491.25)	(497.70)	(379.07)	(261.41)
Threshold parameter (c)	-0.742***	-0.742***	-0.729***	-0.733***
	(0.013)	(0.073)	(0.004)	(0.006)
INF DIF	0.541***	0.544***	0.513***	0.513***
	(0.067)	(0.065)	(0.068)	(0.067)
EXRATE VOL	0.152***	0.124***	0.141***	0.075*
	(0.047)	(0.037)	(0.039)	(0.039)
GG DEBT	0.017**	0.017**	0.014**	0.014**
	(0.008)	(0.008)	(0.006)	(0.006)
GG BALANCE	-0.067***	-0.067***	-0.015	-0.014
	(0.023)	(0.023)	(0.033)	(0.033)
GDP PER CAP	-7.313**	-7.327**	-10.71***	-10.72***
	(3.069)	(3.137)	(3.294)	(3.366)
R2	0.344	0.338	0.491	0.484
Adj R2	0.337	0.330	0.467	0.460
Obs	693	693	693	693

Note: The numbers in column (1) and (2) refer to PSTR model with exponential transition function with fixed effects. The model in column (1) has been estimated with OLS while the model in column (2) with IV estimator. The numbers in columns (3) and (4) stand for parameter estimates for the models with period dummies estimated respecitvelly with OLS and IV method. The detailed description of control variables: see Section 2. HAC standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Parameters for DSGE models

ψ_1	ψ_2	ψ_3	ψ_4
0.0012	-0.0011	50	3

Table 6: Calibration of the DSGE model

Parameter	Value	Description
β, β^*	0.99	Discount factor
h, h^*	0.75	External habit
σ, σ^*	2	Inverse of intertemporal elasticity of substitution
φ, φ^*	2	Inverse of Frisch elasticity of labor supply
μ, μ^*	1.66	Parameter of final good aggregator
μ_H, μ_F, μ_H^*, μ_F^*	1.2	Parameters of home and foreign good aggregator
θ_H, θ_F, θ_H^*, θ_F^*	0.75	Calvo parameters
$1-\eta$	0.5	Import share in the domestic economy
α, α^*	0.33	Capital share
ω	0.01	Size of domestic economy
γ_R, γ_R^*	0.75	Autoreggresion in Taylor rule
γ_π, γ_π^*	2	Response to inflation in Taylor rule
γ_y, γ_y^*	0.125	Response to output in Taylor rule
ρ_u, ρ_u^*	0.75	Autoreggression of preference shock
ρ_z, ρ_z^*	0.75	Autoreggression of technology shock

Figure 1: Interest rate spreads and NFA positions

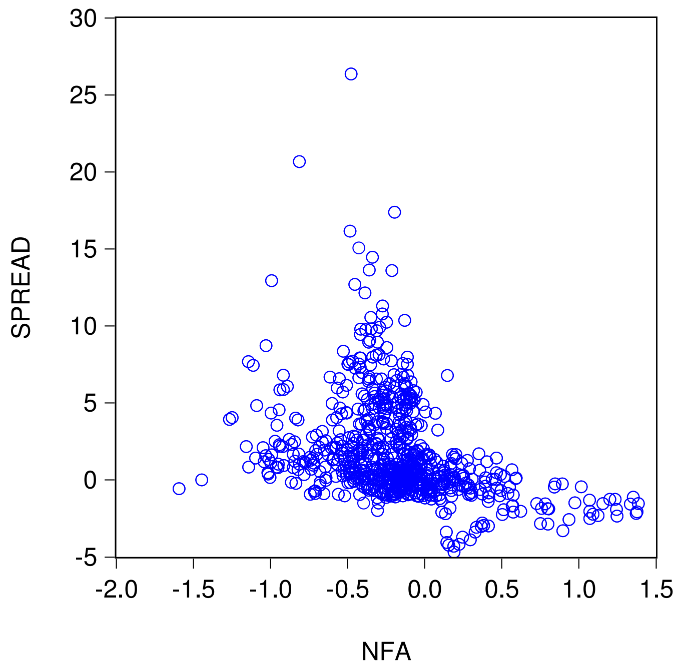


Figure 2: The estimated semi-elasticity of the risk premium with respect to the net foreign asset to GDP ratio

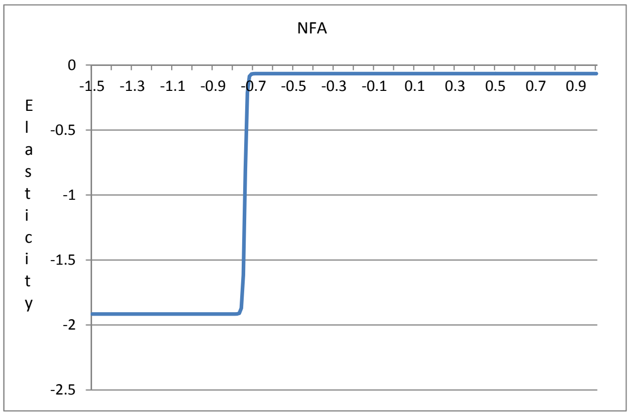
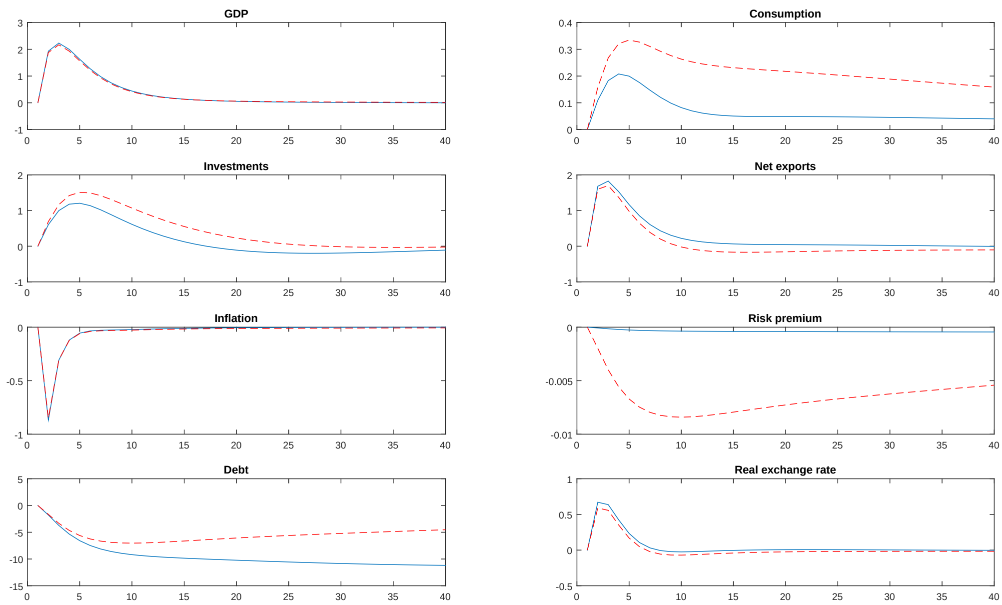
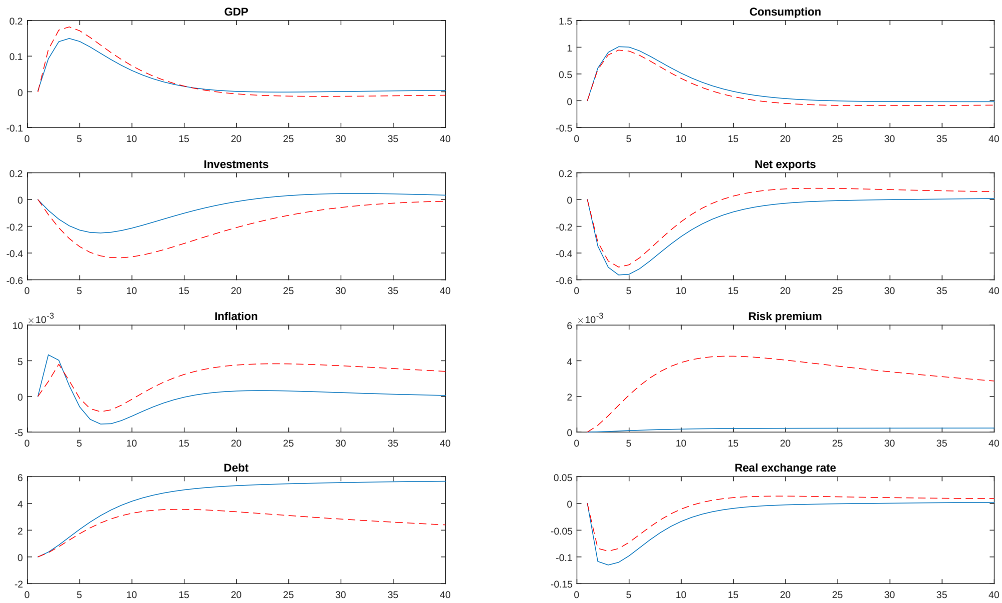


Figure 3: Impulse responses to productivity shock



Note: blue, solid line - zero NFA in steady state. Red, dashed line - NFA in steady state equal to -50% of GDP. All variables presented as deviation from steady state. GDP, consumption, investments and real exchage rate expressed in percent. Inflation and risk premium in quarterly percentage points. Debt and net exports in percent of GDP.

Figure 4: Impulse responses to preference shock



Note: blue, solid line - zero NFA in steady state. Red, dashed line - NFA in steady state equal to -50% of GDP. All variables presented as deviation from steady state. GDP, consumption, investments and real exchage rate expressed in percent. Inflation and risk premium in quarterly percentage points. Debt and net exports in percent of GDP.