The impact of macroeconomic closures on long run trade projections and trade policy experiments

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Abstract

In this paper the impact of the macroeconomic closure in recursive dynamic computable general equilibrium (CGE) models on both long run trade projections and on the effect of trade policy experiments is examined. Six different closures of the trade balance are compared employing the WTO Global Trade Model: a fixed trade balance ratio; a Feldstein-Horioka rule; a converging trade balance ratio; the GTAP rate of return and fixed investment share rules; and a combination of the rate of return rule and the Feldstein-Horioka rule. The paper describes into detail how the different closures are coded, in particular the combination of the rate of return and Feldstein-Horioka rule and the treatment of the omitted region. The simulations on the impact on long run trade projections focuses on outcome variables such as changes in trade balances and the share in global trade of different regions. The simulations will show that long-run trade balances and trade patterns are strongly affected by the choice of macroeconomic closure. The simulations on the effect of trade policy experiments will focus on the projected changes in key outcome variables typically reported such as trade volumes, real GDP, and real income. This will for example shed light on questions such as how the pattern of trade diversion is affected by the macroeconomic closure and how the projected macroeconomic effects change with movements in international investment flows under different closures. An actual trade policy experiment will be employed such as the increase in tariffs and non-tariff barriers between the US and China.

Keywords: Macroeconomic closure,long-run projections,trade policy experiments
JEL codes: D58, F17

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1 Introduction

Nowadays Computable General Equilibrium (CGE) models have become workhorses of quantitative analysis. Researchers, international organisations, policymakers and many others rely on the outputs of various CGE models in their professional activities. These models became widespread for the robustness of the results they generate, transparency of their calculus and flexibility they provide to the users with respect to calibration possibilities. However, these calibrations might lead to drastic variation in the results obtains, therefore shall be thought through and applied with a solid reasoning. Furthermore, researchers have to define the closure of the model, determining which variables are treated as endogenous and which as exogenous. The model closure is usually defined to fit research purposes (Burfisher (2017)). As the set of variables treated within the model changes - the computation paths adjust as well, leading to different outputs of the same model. A range of variables can be defined in the closure, however this paper will focus on macroeconomic closures and their effects on both long run trade projections and on the effect of trade policy experiments in recursive dynamic computable general equilibrium (CGE) models. The paper builds on and extends the work on the role of macroeconomic closures in trade projections in Bekkers et al. (2020).

The macroeconomic closure essentially emerges from the macro-identity (2) which is derived from the foundational macroeconomic equations (1). Macro-identity (2) implies that a country's trade balance $X - M$ must be equal to the difference between its savings and investment $S - I$.[1]

$$\begin{cases} Y = C + I + G + X - M \\ Y + C + S + G \end{cases} \tag{1}$$

$$S - I = X - M \tag{2}$$

Based on equation (1) different options for macroeconomic closure can be distinguished. The first option is to let the trade balance endogenously adjust to the levels of domestic investment and savings, which are separately determined by the model. The second option is to separately determine the savings rate and fix the trade balance, with investment endogenously adjusting according to equation (1). In the standard GTAP model this savings-driven approach would correspond with a fixed savings rate and a fixed trade balance relative to income. The third option is an investment-driven approach. Both investment and the trade balance are then explicitly modelled and savings adjusted according to the macro-identity (2).

The three generic options can be translated into various more concrete options. The paper will focus on six different closures of the trade balance: a fixed trade balance ratio; a Feldstein-Horioka rule; a converging trade balance ratio; the GTAP rate of return rule and fixed investment share rule; and a combination of the rate of return rule and the Feldstein-Horioka rule. These closures are described into detail (with corresponding code) in Section 3 along with the pros and cons of each approach. Preceding this section an overview of the existing research on macroeconomic closures of CGE models will be provided in Section 2.

In order to test for the impact of various closure specifications on long-term projections of the variables of interest (such as trade volumes, real GDP, and real income) first baseline projections will be generated for each of the six closures mentioned before with the WTO Global Trade Model, a recursive dynamic CGE model; then policy experiments will be conducted aiming to identify responses of the WTO GTM model under the specified macroeconomic closures. This will shed light on questions such as how the pattern of trade diversion is affected by the macroeconomic closure and how the projected macroeconomic effects change with movements in international investment flows under different closures. An actual trade policy experiment will be employed such as the increase in tariffs and non-tariff barriers between the US and China. Trade policy experiments will be described in Section 4 and results reported in Section 5. Then the paper will provide overview

[1] For ease of exposition other components of the current account are omitted.

of simulation results, focusing on the performance of the defined variables of interest, sectors, and regions under the specified macroeconomic closures. Sectio 6 concludes.

2 Literature review

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3 Trade balance closure variations

As has been mentioned earlier, the type of closure is usually chosen by a modeller in order to meet the research purposes and obtain the best match with the characteristics of the economy of interest Corong et al. (2017). There is no right or wrong closure as such, however some are more appropriate for certain purposes than others. According to Burfisher (2017) an advantage of the savings-driven closure is that it allows to preserve subjective preferences of a countrys households and government as a nations savings rate remains the same as the rate observed in the base year. At the same time investment-driven closures are more appropriate for investigations of policies influencing savings rates to achieve targeted investment levels. The reasoning behind each closure will be briefly discussed in individual subsections.

3.1 Fixed trade balance ratio

Historically trade imbalances tend to be very persistent. In the framework of a CGE model this phenomenon could be captured by fixing the trade balance ratio (Bekkers et al. (2020), leading to the first closure to be utilised in this paper. It can be obtained in GTAP by fixing net foreign capital flows. "In this case the global bank ignores changes in the relative rates of return, as in the case of a fixed investment allocation, and it is the net saving flow that is fixed, not the regional investment shares."(Corong et al. (2017) note 48, p.42)

3.2 Converging trade balance ratio

Under some closures trade imbalances are assumed to disappear over time. One of the ways to satisfy this assumption is to set trade balance ratio to fall linearly to zero until the end of the simulation period. (Bekkers et al. (2020)) Another way of implementing this assumption is to fix the value of the trade balance. As economies grow the trade balance ratio will be falling over time. These closures are motivated by the fact that "in the long run current account imbalances are unsustainable and thus have to be corrected."(Bekkers et al. (2020))

3.3 n-th region investment re-allocation

The two trade balance closures described in the previous subsection are implemented by simply omitting a rule for the trade balance in the n-th region in order to balance the model. However, an alternative approach to the issue of the n-th region exists and will be considered in the subsection to come.

Since global savings have to be equal to global investment in equilibrium, we cannot impose an exogenous equation for investment in each of the n regions, given that savings are already a

Cobb-Douglas share of regional income. Henceforth, for the n-th region investment has to be kept undetermined. This implies that investment in the n-th region as residually determined by the model (to satisfy the equality of global savings and global investment) could deviate significantly from investment in the n-th region according to either the Feldstein-Horioka rule or the combined closure rule. Multiple ways to address this issue will be covered in the subsections to come.

To address this n-th country problem, the difference between investment residually determined and investment determined according to the closure rule to each of the n regions is allocated to each of the n regions in proportion to the share of each of the regions in global investment. This means that the model is able to both satisfy Walras law (global savings is equal to global investment) and to satisfy (with a small deviation) the chosen closure rule for investment.

3.4 GTAP rate of return rule

Another way to allocate investment across regions by the global bank is such that expected rates of return equalize. Such a closure would imply net flows of capital to countries with an above average rate of return. This approach aligns to a certain extent with "macro-economic intertemporal optimization models in which countries with a high rate of return tend to run a current account deficit, thus receiving on net investment flows." Bekkers et al. (2020)

The net current rate of return is defined in GTAP models as "the rental rate adjusted for the price of replacing capital, less the depreciation rate."(Corong et al. (2017) p.43)

$$RORC_r = \frac{RENTAL_r}{PINV_r} - \delta_r \tag{3}$$

Under the equilibrium mechanism adjustment will occur until expected rates of return, $RORE$ equalize:

$$RORE = RORC_r(\frac{KE_r}{KB_r})^{RORFLEX_r} \tag{4}$$

3.5 GTAP fixed investment share rule

In the other static GTAP model closure global investment is allocated proportionally across the regions (Bekkers et al. (2020)). It is done under the assumption "that the regional composition of capital stocks is invariant and does not respond to changes in expected relative rates of return." (Corong et al. (2017))

3.6 Feldstein-Horioka rule

Feldstein and Horioka (1980) discovered a strong empirical relation between national investment and national savings, indicating that global investment does not flow without restrictions to regions with the highest rates of return: national savings rates are an important determinant of national investment rates. Foure et al. (2013) employ the Feldstein-Horioka relation between national investment and national savings to discipline investment rates of different regions in their recursive-dynamic CGE model. The Feldstein-Horioka relation is part of their macroeconomic model whose results are imposed on their CGE-model. We build the Feldstein-Horioka relation directly into our CGE-model, following the empirically framework estimated by Foure et al. (2013). In particular, the change in the investment rate, $\Delta\frac{I_{it}}{Y_{it}}$, is a function of the change in the savings rate, $\Delta\frac{S_{it}}{Y_{it}}$, a country fixed effect and an error correction term for the difference between the lagged investment and savings rate:

$$\Delta \frac{I_{it}}{Y_{it}} = \zeta_i + \alpha_i \left(\frac{I_{it-1}}{Y_{it-1}} - \gamma_i - \beta_i \frac{S_{it-1}}{Y_{it-1}} \right) + \delta_i \Delta \frac{S_{it}}{Y_{it}} \tag{5}$$

Foure et al. (2013) estimate equation (5) based on the two-step Engle and Granger method separately for OECD and non-OECD countries with the estimated coefficients in Table 1. We work with these estimated coefficients in our implementation of the Feldstein-Horioka closure rule.

Table 1: Empirically estimated coefficients Feldstein-Horioka equation

Regions	α_i	β_i	γ_i	δ_i
ASEAN	-0.238	0.193	0.201	0.165
Brazil	-0.238	0.190	0.161	0.161
Canada	-0.198	0.523	0.096	0.645
China	-0.238	0.190	0.301	0.161
EFTA	-0.198	0.519	0.099	0.639
EU28	-0.201	0.493	0.116	0.601
India	-0.238	0.190	0.189	0.161
Japan	-0.198	0.523	0.129	0.645
LAC	-0.226	0.294	0.152	0.312
MENA	-0.219	0.347	0.152	0.389
Oceania	-0.198	0.521	0.137	0.642
Other EastAsia	-0.215	0.385	0.169	0.444
Rest of World	-0.238	0.191	0.201	0.163
SSA	-0.238	0.195	0.156	0.169
USA	-0.198	0.523	0.100	0.645

Notes: the table displays the GDP-weighted average of the coefficients of the Feldstein-Horioka equation estimated with historical data, separate for OECD and non-OECD countries. Source: Foure et al. (2013)

3.7 Feldstein-Horioka closure with the rate of return closure combined

Although the Feldstein-Horioka rule is appealing because of its empirical foundations, there are at least three problems with this closure. First, the empirical fit of the Feldstein-Horioka equation is far from perfect, implying that the allocation of global investment is also determined by other factors. Second, the Feldstein-Horioka rule is a mechanical rule in which incentives to allocate investment funds based on rates of return do not play a role. Third, under this rule trade imbalances con persist for a very long time, thus potentially being at odds with dynamic consistency and intertemporal budget constraints. To address the first two points, we introduce a combined closure rule in which investment is determined both by differences in regional rates of return and by the empirical Feldstein-Horioka rule. Taking into account intertemporal budget constraints would require information about net debt and asset positions of countries and thus require the collection of additional data. This is left for future work and not addressed in the current paper.

To set the share of investment determined by the rate of return rule, the model is run 21 times increasing the share of investment determined by the Feldstein-Horioka rule from 0% to 100%, in

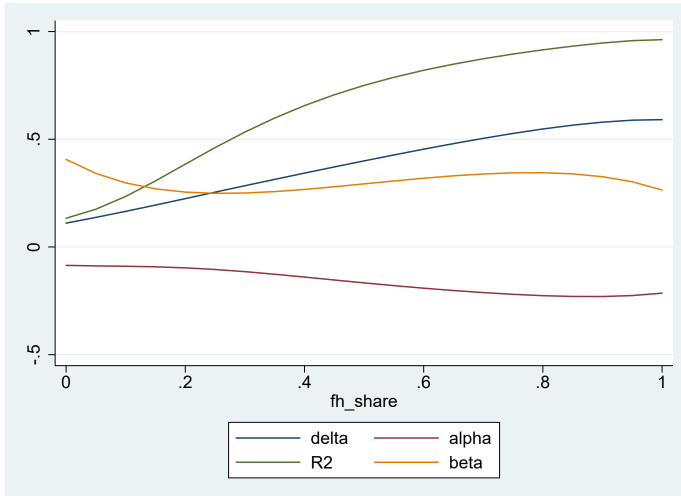

Figure 1: Coefficients and R2 of estimated Feldstein-Horioka relation with simulated data, OECD countries

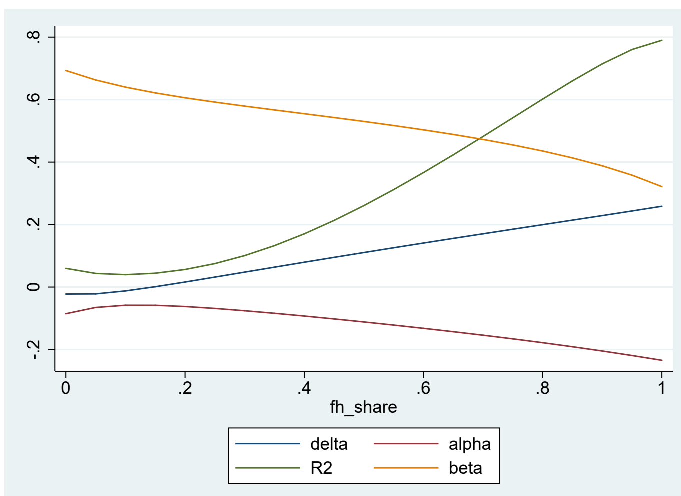

Figure 2: Coefficients and R2 of estimated Feldstein-Horioka relation with simulated data, non-OECD countries

steps of 5%. The results of the simulations are in turn used to estimate the parameters of the Feldstein-horioka relation, equation (5), employing the two step Engle-Granger method as in Foure et al. (2013) for both OECD and non-OECD countries. Figures 1 and 2 display the estimated coefficients and R2's for varying shares of the Feldstein-Horioka closure for respectively the OECD and non-OECD countries. The share of investment determined by the Feldstein-Horioka closure is then set such that the R2 with the simulated data is closest to the R2 with the historical data of respectively 0.56 and 0.17 for OECD and non-OECD countries. Based on Figure **??** the share is set at respectively 35% and 40% for OECD and non-OECD countries.

Table 2: Feldstein-Horioka coefficients, imposed and estimated with simulated and historical data

Regions	α_i	β_i	γ_i	δ_i	$R2$
OECD countries					
Coefficients FH part	-0.593	0.523	0.180	1.645	
Simulated data	-0.183	0.604	0.078	0.636	0.866
Historical data	-0.198	0.523	0.129	0.645	0.564
Non-OECD countries					
Coefficients FH part	-0.477	0.190	0.340	0.061	
Simulated data	-0.240	0.479	0.132	0.164	0.479
Historical data	-0.238	0.190	0.189	0.161	0.172

Notes: the table displays the Feldstein-Horioka coefficients imposed on the Feldstein-Horioka part of the combined closure and the estimated coefficients with both simulated and historical data, separate for OECD and non-OECD countries.
Source: Foure et al. (2013)

A description of the implementation in the model with a detailed overview of the equations added to the Tab-code are provided in Appendix A.

The coefficients of the Feldstein-Horioka relation in equation (5) can be set in two different ways, leading to two different closure rules. In the first closure we combine the rate of return rule with the original Feldstein-Horioka relation and keep the Feldstein-Horioka coefficients fixed at their initial level. In the second closure the Feldstein-Horioka coefficients are adjusted such that estimated coefficients based on the projected data are equal to the estimated coefficients based on the empirical data. Table 2 displays the values of the Feldstein-Horioka coefficients set in the simulations and a comparison of the estimated coefficients with the historical data and with the projected data. This comparison shows that the estimated coefficients of the error-correction equation, α_i and δ_i, are very close to the estimated coefficients based on historical data (in Table 1). However, varying the Feldstein-Horioka coefficients across different values has shown that it is not possible to find values for these coefficients such that the estimated coefficients of the cointegration relation based on the simulated data are close to the estimated coefficients based on the historical data.

4 Defining trade policy experiments

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5 Results of the simulations

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6 Concluding remarks and discussion

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Appendix A Technical details code

To combine the Feldstein-Horioka rule with the rate-of-return rule we have changed the way in which the rate-of-return rule is coded. The Feldstein-Horioka rule prescribes a rule for changes in the investment rate. Therefore, the rate-of-return rule has also been recoded as prescribing changes in the investment rate, so that it can be combined with the Feldstein-Horioka rule. To code the combined rule we proceed in four steps.

First, we start by writing changes in the value of investment, $DTINV(r)$ and the ratio of investment to GDP, $DTINVR(r)$, as a function of the percentage change in the value of investment and gdp, respectively $vinv(r)$ and $vgdp(r)$, in the same way as changes in the trade balance ($TBAL$) are coded:

$$DTINV(r) = (REGINV(r)/100) * vinv(r) \tag{A.1}$$

$$100 * GDP(r) * DTINVR(r) = 100 * DTINV(r) - REGINV(r) * vgdp(r) \tag{A.2}$$

$REGINV(r)$ and $GDP(r)$ are respectively the values of investment and GDP. The complete code is provided below.

Listing 1: GEMPACK equations for the change in the ratio of investment to GDP

```
Variable (all,r,REG)
vinv(r) # value of investment #;

EQUATION E_vinv
# equation for value of savings #
(all,r,REG)
REGINV(r) * vinv(r) = REGINV(r) * {pinv(r) + qinv(r)};

Variable (change)(all,r,REG)
DTINV(r) # change in value of investment, $ US million #;
Equation E_dtinv
# computes change in value of investment, by region #
(all,r,REG)
DTINV(r) = (REGINV(r)/100) * vinv(r);

Variable (change)(all,r,REG)
DTINVR(r) # change in ratio of investment to GDP according to combi of FH and ROR rule #;
Equation E_dtinvr
# change in ratio of investment to regional GDP #
(all,r,REG)
100 * GDP(r) * DTINVR(r) = 100 * DTINV(r) - REGINV(r) * vgdp(r);
```

Second, we write the percentage change in the quantity of investment according to the rate of return rule, $qinv\_ror(r)$ as follows with $rorg$ the percentage change in the global rate of return, $rorc(r)$ the percentage change in the current rate of return, and $kb(r)$ the percentage change in the beginning-of-period capital stock:

$$rorg = rorc(r) - RORFLEX(r) * INVKERATIO(r) * (qinv\_ror(r) - kb(r)) \tag{A.3}$$

Equation (A.3) is equivalent to the standard way to code the rate of return rule, which is given by the following three equations:

$$RORDELTA * rore(r) = RORDELTA * rorg + cgdslack(r) \tag{A.4}$$

$$rore(r) = rorc(r) - RORFLEX(r) * [ke(r) - kb(r)] \tag{A.5}$$

$$ke(r) = INVKERATIO(r) * qinv(r) + [1.0 - INVKERATIO(r)] * kb(r) \tag{A.6}$$

In equation (A.4) only the component corresponding with the rate-of-return rule (with $RORDELTA = 1$) is displayed and the initial shares component of the equation is omitted. The equivalence can be seen by solving for $ke(r) - kb(r)$ from equation (A.6) and substituting into equation (A.5). The complete code is provided below.

Listing 2: GEMPACK equations to code the rate-of-return rule for investment

```
Variable (all,r,REG)
qinv_ror(r) # change in investment according to ror-rule # ;
Variable (change)(all,r,REG)
DTINV_ROR(r) # change in value of investment according to ROR rule, $ US million #;
Variable (change)(all,r,REG)
DTINVR_ROR(r) # change in ratio of investment to GDP according to ROR rule #;

Equation E_qinv_ror
# change in investment according to ror-rule #
(all,r,REG)
rorg = rorc(r) - RORFLEX(r) * INVKERATIO(r) * (qinv_ror(r) - kb(r));
Equation E_dtinv_ror
# computes change in value of investment according to ror-rule, by region #
(all,r,REG)
DTINV_ROR(r) = (REGINV(r)/100) * pinv(r) + (REGINV(r)/100) * qinv_ror(r);
Equation E_dtinvr_ror
# change in ratio of investment to regional GDP according to ror-rule#
(all,r,REG)
100 * GDP(r) * DTINVR_ROR(r) = 100 * DTINV_ROR(r) - REGINV(r) * vgdp(r);
```

Third, we code the Feldstein-Horioka rule for the change in the investment rate. In particular, we write the change in the ratio of investment to GDP, $DTINVR\_FH(r)$, as a function of the change in the savings rate, $DTSAVER(r)$, and an error correction term, $FHCOREL(r)$:

$$\begin{aligned} DTINVR\_FH(r) &= FHCO(r, "adjt") * FHCOREL(r) * fh\_unity \\ &\quad + FHCO(r, "delta") * DTSAVER(r) \end{aligned} \tag{A.7}$$

The error correction term is in turn defined as a formula with the conditioner "initial", since it is a function of the lagged (initial) values of the investment rate, $GINVRGDP(r)$, and the savings rate, $GSAVERGDP(r)$:

$$\begin{aligned} FHCOREL(r) &= GINVRGDP(r) - FHCO(r, "cons") \\ &\quad - FHCO(r, "beta") * GSAVERGDP(r) \end{aligned} \tag{A.8}$$

$FHCO(r, c)$ is a matrix of coefficients based on the estimated values by Foure et al. (2013) in Table 1.

$GINVRGDP(r)$ and $GSAVERGDP(r)$ are defined in a straightforward way and the full code is provided below.

Listing 3: GEMPACK equations to code the Feldstein-Horioka rule for investment

```
Variable (change)(all,r,REG)
DTINVR_FH(r) # change in ratio of investment to GDP according to Feldstein—Horioka rule #;

Coefficient (parameter) (all,r,REG)
GINVRGDP(r) # Gross investment relative to GDP #;
Formula (initial) (all,r,REG)
GINVRGDP(r) = REGINV(r)/GDP(r) ;
Coefficient (parameter) (all,r,REG)
GSAVERGDP(r) # Gross savings relative to GDP #;
Formula (initial) (all,r,REG)
GSAVERGDP(r) = (SAVE(r)+VDEP(r))/GDP(r);

Set
COEF # Feldstein—Horioka parameters set #
read elements from file GTAPSETS header "COEF";

Coefficient (parameter) (all,r,REG)(all,c,COEF)
FHCO(r,c) # Feldstein—Horioka parameters #;
Read FHCO from file GTAPPARM header "FHCO";

Coefficient (parameter)(all,r,REG)
FHCOREL(r) # Feldstein—Horioka cointegration relationship #;
Formula (initial)(all,r,REG)
FHCOREL(r) = GINVRGDP(r) — FHCO(r,"cons") — FHCO(r,"beta") * GSAVERGDP(r);

Variable (change)
fh_unity # shifter for activating Feldstein—Horioka equation #;

Equation E_DTINVR_FH
# change in ratio of investment to GDP according to Feldstein—Horioka #
(all,r,REG)
DTINVR_FH(r) = FHCO(r,"adjt") * FHCOREL(r) * fh_unity
+ FHCO(r,"delta") * DTSAVER(r);
```

Fourth, we combine the Feldstein-Horioka and rate-of-return closure and reallocate the excess investment/savings of the n-th region. Combining the two rules is straightforward, generating the following expression for the change in the ratio of investment to GDP, $DTINVR\_FHROR(r)$:

$$\begin{aligned} DTINVR\_FHROR(r) \quad &= \quad FH\_share(r) * DTINVR\_FH(r) \\ &\quad +(1 - FH\_share(r)) * DTINVR\_ROR(r) \end{aligned} \tag{A.9}$$

Reallocating excess investment/savings requires a bit more work. First we convert the change in the ratio of investment to GDP according to the combined rule, $DTINVR\_FHROR(r)$, into the change in the value of investment according to the combined rule, $DTINV\_FHROR(r)$:

$$100 * GDP(r) * DTINVR\_FHROR(r) = 100 * DTINV\_FHROR(r) - REGINV(r) * vgdp(r) \tag{A.10}$$

Next we define the change in the value of investment residually determined for the omitted (Walras) region, $RWAL$, as follows:

$$\begin{aligned} DTINV\_WALRAS(r) \quad &= \quad DTSAVE(r) + \\ &\quad sum(s, REG : s <> r, [DTSAVE(s) - DTINV\_FHROR(s)]) \end{aligned} \tag{A.11}$$

Based on equations (A.10) and (A.11) we define the change in excess investment, $DTINV\_EXCESS(r)$, as the difference between the change in residually determined investment, $DTINV\_WALRAS(r)$, and the change in investment according the combined rule, $DTINV\_FHROR(r)$:

$$DTINV\_EXCESS(r) = DTINV\_WALRAS(r) - DTINV\_FHROR(r) \tag{A.12}$$

Finally, we reallocate the change in excess investment, $DTINV\_EXCESS(r)$, to each of the regions in proportion to their share in global investment, $REGINVSH\_NRW(r)$, and add it to the change in investment according to the combined rule:

$$\begin{aligned} DTINV(r) &= DTINV\_FHROR(r) + corr\_fhror * REGINVSH\_NRW(r) \\ &\quad * sum\{s, RWAL, DTINV\_EXCESS(s)\} + fhroradd(r) \end{aligned} \tag{A.13}$$

$corr\_fhror$ is a parameter determining whether investment in the n-th region is reallocated or not and $fhroradd(r)$ is a swap parameter to turn the combined closure rule on/off. The exact code of the fourth step is included below.

Listing 4: GEMPACK equations to code the combined rule (rate of return and Feldstein-Horioka)

```
Set RWAL # Walras region, i.e. the n-th region in trade balance closure #
read elements from file GTAPSETS header "RWAL";
Subset RWAL is subset of REG;

Set NRWAL # Non-Walras regions, i.e. the n-1 regions in trade balance closure # = REG - RWAL;

Coefficient (parameter)
corr_fhror # dummy for the presence of a correction term for the n-th region in the FH closure # ;
Read corr_fhror from file GTAPPARM header "CFHR";

Coefficient
(all,r,REG)
REGINVSH_NRW(r) # share of investment in non-walras region in total investment in non-walras regions # ;

Formula
(all,r,REG)
REGINVSH_NRW(r) = REGINV(r) / sum{s,REG,REGINV(s)};

Variable (change)(all,r,REG)
DTINVR_FHROR(r) # change in ratio of investment to GDP according to combined FH/ROR rule #;
Variable (change)(all,r,REG)
DTINV_FHROR(r) # change in value of investment, $ US million, according to combined FH/ROR rule #;
Variable (change)(all,r,RWAL)
DTINV_WALRAS(r) # change in value of investment in RWAL region according to FH/ROR rule non-RWAL regions #;
Variable (change)(all,r,RWAL)
DTINV_EXCESS(r) # difference change in value of inv. in RWAL region according to Walras law and to FH/ROR rule #;

Variable (change) (all,r,REG)
fhroradd(r) # swap variable to activate Feldstein-Horioka/rate of return closure #;

!To activate the combined FH-ROR closure for investment, we swap fhroradd with cgdslack,
turning off the rate of return closure!

Coefficient (parameter)(all,r,REG)
FH_share(r) # Share of investment-GDP ratio determined by Feldstein-Horioka # ;
Read
FH_share from file GTAPPARM header "FHSH";

Equation E_dtinvr_fhror
# Combined Feldstein-Horioka/rate of return allocation of investment #
(all,r,REG)
DTINVR_FHROR(r) = FH_share(r) * DTINVR_FH(r) + (1-FH_share(r)) * DTINVR_ROR(r);

Equation E_dtinv_fhror
# change in ratio of investment to regional GDP according to combined FH/ROR rule#
(all,r,REG)
100 * GDP(r) * DTINVR_FHROR(r) = 100 * DTINV_FHROR(r) - REGINV(r) * vgdp(r);
```

```
Equation E_DTINV_WALRAS
# change in value of investment in RWAL region according to FH/ROR rule non-RWAL regions #
(all,r,RWAL)
DTINV_WALRAS(r) = DTSAVE(r) + sum(s,REG: s<>r,[DTSAVE(s)-DTINV_FHROR(s)]);

Equation E_DTINV_EXCESS
# difference change in value of inv. in RWAL region according to Walras law and to FH/ROR rule #
(all,r,RWAL)
DTINV_EXCESS(r) = DTINV_WALRAS(r) - DTINV_FHROR(r) ;

Equation E_fhroradd
# change in ratio of investment to regional GDP#
(all,r,REG)
DTINV(r) = DTINV_FHROR(r) + corr_fhror * REGINVSH_NRW(r) * sum{s,RWAL,DTINV_EXCESS(s)} + fhroradd(r) ;
```

Appendix B Implementation

To implement the two described trade balance closures in the code, the following four steps should be taken:

1. Add the following headers to the sets file:
   (a) $COEF$ # Feldstein-Horioka parameters set #
   (b) $RWAL$ # Walras region, i.e. the n-th region in trade balance closure #

2. Add the following headers to the parameter file:
   (a) $FHCO$ # Feldstein-Horioka parameters #
   This set of parameters is automatically generated as part of the har-file with projections and should thus be included in the parameter file.
   (b) $corr\_fhror$ # dummy for the presence of a correction term for the n-th region in the FH closure #
   This parameter can be set at 0 or 1, depending on whether a correction term for the n-th region is modelled or not.
   (c) $FH\_share(r)$ # Share of investment-GDP ratio determined by Feldstein-Horioka #.
   This region-specific header defines which share of investment is determined by the Feldstein-Horioka rule.

3. Include the statement $fh\_unity = 1$ in the shock-file to activate the error-correction term in the Feldstein-Horioka equation

4. Include the following statements in the swap-file to activate the combined closure rule for n-1 regions:

$$swapfhroradd(REG) = cgdslack(REG) \tag{B.1}$$
$$cgdslack(ROW) = swapfhroradd(ROW) \tag{B.2}$$