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Global Current Account Imbalances and Exchange Rate Adjustment: The Role of Oil Suppliers

by

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Abstract

The present paper extends the Obstfeld and Rogoff (2005) framework of current account imbalances by the oil exporting countries as a fourth region. It sets the stage for a variety of analysis that can be conducted within a four-region-setting that accounts for the importance of OPEC as a major current account surplus provider in the process of narrowing global current account imbalances. We find that including the oil exporting countries as an additional region consisting of OPEC and Russia lowers the adjustment effects predicted by Obstfeld and Rogoff. Depending on different assumptions on how global imbalances might be eliminated, our model predicts a real dollar depreciation in the range of 29.9 to 52.6 percent.

Key words: current account, exchange rates, global imbalances
JEL classification: F31, F32, F41

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1 Introduction

There have been two developments in the international economic landscape which have caused a lot of research and controversial discussion. The first is the persisting large global external imbalance, especially the large current account deficit of the United States.[1] As Figure 1 illustrates, in 2006 the US current account deficit was at around 856 billion US dollars soaking up the surpluses of China, Japan, Germany as well as Saudi Arabia and Russia, while it is expected to grow even further if no adjustment processes will be started.

The second is the sharp rise of energy prices, driven by both increased international demand and recent concerns about the future supply.[2] Even though oil prices (in real terms) are still significantly below their peak values in the late 1970s and early 1980s, they sharply rose since 1999 and are expected to at least persist on recent levels in the medium run.[3]

Obstfeld and Rogoff (2000, 2004, 2005) investigated the impact of a (sudden) closing of the current account deficit of the United States on terms of trade and real exchange rates. Obstfeld and Rogoff (2005) uses a three-region model including the United States, Asia and Europe to compute the terms of trade and real exchange rate changes between these countries that might accompany a closing of the current account deficit of the United States and its counterpart current account surplus of Asia.[4] Their results of a global rebalancing scenario predict a U.S. dollar depreciation ranging up to 40% against Asia's and Europe's currencies.

This paper investigates the impact of adding OPEC and Russia (in the remaining we will use the term *OPEC* implicitly meaning *OPEC + Russia*) as major current account surplus providers to the Obstfeld and Rogoff (2005) framework, in order to compute the effect that this fourth region as part of the global rebalancing process has on the terms of trade and the real exchange rate effects and to see whether and to what extent this will change the results derived by Obstfeld and Rogoff. The purpose is to set the

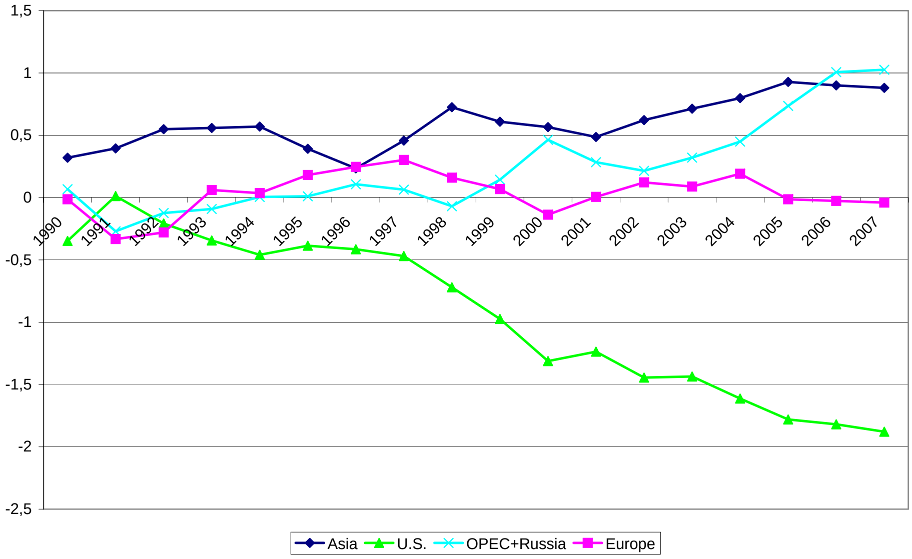
[1] There are arguments in favor of this phenomenon being rational by e.g. Federal Reserve Chairman Bernanke (2005) and Dooley et al. (2006) who explain that the high U.S. current account deficit is a result of rational investment decisions of international savers and investors.

[2] See IMF (2005), Hamilton (2005), and Kilian (2006).

[3] See IMF, World Economic Outlook, April 2006.

[4] As Europe's current account is almost in balance, United States' and Asia's current account positions are predominant.

Figure 1: Current Account Balances 1990–2007 (in % of World GDP)



Source: IMF, World Economic Outlook Database, September 2006,
2005, 2006 and 2007 are projections by the IMF

stage for shedding light into the question, whether the effects of varying oil and energy prices[5] make a significant difference on the effects of narrowing global imbalances.

Based on different assumptions about the way the narrowing of the external positions is happening, our model predicts a real dollar depreciation against Europe between 29.8% and 31.7%, against Asia between 34.7% and 35.9% and against OPEC between 27.2% and 54%.

The remainder of the paper is organized as follows. In section 2, the model by Obstfeld and Rogoff (2005) is extended by the oil exporting countries. The third chapter is devoted to the calibration and the simulation of the model and discusses results. Chapter 4 concludes. A mathematical Appendix is added.

2 The Model

Consumption

Each country's consumption consists of tradable and nontradable goods

$$C^i = \left[\gamma^{\frac{1}{\theta}} \left(C_T^i\right)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} \left(C_N^i\right)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}, \text{ for } i = U, E, A, O, \tag{1}$$

[5] Which could be accounted for by the effects price changes have on the oil (and gas) exporting countries' current account positions.

where the consumption of tradable goods is divided in the consumption of goods that are produced in the home country and others that are produced in one of the other three regions of the world. Parameter γ gives the share of traded goods in the overall consumption of each region. The regions are labeled by U for the United States, E for Europe, A for Asia and O for OPEC (+Russia). The elasticity of substitution between tradable and nontradable goods is given by θ and reflects the impact of a change in consumption on prices.

Accordingly, each country's consumption of home and foreign tradable goods is given as

$$C_T^U = \left[\alpha_U^{\frac{1}{\eta}}\left(C_U^U\right)^{\frac{\eta-1}{\eta}} + \alpha_E^{\frac{1}{\eta}}\left(C_E^U\right)^{\frac{\eta-1}{\eta}} + \alpha_A^{\frac{1}{\eta}}\left(C_A^U\right)^{\frac{\eta}{\eta-1}} + \alpha_O^{\frac{1}{\eta}}\left(C_O^U\right)^{\frac{\eta}{\eta-1}}\right]^{\frac{\eta}{\eta-1}}, \quad (2)$$

$$C_T^E = \left[\beta_E^{\frac{1}{\eta}}\left(C_E^E\right)^{\frac{\eta-1}{\eta}} + \beta_U^{\frac{1}{\eta}}\left(C_U^E\right)^{\frac{\eta-1}{\eta}} + \beta_A^{\frac{1}{\eta}}\left(C_A^E\right)^{\frac{\eta}{\eta-1}} + \beta_O^{\frac{1}{\eta}}\left(C_O^E\right)^{\frac{\eta}{\eta-1}}\right]^{\frac{\eta}{\eta-1}}, \quad (3)$$

$$C_T^A = \left[\chi_A^{\frac{1}{\eta}}\left(C_A^A\right)^{\frac{\eta-1}{\eta}} + \chi_E^{\frac{1}{\eta}}\left(C_E^A\right)^{\frac{\eta-1}{\eta}} + \chi_U^{\frac{1}{\eta}}\left(C_U^A\right)^{\frac{\eta}{\eta-1}} + \chi_O^{\frac{1}{\eta}}\left(C_O^A\right)^{\frac{\eta}{\eta-1}}\right]^{\frac{\eta}{\eta-1}}, \quad (4)$$

$$C_T^O = \left[\delta_O^{\frac{1}{\eta}}\left(C_O^O\right)^{\frac{\eta-1}{\eta}} + \delta_E^{\frac{1}{\eta}}\left(C_E^O\right)^{\frac{\eta-1}{\eta}} + \delta_A^{\frac{1}{\eta}}\left(C_A^O\right)^{\frac{\eta}{\eta-1}} + \delta_U^{\frac{1}{\eta}}\left(C_U^O\right)^{\frac{\eta}{\eta-1}}\right]^{\frac{\eta}{\eta-1}}, \quad (5)$$

where the parameters α_i (U.S.), β_i (Europe), χ_i (Asia) and δ_i (OPEC) stand for the corresponding country's biases towards traded goods from country i. Therefore, α_U, β_E, χ_A and δ_O represent each countries' consumer's bias for home produced tradable goods while the parameters α_i with $i = E, A, O$, β_i with $i = U, A, O$, χ_i with $i = U, E, O$ and δ_i with $i = U, E, A$ reflect the consumer's bias towards tradable goods from the other regions of the world. These parameters are restricted such that $j_U + j_E + j_A + j_O = 1,\ j = \alpha, \beta, \chi, \delta$ holds. They will result to be critical and have to be chosen carefully according to economic intuition and empirical evidence (for the calibration of these parameters see chapter 3).[6]

Parameter η is the elasticity of substitution between tradable goods of the different regions of the world. It reflects the impact of a change in consumption on the prices of tradable goods. The Parameters θ and η are critical because the lower these values are the greater the relative price changes, the terms of trade changes, and the real exchange rate changes accompanying a closing of global current account imbalances will be.

[6] E.g. while $\alpha_i > 1/2$ for $i = U, A, E$ we should have $\alpha_O < 1/2$ since OPEC produces mainly oil as a tradable good and therefore imports more tradable goods than it consumes from its own tradable good.

Price Indexes

Following Obstfeld and Rogoff (1996) we can derive price indexes for the countries' consumption baskets consisting of all consumed tradable and nontradable goods

$$P_C^i = \left[\gamma \left(P_T^i\right)^{1-\theta} + (1-\gamma)\left(P_N^i\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}, \text{ for } i = U, E, A, O, \tag{6}$$

and the price indexes for tradable goods in each country, consisting of the price of each country's tradable weighted by the country's bias towards goods from that country:

$$P_T^U = \left[\alpha_U P_U^{1-\eta} + \alpha_E P_E^{1-\eta} + \alpha_A P_A^{1-\eta} + \alpha_O P_O^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{7}$$

$$P_T^E = \left[\beta_E P_E^{1-\eta} + \beta_U P_U^{1-\eta} + \beta_A P_A^{1-\eta} + \beta_O P_O^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{8}$$

$$P_T^A = \left[\chi_A P_A^{1-\eta} + \chi_E P_E^{1-\eta} + \chi_U P_U^{1-\eta} + \chi_O P_O^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{9}$$

$$P_T^O = \left[\delta_O P_O^{1-\eta} + \delta_E P_E^{1-\eta} + \delta_A P_A^{1-\eta} + \delta_U P_U^{1-\eta}\right]^{\frac{1}{1-\eta}}. \tag{10}$$

We assume that the law of one price holds, so that the price of any given country's good is the same in all regions. However, because of different biases in consumption towards traded goods from different regions the indexes for tradable goods P_T^i can differ across countries.

Bilateral Terms of Trade

The bilateral terms of trade are defined as the price that a country pays for imports from another country relative to the price of its exports to the same country.

$$\tau_{U,E} = \frac{P_E}{P_U},\ \tau_{U,A} = \frac{P_A}{P_U},\ \tau_{U,O} = \frac{P_O}{P_U},$$
$$\tau_{E,A} = \frac{P_A}{P_E},\ \tau_{E,O} = \frac{P_O}{P_E},\ \tau_{A,O} = \frac{P_O}{P_A}.$$

Since we are interested in the effect of a global imbalances adjustment on real exchange rates, it is important to know how changes in the terms of trade affect the relative prices of traded goods between two countries. Therefore, we can calculate the impact of a percentage change in the terms of trade on the relative prices of traded goods, using a logarithmic approximation:

$$\hat{P}_E^T - \hat{P}_U^T = (\beta_E - \alpha_E)\,\hat{\tau}_{U,E} + (\beta_A - \alpha_A)\,\hat{\tau}_{U,A} + (\beta_O - \alpha_O)\,\hat{\tau}_{U,O}, \tag{11}$$

$$\hat{P}_A^T - \hat{P}_U^T = (\chi_A - \alpha_A)\,\hat{\tau}_{U,A} + (\chi_E - \alpha_E)\,\hat{\tau}_{U,E} + (\chi_O - \alpha_O)\,\hat{\tau}_{U,O}, \tag{12}$$

$$\hat{P}_O^T - \hat{P}_U^T = (\delta_O - \alpha_O)\,\hat{\tau}_{U,O} + (\delta_E - \alpha_E)\,\hat{\tau}_{U,E} + (\delta_A - \alpha_A)\,\hat{\tau}_{U,A}. \tag{13}$$

The change in the relative tradable goods prices between countries is determined by the changes in each of the terms of trade, weighted with the log-differences of the biases between these countries.

Bilateral Real Exchange Rates

Bilateral real exchange rates are given as (see A.2 in the Appendix for more details)

$$q_{U,E} = \frac{P_C^E}{P_C^U},\ q_{U,A} = \frac{P_C^A}{P_C^U},\ q_{U,O} = \frac{P_C^O}{P_C^U},$$
$$q_{E,A} = \frac{P_C^A}{P_C^E},\ q_{E,O} = \frac{P_C^O}{P_C^E},\ q_{A,O} = \frac{P_C^O}{P_C^A}.$$

By again using a logarithmic approximation one can derive the log-change in the bilateral real exchange rates:

$$\begin{aligned}
\hat{q}_{U,E} =& \gamma \left(\hat{P}_E^T - \hat{P}_U^T\right) + (1-\gamma)\left(\hat{P}_N^E - \hat{P}_N^U\right) && (14)\\
=& \gamma \left[(\beta_E - \alpha_E)\,\hat{\tau}_{U,E} + (\beta_A - \alpha_A)\,\hat{\tau}_{U,A} + (\beta_O - \alpha_O)\,\hat{\tau}_{U,O}\right]\\
& + (1-\gamma)\left(\hat{P}_N^E - \hat{P}_N^U\right)\\
\hat{q}_{U,A} =& \gamma \left(\hat{P}_A^T - \hat{P}_U^T\right) + (1-\gamma)\left(\hat{P}_N^A - \hat{P}_N^U\right) && (15)\\
=& \gamma \left[(\chi_A - \alpha_A)\,\hat{\tau}_{U,A} + (\chi_E - \alpha_E)\,\hat{\tau}_{U,E} + (\chi_O - \alpha_O)\,\hat{\tau}_{U,O}\right]\\
& + (1-\gamma)\left(\hat{P}_N^A - \hat{P}_N^U\right)\\
\hat{q}_{U,O} =& \gamma \left(\hat{P}_O^T - \hat{P}_U^T\right) + (1-\gamma)\left(\hat{P}_N^O - \hat{P}_N^U\right) && (16)\\
=& \left[(\delta_O - \alpha_O)\,\hat{\tau}_{U,O} + (\delta_E - \alpha_E)\,\hat{\tau}_{U,E} + (\delta_A - \alpha_A)\,\hat{\tau}_{U,A}\right]\\
& + (1-\gamma)\left(\hat{P}_N^O - \hat{P}_N^U\right)
\end{aligned}$$

Thus, changes in the real exchange rates depend on changes of both, the various terms of trade and the prices of nontradables.

Several assumptions are inherent in the model we work with.[7] Firstly, since endowments for all kinds of outputs are given exogenously it is implicitly assumed that neither capital nor labor is mobile between the sectors in the short run. Secondly, the mix of traded goods produced stays unchanged, furthermore the range of nontraded goods is not determined endogenously. And thirdly, nominal prices are completely flexible. While the first two of these assumptions are overstating the effect of a global rebalancing on the real exchange rates, the third assumption is understating these effects.

[7] For a detailed discussion of these assumptions see Obstfeld and Rogoff (2005).

3 Model Calibrations and Simulations

3.1 Calibration of the Parameters

Besides the U.S., all regions in our model consist of a group of countries.[8] Based on Obstfeld and Rogoff (2005) and the accumulated data of OPEC we derived the parameter values for our simulations. In general, we decided to take most parameter values according to the simulations in Obstfeld and Rogoff (2005) in order to keep the simulation outcomes as comparable as possible.

It was necessary, however, to adjust the coefficients (α_i, β_i, χ_i, δ_i) in our model to include a fourth region, as the sum of each regions biases should add up to one. We kept the home bias for the U.S., Europe and Asia the same as in Obstfeld and Rogoff (2005) and redistributed the residual bias among the left over regions. Therefore, we took the quantity of oil imports relative to all imports of the regions U.S., Europe and Asia, then subtracted this percentage from each bias except the home bias and added up the subtracted quantity to receive each country's bias towards OPEC. According to our calculations based on the empirical data, we found that roughly 15% of all U.S. imports were oil and gas (with 9% for Europe and 17% for Asia).[9]

OPEC's bias towards goods from the other regions were computed according to the import shares that each of the three regions has of all imports into OPEC, resulting in imports from Asia and Europe to be higher than from the United States. As this simulation tries to capture the effect of oil as OPEC's tradable good, its home bias (i.e. its bias towards oil) is supposed to be smaller than the other regions' home biases. Because this is an important assumption we will run two different simulations with different values for OPEC's home bias. As baseline case we assume that the home bias is $\delta_O = 0.1$, while for a benchmark case we use $\delta_O = 0.35$. Depending on this value, OPEC's bias towards tradable goods from Asia (δ_A) and Europe (δ_E) is set to 0.35 (0.25) while the bias towards U.S. tradable goods (δ_U) equals 0.20 (0.15). The figures in brackets represent the bias-values in the benchmark case. All bias-parameters we use in our simulations are shown in table 1.

There is a range of other parameters that need to be fixed. Where possible we used the same values as Obstfeld and Rogoff (2005). As the basic assumption for the

[8] Asia: China, Hong Kong, Japan, Korea, Singapore, Taiwan; Europe: Euro-area (without Slovenia and Luxemburg), Australia, Canada, United Kingdom; OPEC (meaning OPEC + Russia): Algeria, Angola, Indonesia, Iran, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, Venezuela, Russia.

[9] For example, our calculation for the U.S. bias towards Europe, Asia and OPEC was as follows: $\alpha_U = 0.7$, $\alpha_E = 0.1 - 0.1 \cdot 0.15 = 0.085$, $\alpha_A = 0.2 - 0.2 \cdot 0.15 = 0.17$ resulting in a bias of the U.S. towards tradable goods from OPEC of $\alpha_O = 0.045$. For Europe and Asia we calculated their bias towards OPEC in the same way.

Table 1: Biases in Traded Goods Consumption

Region	Parameter (new/old)	Value		Bias towards traded goods from
U.S.	α_U	0.7		U.S. (home bias)
U.S.	α_E	0.085		Europe
U.S.	α_A	0.17		Asia
U.S.	α_O	0.045		OPEC
Europe	β_E	0.7		Europe (home bias)
Europe	β_U	0.09		U.S.
Europe	β_A	0.18		Asia
Europe	β_O	0.03		OPEC
Asia	χ_A	0.7		Asia (home bias)
Asia	χ_U	0.1245		U.S.
Asia	χ_E	0.1245		Europe
Asia	χ_O	0.051		OPEC
OPEC	δ_O	0.1	0.35*	OPEC (home bias)
OPEC	δ_U	0.2	0.15*	U.S.
OPEC	δ_E	0.35	0.25*	Europe
OPEC	δ_A	0.35	0.25*	Asia

* Scenario with a higher OPEC home bias in traded goods

elasticities between tradable and nontradable goods (θ) as well as between tradables from different regions (η) we use 1 and 2, respectively[10]. Following Obstfeld and Rogoff (2005, p. 92) we use for the share of tradable goods in total consumption in the four regions (γ) a value of one quarter and for the relations between U.S. real tradable output and real tradable output in Europe and Asia we assume a relation of one ($\sigma_{UE} = Y_T^U/Y_T^E = 1,\ \sigma_{UA} = Y_T^U/Y_T^A = 1$), which basically says that the United States, Europe and Asia are of about the same size. However, for OPEC this assumption would not be adequate, and consequently OPEC's real tradable output was set to one third of U.S. tradable output ($\sigma_{UO} = Y_T^U/Y_T^O = 3$). This does not mean that we assume OPEC to be one third of the economic size of the United States, but to account for the fact that OPEC's ratio of tradable to nontradable output is relatively bigger compared to the U.S.,

[10]This is the basic assumption underlying the results derived by Obstfeld and Rogoff (2005). The decision of choosing these values is discussed in Obstfeld and Rogoff (2005, pp. 94). Further discussion and estimates for the price elasticities can be be found in Lane and Milesi-Ferretti (2004), Mendoza (1991), Ostry and Reinhart (1992) and Stockman and Tesar (1995).

Europe or Asia, we assumed its tradable output to be bigger than it would have been set according to the relative (economic) sizes of these regions.

Another parameter needed is the relative size of the tradable and nontradable sectors in each of the regions. Again, for U.S., Europe and Asia we use the same values as Obstfeld and Rogoff ($\sigma_{NU} = Y_N^U/Y_T^U = 3,\ \sigma_{NE} = Y_N^E/Y_T^E = 3,\ \sigma_{NA} = Y_N^A/Y_T^A = 3$), while for OPEC we assume this figure to be one, hence lower compared to the other regions ($\sigma_{NO} = 1$). For a summary of all parameters see table 2.

Table 2: Parameter Values

Parameter	Value	Description
η	2	Elasticity of substitution for traded goods
θ	1	Elasticity of substitution for nontraded and traded
γ	0.25	Share of traded goods in consumption
σ_{UE}	1	U.S. real tradable output relative to Europe's tradable output
σ_{UA}	1	U.S. real tradable output relative to Asia's tradable output
σ_{UO}	3	U.S. real tradable output relative to OPEC's tradable output
σ_{NU}	3	real nontradable output relative to real tradable output in U.S.
σ_{NE}	3	real nontradable output relative to real tradable output in Europe
σ_{NA}	3	real nontradable output relative to real tradable output in Asia
σ_{NO}	1	real nontradable output relative to real tradable output in OPEC

3.2 Calibration of the Current Account Positions

There are two additional pieces of information about each of the regions necessary to run simulations of our four-country model, namely the size of the current account deficits or surpluses and the net interest receipts or payments that each region is exposed to, depending on its foreign asset and liability positions. The first two columns of table 3 represent the values used by Obstfeld and Rogoff (2005), while columns three and four show the values we used for the four-region-version. As we wanted to figure out the general impact of including another current account surplus region into the Obstfeld/Rogoff framework, we kept the value of the current account deficit of the United States of 20% of tradable GDP[11] but distributed it differently among the remaining re-

[11] This corresponds to a current account deficit of 5% of U.S. GDP.

gions. Where Obstfeld and Rogoff assumed a current account surplus of Asia as being 15% and the one of Europe as 5% of U.S. tradable GDP, we reduced these two values by one third to create an adequate OPEC current account surplus. According to the figures of the IMF for 2004, this is a quite realistic distribution of current account surpluses, since Asia's current account surplus was 11.9%, Europe's 2.9% and OPEC's 6.7% of the tradable GDP of the United States.[12]

As values for the net interest flows we kept a value of zero for the United States, but increased Europe's interest payments while lowering Asia's interest receipts to create interest receipts for OPEC in the height of 0.25% of the tradable GDP of the United States. The relevant numbers are shown in table 3.

Table 3: Current Account Positions and Net Interest Payments (relative to tradable GDP of U.S.)

	3-Regions		4-Regions	
	ca	rf	ca	rf
United States	-0.200	0.00000	-0.200	0.0000
Europe	0.050	-0.01375	0.033	-0.0150
Asia	0.150	0.01375	0.100	0.0125
OPEC	—	—	0.066	0.0025

3.3 Simulations and Results

With all the parameters in hand (which are already normalized on the U.S. tradable GDP, which Obstfeld and Rogoff define as 25% of total GDP, thus approximately 11/4 trillion) we are able to simulate different scenarios of global external imbalance adjustment.

As a first pass we want to compare our results with the ones from Obstfeld and Rogoff (2005) in the "Global Rebalancing"- scenario,[13] where all current accounts go immediately to zero (Scenario I). Table 4 shows the terms of trade and the real exchange rate changes derived by Obstfeld and Rogoff (2005) and the results of the four-region-version for two different assumptions about the home bias in traded goods for OPEC. In the first column we provide the results of Obstfeld and Rogoff's three-region model, the numbers in brackets are the results that we get by running the three-region-version. Our results differ slightly from the ones derived by Obstfeld and Rogoff, due to different assumptions about the net asset positions between the regions. Columns two to five

[12] See IMF, World Economic Outlook, April 2006.

[13] Without valuation or interest rate effects, which are elaborated in Oberpriller (2007).

show the results for the four-region-version of the model, where columns two and four give the resulting terms of trade and real exchange rate changes in a global rebalancing scenario for the baseline case ($\delta_O = 0.1$) and the benchmark case ($\delta_O = 0.35$).

The most obvious result from the four-region simulation in both scenarios (I & II) is that the real exchange rate changes are considerably smaller than the ones predicted by Obstfeld and Rogoff's three-region model – even more in the case of a very low OPEC home bias. The necessary real exchange rate change between the United States and Europe is 3.8 percentage points (1.9 p.p.) smaller, the one between the United States and Asia even 5.9 percentage points (4.7 p.p.). For Europe and Asia the model predicts a Euro depreciation against the Asian currencies of 4.9% (4.2%) which is 2.1 percentage points smaller than in the three regions case. For the real exchange rates vis-a-vis OPEC the model states a very high real dollar depreciation of 50.9% (52.6%) and a moderate depreciation of the Euro and the Asian currencies of 21.0% (20.8%) and 16.1% (16.6%), respectively.

These lower depreciation of the dollar against the Euro and the Asian currencies stems from a lower deterioration of the U.S. terms of trade against Europe and Asia. To keep the explanation simple, the reason for the different size of the real exchange rate changes between our analysis and the results by Obstfeld and Rogoff is that the current account deficit of the United States against Europe and Asia was reduced in our simulations. This clearly reduces the need for the dollar to depreciate (in real terms) against the European and the Asian currencies, while the dollar has to depreciate significantly against OPEC's currency (this is in our case replacing parts of the depreciation against Europe and Asia).

Regarding the prices of nontradable goods in each region, the simulation outcome provides the intuitive result that the prices of nontradables in the U.S. have to decrease by 18.2% to increase domestic demand for the home produced goods and thereby reducing demand for imported tradable goods. Another remarkable result is the size of the needed increase of nontradable prices in OPEC of 48.1% (48.7%), which is necessary to increase OPEC's consumption of tradable goods from the other three regions to balance the bilateral current accounts.

In order to account for the possible case that all current accounts go to zero, except for the deficits caused by trade with OPEC, as they might be more persistent, the reader may find the results of this simulation (Scenario II) in columns four and five. As values for the current accounts for scenario II we set OPEC's surplus to 6% and the deficits of the United States, Europe and Asia to 2% of U.S. tradable GDP.

Table 4: Simulation Outcomes

	O&R	Four-Regions Model			
	(U,E,A)	(U,E,A,O)			
		Scenario I[1]		Scenario II[2]	
Log-change $\times$ 100		$\delta_O = 0.1$	$\delta_O = 0.35$	$\delta_O = 0.1$	$\delta_O = 0.35$
Real exchange rate[3]					
United States / Europe	33.7 (33.2)	29.9	31.8	30.9	31.2
United States / Asia	40.7 (41.0)	34.8	36.0	36.6	35.4
United States / OPEC		50.9	52.6	27.8	27.8
Europe / Asia	7.0 (7.7)	4.9	4.2	4.3	4.2
Europe / OPEC		21.0	20.8	-4.6	-3.4
Asia / OPEC		16.1	16.6	-8.8	-7.5
Terms of trade[4]					
United States / Europe	16.5 (16.3)	14.3	16.5	15.2	15.8
United States / Asia	16.5 (16.7)	14.7	16.1	15.0	15.6
United States / OPEC		10.6	17.5	9.8	11.6
Europe / Asia	0.0 (0.4)	0.4	-0.4	-0.2	-0.2
Europe / OPEC		-3.6	1.0	-5.5	-4.2
Asia / OPEC		-4.0	1.4	-5.2	-4.0
Nontradable Prices					
United States (P_N^U)	(-18.2)	-18.2	-18.2	-16.3	-16.3
Europe (P_N^E)	(22.8)	18.7	20.8	21.8	22.1
Asia (P_N^A)	(33.4)	25.5	26.7	27.6	28.0
OPEC (P_N^O)		48.1	48.7	17.5	18.4
Nominal exchange rate[5]					
United States / Europe		31.3	30.7	32.4	32.7
United States / Asia		36.5	34.2	36.6	37.1
United States / OPEC		52.4	54.3	27.8	28.9
Europe / Asia		5.2	3.5	4.3	4.3
Europe / OPEC		21.1	23.6	-4.6	-3.8
Asia / OPEC		15.9	20.1	-8.8	-8.2

[1] All current account go to zero.
[2] All current accounts go to zero except for the deficits caused by trade with OPEC.
[3] The real exchange rates are defined such that an increase represents a real depreciation of the first region's currency against the second's.
[4] The terms of trade are defined such that an increase represents a deterioration for the first region.
[5] Nominal exchange rate changes have been calculated under the assumption that central banks target a GDP deflator, in this case a geometric average of prices for tradable and nontradable domestic output.

This almost has no impact on the bilateral real exchange rate changes between the U.S., Europe and Asia, but it has a relatively strong effect on the real exchange rates vis-a-vis OPEC. The dollar depreciation against the OPEC currencies is only half the size (27.8%) than in scenario I. In the case of Europe and Asia this effect is even stronger: while both, the European and the Asian currencies depreciate against OPEC's currency in scenario I, they are appreciating in scenario II. The reason is that in scenario II the increase in nontradable prices in OPEC is only half the size than in scenario I, while the changes in the terms of trade against OPEC and the prices of nontradables in Europe and Asia stay almost constant in the two scenarios.

The nominal exchange rate changes associated with scenarios I and II of a narrowing of global current account imbalances are computed under the assumption that central banks target the GDP deflator. Here, we follow Obstfeld and Rogoff (2005) and assume that central banks stabilize the geometric average of the price of domestic output of tradable and nontradable goods. The outcome is very similar to the real exchange rate changes. In the case that central banks would stabilize the CPI (consumer price index) the nominal exchange rates would be exactly the same as the real exchange rate changes.[14]

4 Conclusion

Obstfeld and Rogoff (2005) assess the real exchange rate changes that are associated with a reduction of the world's current account imbalances in a three-region model (United States, Europe, Asia). The present paper extends their approach by considering explicitly also the oil exporting regions of the world. By allowing for OPEC and Russia as a fourth region in the Obstfeld and Rogoff framework it is shown that the existence of this further current account surplus provider reduces the need for the dollar to depreciate against the other currencies by a considerable degree of up to 6 percentage points, depending on different scenarios and different modeling of the OPEC region.

Furthermore, this analysis sets the stage for further research with respect to the impact that changes in the oil or energy prices – which might be modeled within this framework in a variety of ways – could have on the global external rebalancing process. In a follow-up paper (Oberpriller, 2007) the valuation effects of nominal exchange rate changes as well as the effects of changes in the world's interest rates will be implemented into the four-region framework derived in the present paper. The extension of the analysis with respect to different scenarios is left for later research.

[14] Obstfeld and Rogoff (2005, Appendix B)

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Appendix

A.1 Equilibrium Prices in the Four-Regions Model

Rearranging the terms of trade equations gives:

$$P_E = \tau_{U,E} \cdot P_U,\ P_A = \tau_{U,A} \cdot P_U,\ P_O = \tau_{U,O} \cdot P_U,$$

$$P_A = \tau_{E,A} \cdot P_E,\ P_O = \tau_{E,O} \cdot P_E,\ P_O = \tau_{A,O} \cdot P_A.$$

Substituting these expressions into the price equations for tradable goods (7)–(10) gives the prices of tradable goods in every region, depending on the price of tradables produced in this region and the various terms of trade:

$$P_T^U = \left[\alpha_U P_U^{1-\eta} + \alpha_E \left(\tau_{U,E} P_U\right)^{1-\eta} + \alpha_A \left(\tau_{U,A} P_U\right)^{1-\eta} + \alpha_O \left(\tau_{U,O} P_U\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{A.1}$$

$$P_T^E = \left[\beta_E \left(\tau_{U,E} P_U\right)^{1-\eta} + \beta_U P_U^{1-\eta} + \beta_A \left(\tau_{U,A} P_U\right)^{1-\eta} + \beta_O \left(\tau_{U,O} P_U\right)^{1-\eta}\right]^{\frac{1}{1-\eta}},$$

$$P_T^A = \left[\chi_A \left(\tau_{U,A} P_U\right)^{1-\eta} + \chi_E \left(\tau_{U,E} P_U\right)^{1-\eta} + \chi_U P_U^{1-\eta} + \chi_O \left(\tau_{U,O} P_U\right)^{1-\eta}\right]^{\frac{1}{1-\eta}},$$

$$P_T^O = \left[\delta_O \left(\tau_{U,O} P_U\right)^{1-\eta} + \delta_E \left(\tau_{U,E} P_U\right)^{1-\eta} + \delta_A \left(\tau_{U,A} P_U\right)^{1-\eta} + \delta_U P_U^{1-\eta}\right]^{\frac{1}{1-\eta}}.$$

Because of the asymmetric preferences for tradables, the law of one price does not hold for tradables. Therefore, the ratio of prices for tradables between two regions is not unity, but given as:

$$\frac{P_T^E}{P_T^U} = \left[\frac{\beta_E \left(\tau_{U,E} \cdot P_U\right)^{1-\eta} + \beta_U P_U^{1-\eta} + \beta_A \left(\tau_{U,A} \cdot P_U\right)^{1-\eta} + \beta_O \left(\tau_{U,O} \cdot P_U\right)^{1-\eta}}{\alpha_U P_U^{1-\eta} + \alpha_E \left(\tau_{U,E} \cdot P_U\right)^{1-\eta} + \alpha_A \left(\tau_{U,A} \cdot P_U\right)^{1-\eta} + \alpha_O \left(\tau_{U,O} \cdot P_U\right)^{1-\eta}}\right]^{\frac{1}{1-\eta}} \tag{A.2}$$

$$= \left[\frac{\beta_E \left(\tau_{U,E}\right)^{1-\eta} + \beta_U + \beta_A \left(\tau_{U,A}\right)^{1-\eta} + \beta_O \left(\tau_{U,O}\right)^{1-\eta}}{\alpha_U + \alpha_E \left(\tau_{U,E}\right)^{1-\eta} + \alpha_A \left(\tau_{U,A}\right)^{1-\eta} + \alpha_O \left(\tau_{U,O}\right)^{1-\eta}}\right]^{\frac{1}{1-\eta}},$$

$$\frac{P_T^A}{P_T^U} = \left[\frac{\chi_A \left(\tau_{U,A} \cdot P_U\right)^{1-\eta} + \chi_E \left(\tau_{U,E} \cdot P_U\right)^{1-\eta} + \chi_U P_U^{1-\eta} + \chi_O \left(\tau_{U,O} \cdot P_U\right)^{1-\eta}}{\alpha_U P_U^{1-\eta} + \alpha_E \left(\tau_{U,E} \cdot P_U\right)^{1-\eta} + \alpha_A \left(\tau_{U,A} \cdot P_U\right)^{1-\eta} + \alpha_O \left(\tau_{U,O} \cdot P_U\right)^{1-\eta}}\right]^{\frac{1}{1-\eta}} \tag{A.3}$$

$$= \left[\frac{\chi_A \left(\tau_{U,A}\right)^{1-\eta} + \chi_E \left(\tau_{U,E}\right)^{1-\eta} + \chi_U + \chi_O \left(\tau_{U,O}\right)^{1-\eta}}{\alpha_U + \alpha_E \left(\tau_{U,E}\right)^{1-\eta} + \alpha_A \left(\tau_{U,A}\right)^{1-\eta} + \alpha_O \left(\tau_{U,O}\right)^{1-\eta}}\right]^{\frac{1}{1-\eta}},$$

$$\frac{P_T^O}{P_T^U} = \left[\frac{\delta_O \left(\tau_{U,O} \cdot P_U\right)^{1-\eta} + \delta_E \left(\tau_{U,E} \cdot P_U\right)^{1-\eta} + \delta_A \left(\tau_{U,A} \cdot P_U\right)^{1-\eta} + \delta_U P_U^{1-\eta}}{\alpha_U P_U^{1-\eta} + \alpha_E \left(\tau_{U,E} \cdot P_U\right)^{1-\eta} + \alpha_A \left(\tau_{U,A} \cdot P_U\right)^{1-\eta} + \alpha_O \left(\tau_{U,O} \cdot P_U\right)^{1-\eta}}\right]^{\frac{1}{1-\eta}} \tag{A.4}$$

$$= \left[\frac{\delta_O \left(\tau_{U,O}\right)^{1-\eta} + \delta_E \left(\tau_{U,E}\right)^{1-\eta} + \delta_A \left(\tau_{U,A}\right)^{1-\eta} + \delta_U}{\alpha_U + \alpha_E \left(\tau_{U,E}\right)^{1-\eta} + \alpha_A \left(\tau_{U,A}\right)^{1-\eta} + \alpha_O \left(\tau_{U,O}\right)^{1-\eta}}\right]^{\frac{1}{1-\eta}}.$$

A.2 Real Exchange Rates

To calculate the impact of changes of both, the terms of trade and the prices of nontradables on the real exchange rate between two countries, the real exchange rates can be expressed as:

$$q_{U,E} = \frac{P_T^E}{P_T^U} \times \left[\frac{\gamma + (1-\gamma)\left(P_N^E/P_T^E\right)^{1-\theta}}{\gamma + (1-\gamma)\left(P_N^U/P_T^U\right)^{1-\theta}} \right]^{\frac{1}{1-\theta}}, \tag{A.5}$$

$$q_{U,A} = \frac{P_T^A}{P_T^U} \times \left[\frac{\gamma + (1-\gamma)\left(P_N^A/P_T^A\right)^{1-\theta}}{\gamma + (1-\gamma)\left(P_N^U/P_T^U\right)^{1-\theta}} \right]^{\frac{1}{1-\theta}}, \tag{A.6}$$

$$q_{U,O} = \frac{P_T^O}{P_T^U} \times \left[\frac{\gamma + (1-\gamma)\left(P_N^O/P_T^O\right)^{1-\theta}}{\gamma + (1-\gamma)\left(P_N^U/P_T^U\right)^{1-\theta}} \right]^{\frac{1}{1-\theta}}, \tag{A.7}$$

$$q_{E,A} = \frac{P_T^A}{P_T^E} \times \left[\frac{\gamma + (1-\gamma)\left(P_N^A/P_T^A\right)^{1-\theta}}{\gamma + (1-\gamma)\left(P_N^E/P_T^E\right)^{1-\theta}} \right]^{\frac{1}{1-\theta}}, \tag{A.8}$$

$$q_{E,O} = \frac{P_T^O}{P_T^E} \times \left[\frac{\gamma + (1-\gamma)\left(P_N^O/P_T^O\right)^{1-\theta}}{\gamma + (1-\gamma)\left(P_N^E/P_T^E\right)^{1-\theta}} \right]^{\frac{1}{1-\theta}}, \tag{A.9}$$

$$q_{A,O} = \frac{P_T^O}{P_T^A} \times \left[\frac{\gamma + (1-\gamma)\left(P_N^O/P_T^O\right)^{1-\theta}}{\gamma + (1-\gamma)\left(P_N^A/P_T^A\right)^{1-\theta}} \right]^{\frac{1}{1-\theta}}. \tag{A.10}$$

A log-linear approximation of (A.5), (A.6) and (A.7) gives (14), (15) and (16).

A.3 Market clearing conditions

To reach an equilibrium, the global market clearing conditions for each region's goods have to be fulfilled. Therefore, all nontradable goods have to be consumed by the producing region. This leads to the market clearing conditions for nontradable goods:

$$Y_N^i = (1-\gamma)\left(\frac{P_N^i}{P_C^i}\right)^{-\theta} C^i, i = U, E, A, O. \tag{A.11}$$

All produced tradable goods have to be consumed either by the region that produced the good or by one of the other three regions.[15] The market clearing conditions for tradables are:

$$\begin{aligned} Y_T^U &= \gamma\alpha_U \left(\frac{P^U}{P_T^U}\right)^{-\eta} \left(\frac{P_T^U}{P_C^U}\right)^{-\theta} C^U + \gamma\beta_U \left(\frac{P^U}{P_T^E}\right)^{-\eta} \left(\frac{P_T^E}{P_C^E}\right)^{-\theta} C^E \\ &+ \gamma\chi_U \left(\frac{P^U}{P_T^A}\right)^{-\eta} \left(\frac{P_T^A}{P_C^A}\right)^{-\theta} C^A + \gamma\delta_U \left(\frac{P^U}{P_T^O}\right)^{-\eta} \left(\frac{P_T^O}{P_C^O}\right)^{-\theta} C^O, \end{aligned} \tag{A.12}$$

$$\begin{aligned} Y_T^E &= \gamma\alpha_E \left(\frac{P^E}{P_T^U}\right)^{-\eta} \left(\frac{P_T^U}{P_C^U}\right)^{-\theta} C^U + \gamma\beta_E \left(\frac{P^E}{P_T^E}\right)^{-\eta} \left(\frac{P_T^E}{P_C^E}\right)^{-\theta} C^E \\ &+ \gamma\chi_E \left(\frac{P^E}{P_T^A}\right)^{-\eta} \left(\frac{P_T^A}{P_C^A}\right)^{-\theta} C^A + \gamma\delta_E \left(\frac{P^E}{P_T^O}\right)^{-\eta} \left(\frac{P_T^O}{P_C^O}\right)^{-\theta} C^O, \end{aligned} \tag{A.13}$$

$$\begin{aligned} Y_T^A &= \gamma\alpha_A \left(\frac{P^A}{P_T^U}\right)^{-\eta} \left(\frac{P_T^U}{P_C^U}\right)^{-\theta} C^U + \gamma\beta_A \left(\frac{P^A}{P_T^E}\right)^{-\eta} \left(\frac{P_T^E}{P_C^E}\right)^{-\theta} C^E \\ &+ \gamma\chi_A \left(\frac{P^A}{P_T^A}\right)^{-\eta} \left(\frac{P_T^A}{P_C^A}\right)^{-\theta} C^A + \gamma\delta_A \left(\frac{P^A}{P_T^O}\right)^{-\eta} \left(\frac{P_T^O}{P_C^O}\right)^{-\theta} C^O. \end{aligned} \tag{A.14}$$

Walras' Law implies that the market clearing condition for OPEC's tradable goods is met, if (A.12), (A.13) and (A.14) are fulfilled.

Knowing that

$$C^i = \frac{1}{\gamma} \cdot \left(\frac{P_T^i}{P_C^i}\right)^{\theta},$$

we can reformulate the market clearing conditions to:

$$\begin{aligned} Y_T^U &= \alpha_U \left(\frac{P^U}{P_T^U}\right)^{-\eta} C_T^U + \beta_U \left(\frac{P^U}{P_T^E}\right)^{-\eta} C_T^E \\ &+ \chi_U \left(\frac{P^U}{P_T^A}\right)^{-\eta} C_T^A + \delta_U \left(\frac{P^U}{P_T^O}\right)^{-\eta} C_T^O, \end{aligned} \tag{A.15}$$

$$\begin{aligned} Y_T^E &= \alpha_E \left(\frac{P^E}{P_T^U}\right)^{-\eta} C_T^U + \beta_E \left(\frac{P^E}{P_T^E}\right)^{-\eta} C_T^E \\ &+ \chi_E \left(\frac{P^E}{P_T^A}\right)^{-\eta} C_T^A + \delta_E \left(\frac{P^E}{P_T^O}\right)^{-\eta} C_T^O, \end{aligned} \tag{A.16}$$

$$\begin{aligned} Y_T^A &= \alpha_A \left(\frac{P^A}{P_T^U}\right)^{-\eta} C_T^U + \beta_A \left(\frac{P^A}{P_T^E}\right)^{-\eta} C_T^E \\ &+ \chi_A \left(\frac{P^A}{P_T^A}\right)^{-\eta} C_T^A + \delta_A \left(\frac{P^A}{P_T^O}\right)^{-\eta} C_T^O, \end{aligned} \tag{A.17}$$

[15] How to compute this, see Obstfeld and Rogoff (1996)

and express them in nominal terms by multiplying the market clearing condition for tradables of every region i with their price P_i:

$$\begin{aligned} P_U Y_T^U = {} & \alpha_U \left(\frac{P^U}{P_T^U}\right)^{1-\eta} P_T^U C_T^U + \beta_U \left(\frac{P^U}{P_T^E}\right)^{1-\eta} P_T^E C_T^E \\ & + \chi_U \left(\frac{P^U}{P_T^A}\right)^{1-\eta} P_T^A C_T^A + \delta_U \left(\frac{P^U}{P_T^O}\right)^{1-\eta} P_T^O C_T^O, \end{aligned} \tag{A.18}$$

$$\begin{aligned} P_E Y_T^E = {} & \alpha_E \left(\frac{P^E}{P_T^U}\right)^{1-\eta} P_T^U C_T^U + \beta_E \left(\frac{P^E}{P_T^E}\right)^{1-\eta} P_T^E C_T^E \\ & + \chi_E \left(\frac{P^E}{P_T^A}\right)^{1-\eta} P_T^A C_T^A + \delta_E \left(\frac{P^E}{P_T^O}\right)^{1-\eta} P_T^O C_T^O, \end{aligned} \tag{A.19}$$

$$\begin{aligned} P_A Y_T^A = {} & \alpha_A \left(\frac{P^A}{P_T^U}\right)^{1-\eta} P_T^U C_T^U + \beta_A \left(\frac{P^A}{P_T^E}\right)^{1-\eta} P_T^E C_T^E \\ & + \chi_A \left(\frac{P^A}{P_T^A}\right)^{1-\eta} P_T^A C_T^A + \delta_A \left(\frac{P^A}{P_T^O}\right)^{1-\eta} P_T^O C_T^O. \end{aligned} \tag{A.20}$$

A.4 Current Account

Allowing for international trade and debt, and therefore for current account imbalances within our model, by the definition of the current account each region's surplus is given as:[16]

$$CA^U = P_U Y_T^U + rF^U - P_T^U C_T^U, \tag{A.21}$$

$$CA^E = P_E Y_T^E + rF^E - P_T^E C_T^E, \tag{A.22}$$

$$CA^A = P_A Y_T^A + rF^A - P_T^A C_T^A, \tag{A.23}$$

where r is the nominal interest rate and F^i the net international investment position of region i.

The (theoretical) equilibrium conditions for the current accounts and for the international investment positions of all regions in our model-world are:

$$CA^U + CA^E + CA^A + CA^O = 0 \tag{A.24}$$

and

$$F^U + F^E + F^A + F^O = 0 \tag{A.25}$$

[16]Because of Walras' Law CA^O results out of the other three current accounts.

Now we can rewrite (A.24) and plug (A.21), (A.22), and (A.23) to get:

$$CA^O = -\left(CA^U + CA^E + CA^A\right) = P_O Y_T^O - r\left(F^U + F^E + F^A\right) - P_T^O C_T^O$$

Rearranging this equation yields:

$$P_T^O C_T^O = P_O Y_T^O - r\left(F^U + F^E + F^A\right) + CA^U + CA^E + CA^A \tag{A.26}$$

Plugging (A.21), (A.22), (A.23), and (A.26) into the market clearing conditions for tradables:

$$\begin{aligned} P_U Y_T^U = {} & \alpha_U \left(\frac{P_U}{P_T^U}\right)^{1-\eta}\left(P_U Y_T^U + rF^U - CA^U\right) \\ & + \beta_U \left(\frac{P_U}{P_T^E}\right)^{1-\eta}\left(P_E Y_T^E + rF^E - CA^E\right) \\ & + \chi_U \left(\frac{P_U}{P_T^A}\right)^{1-\eta}\left(P_A Y_T^A + rF^A - CA^A\right) \\ & + \delta_U \left(\frac{P_U}{P_T^O}\right)^{1-\eta}\left[P_O Y_T^O - r\left(F^U + F^E + F^A\right) + CA^U + CA^E + CA^A\right], \end{aligned} \tag{A.27}$$

$$\begin{aligned} P_E Y_T^E = {} & \alpha_E \left(\frac{P_E}{P_T^U}\right)^{1-\eta}\left(P_U Y_T^U + rF^U - CA^U\right) \\ & + \beta_E \left(\frac{P_E}{P_T^E}\right)^{1-\eta}\left(P_E Y_T^E + rF^E - CA^E\right) \\ & + \chi_E \left(\frac{P_E}{P_T^A}\right)^{1-\eta}\left(P_A Y_T^A + rF^A - CA^A\right) \\ & + \delta_E \left(\frac{P_E}{P_T^O}\right)^{1-\eta}\left[P_O Y_T^O - r\left(F^U + F^E + F^A\right) + CA^U + CA^E + CA^A\right], \end{aligned} \tag{A.28}$$

$$\begin{aligned} P_A Y_T^A = {} & \alpha_A \left(\frac{P_A}{P_T^U}\right)^{1-\eta}\left(P_U Y_T^U + rF^U - CA^U\right) \\ & + \beta_A \left(\frac{P_A}{P_T^E}\right)^{1-\eta}\left(P_E Y_T^E + rF^E - CA^E\right) \\ & + \chi_A \left(\frac{P_A}{P_T^A}\right)^{1-\eta}\left(P_A Y_T^A + rF^A - CA^A\right) \\ & + \delta_A \left(\frac{P_A}{P_T^O}\right)^{1-\eta}\left[P_O Y_T^O - r\left(F^U + F^E + F^A\right) + CA^U + CA^E + CA^A\right], \end{aligned} \tag{A.29}$$

and nontradables

$$P_N^U Y_N^U = \frac{1-\gamma}{\gamma}\left(\frac{P_N^U}{P_T^U}\right)^{1-\theta}\left(P_U Y_T^U + rF^U - CA^U\right), \tag{A.30}$$

$$P_N^E Y_N^E = \frac{1-\gamma}{\gamma}\left(\frac{P_N^E}{P_T^E}\right)^{1-\theta}\left(P_E Y_T^E + rF^E - CA^E\right), \tag{A.31}$$

$$P_N^A Y_N^A = \frac{1-\gamma}{\gamma}\left(\frac{P_N^A}{P_T^A}\right)^{1-\theta}\left(P_A Y_T^A + rF^A - CA^A\right), \tag{A.32}$$

$$P_N^O Y_N^O = \frac{1-\gamma}{\gamma}\left(\frac{P_N^O}{P_T^O}\right)^{1-\theta}\left[P_O Y_T^O - r\left(F^U + F^E + F^A\right) + CA^U + CA^E + CA^A\right] \tag{A.33}$$

gives us the basic equations of the framework which we use to conduct the simulations of different current account changes and of an adjustment of the global external imbalances.

A.5 Normalization

Following Obstfeld and Rogoff (2005) we conduct our simulations with the current accounts and the foreign investment positions normalized on the U.S. tradable GDP. To do so, we write for simplicity:

$$ca^U = \frac{CA^U}{P_U Y_T^U},\ ca^E = \frac{CA^E}{P_U Y_T^U},\ ca^A = \frac{CA^A}{P_U Y_T^U},$$

$$f^U = \frac{F^U}{P_U Y_T^U},\ f^E = \frac{F^E}{P_U Y_T^U},\ f^A = \frac{F^A}{P_U Y_T^U},$$

$$\sigma_{U/E} = \frac{Y_T^U}{Y_T^E},\ \sigma_{U/A} = \frac{Y_T^U}{Y_T^A},\ \sigma_{U/O} = \frac{Y_T^U}{Y_T^O},$$

$$\sigma_{N/U} = \frac{Y_N^U}{Y_T^U},\ \sigma_{N/E} = \frac{Y_N^E}{Y_T^E},\ \sigma_{N/A} = \frac{Y_N^A}{Y_T^A},\ \sigma_{N/O} = \frac{Y_N^O}{Y_T^O},$$

$$x^U = \frac{P_N^U}{P_T^U},\ x^E = \frac{P_N^E}{P_T^E},\ x^A = \frac{P_N^A}{P_T^A},\ x^O = \frac{P_N^O}{P_T^O}.$$

Now we divide (A.27), (A.28) and (A.29) by $P_U Y_T^U$, $P_E Y_T^E$ and $P_A Y_T^A$, respectively and use the simplifying expressions above:

$$\begin{aligned}
1 = {} & \alpha_U \frac{1}{\alpha_U + \alpha_E \tau_{U,E}^{1-\eta} + \alpha_A \tau_{U,A}^{1-\eta} + \alpha_O \tau_{U,O}^{1-\eta}}\left(1 + rf^U - ca^U\right) \\
& + \beta_U \frac{1}{\beta_E \tau_{U,E}^{1-\eta} + \beta_U + \beta_A \tau_{U,A}^{1-\eta} + \beta_O \tau_{U,O}^{1-\eta}}\left(\frac{\tau_{U,E}}{\sigma_{U/E}} + rf^E - ca^E\right) \\
& + \chi_U \frac{1}{\chi_A \tau_{U,A}^{1-\eta} + \chi_E \tau_{U,E}^{1-\eta} + \chi_U + \chi_O \tau_{U,O}^{1-\eta}}\left(\frac{\tau_{U,A}}{\sigma_{U/A}} + rf^A - ca^A\right) \\
& + \delta_U \frac{1}{\delta_O \tau_{U,O}^{1-\eta} + \delta_E \tau_{U,E}^{1-\eta} + \delta_A \tau_{U,A}^{1-\eta} + \delta_U} \\
& \times \left[\frac{\tau_{U,O}}{\sigma_{U/O}} - r\left(f^U + f^E + f^A\right) + ca^U + ca^E + ca^A\right],
\end{aligned} \tag{A.34}$$

$$1 = \alpha_E \frac{\tau_{U,E}^{1-\eta}}{\alpha_U + \alpha_E \tau_{U,E}^{1-\eta} + \alpha_A \tau_{U,A}^{1-\eta} + \alpha_O \tau_{U,O}^{1-\eta}} \left[\frac{\sigma_{U/E}}{\tau_{U,E}} \left(1 + rf^U - ca^U \right) \right] \tag{A.35}$$
$$+ \beta_E \frac{\tau_{U,E}^{1-\eta}}{\beta_E \tau_{U,E}^{1-\eta} + \beta_U + \beta_A \tau_{U,A}^{1-\eta} + \beta_O \tau_{U,O}^{1-\eta}} \left[1 + \frac{\sigma_{U/E}}{\tau_{U,E}} \left(rf^E - ca^E \right) \right]$$
$$+ \chi_E \frac{\tau_{U,E}^{1-\eta}}{\chi_A \tau_{U,A}^{1-\eta} + \chi_E \tau_{U,E}^{1-\eta} + \chi_U + \chi_O \tau_{U,O}^{1-\eta}} \left[\frac{\sigma_{U/E}}{\tau_{U,E}} \left(\frac{\tau_{U,A}}{\sigma_{U/A}} + rf^A - ca^A \right) \right]$$
$$+ \delta_E \frac{\tau_{U,E}^{1-\eta}}{\delta_O \tau_{U,O}^{1-\eta} + \delta_E \tau_{U,E}^{1-\eta} + \delta_A \tau_{U,A}^{1-\eta} + \delta_U}$$
$$\times \left[\frac{\sigma_{U/E}}{\tau_{U,E}} \left(\frac{\tau_{U,O}}{\sigma_{U/O}} - r \left(f^U + f^E + f^A \right) + ca^U + ca^E + ca^A \right) \right],$$

$$1 = \alpha_A \frac{\tau_{U,A}^{1-\eta}}{\alpha_U + \alpha_E \tau_{U,E}^{1-\eta} + \alpha_A \tau_{U,A}^{1-\eta} + \alpha_O \tau_{U,O}^{1-\eta}} \left[\frac{\sigma_{U/A}}{\tau_{U,A}} \left(1 + rf^U - ca^U \right) \right] \tag{A.36}$$
$$+ \beta_A \frac{\tau_{U,A}^{1-\eta}}{\beta_E \tau_{U,E}^{1-\eta} + \beta_U + \beta_A \tau_{U,A}^{1-\eta} + \beta_O \tau_{U,O}^{1-\eta}} \left[\frac{\sigma_{U/A}}{\tau_{U,A}} \left(\frac{\tau_{U,E}}{\sigma_{U/E}} + rf^E - ca^E \right) \right]$$
$$+ \chi_A \frac{\tau_{U,A}^{1-\eta}}{\chi_A \tau_{U,A}^{1-\eta} + \chi_E \tau_{U,E}^{1-\eta} + \chi_U + \chi_O \tau_{U,O}^{1-\eta}} \left[1 + \frac{\sigma_{U/A}}{\tau_{U,A}} \left(rf^A - ca^A \right) \right]$$
$$+ \delta_A \frac{\tau_{U,A}^{1-\eta}}{\delta_O \tau_{U,O}^{1-\eta} + \delta_E \tau_{U,E}^{1-\eta} + \delta_A \tau_{U,A}^{1-\eta} + \delta_U}$$
$$\times \left[\frac{\sigma_{U/A}}{\tau_{U,A}} \left(\frac{\tau_{U,O}}{\sigma_{U/O}} - r \left(f^U + f^E + f^A \right) + ca^U + ca^E + ca^A \right) \right],$$

$$\sigma_{N/U} = \frac{1-\gamma}{\gamma} \left(x^U \right)^{-\theta} \left(\alpha_U + \alpha_E \tau_{U,E}^{1-\eta} + \alpha_A \tau_{U,A}^{1-\eta} + \alpha_O \tau_{U,O}^{1-\eta} \right)^{-\frac{1}{1-\eta}} \tag{A.37}$$
$$\times \left(1 + rf^U - ca^U \right),$$

$$\sigma_{N/E} = \frac{1-\gamma}{\gamma} \left(x^E \right)^{-\theta} \left(\beta_E + \beta_U \tau_{U,E}^{-(1-\eta)} + \beta_A \tau_{E,A}^{1-\eta} + \beta_O \tau_{E,O}^{1-\eta} \right)^{-\frac{1}{1-\eta}} \tag{A.38}$$
$$\times \left[1 + \frac{\sigma_{U/E}}{\tau_{U,E}} \left(rf^E - ca^E \right) \right],$$

$$\sigma_{N/A} = \frac{1-\gamma}{\gamma} \left(x^A \right)^{-\theta} \left(\chi_A + \chi_E \tau_{A,E}^{1-\eta} + \chi_U \tau_{U,A}^{-(1-\eta)} + \chi_O \tau_{A,O}^{1-\eta} \right)^{-\frac{1}{1-\eta}} \tag{A.39}$$
$$\times \left[1 + \frac{\sigma_{U/A}}{\tau_{U,A}} \left(rf^A + ca^A \right) \right],$$

$$\sigma_{N/O} = \frac{1-\gamma}{\gamma} \left(x^O \right)^{-\theta} \left(\delta_O + \delta_E \tau_{O,E}^{1-\eta} + \delta_A \tau_{O,A}^{1-\eta} + \delta_U \tau_{U,O}^{-(1-\eta)} \right)^{-\frac{1}{1-\eta}} \tag{A.40}$$
$$\times \left[1 - \frac{\sigma_{U/O}}{\tau_{U,O}} \left[r \left(f^U + f^E + f^A \right) + ca^U + ca^E + ca^A \right] \right].$$

A.6 Nominal Exchange Rates (GDP deflator)

For the computation of the nominal exchange rate changes that might go along with changes in the current account positions of the four regions U, E, A, O, we follow Obstfeld and Rogoff (2005) by assuming that all central banks stabilize the geometric average of prices of tradable and nontradable domestic output. Thus, we have:

$$P_U^{\gamma}\left(P_N^U\right)^{1-\gamma} = 1 \;\rightarrow\; P_U^{\frac{\gamma}{\gamma-1}} = P_N^U, \tag{A.41}$$

$$P_E^{*\gamma}\left(P_N^{E*}\right)^{1-\gamma} = 1 \;\rightarrow\; P_E^{*\frac{\gamma}{\gamma-1}} = P_N^{E*}, \tag{A.42}$$

$$P_A^{*\gamma}\left(P_N^{A*}\right)^{1-\gamma} = 1 \;\rightarrow\; P_A^{*\frac{\gamma}{\gamma-1}} = P_N^{A*}, \tag{A.43}$$

$$P_O^{*\gamma}\left(P_N^{O*}\right)^{1-\gamma} = 1 \;\rightarrow\; P_O^{*\frac{\gamma}{\gamma-1}} = P_N^{O*}, \tag{A.44}$$

where the asterisk labels the nominal prices denominated in local currency.

From this, one can show (and we need this for the purpose of including valuation effects into the model as it is done by Oberpriller (2007)):

$$P_U^{\frac{\gamma}{\gamma-1}} = P_N^U = P_N^U \cdot \frac{P_T^U}{P_T^U} \Rightarrow P_U^{\gamma} = \left(\frac{P_N^U}{P_T^U}\right)^{\gamma-1} P_T^{U\,\gamma-1} \Longrightarrow$$

$$P_U = \left(\frac{P_N^U}{P_T^U}\right)^{\gamma-1}\left(\frac{P_T^U}{P_U}\right)^{\gamma-1}, \text{with } \frac{P_T^U}{P_U} = \left[\alpha_U + \alpha_E\tau_{U,E} + \alpha_A\tau_{U,A} + \alpha_O\tau_{U,O}\right]^{\frac{1}{1-\eta}}$$

$$\Longrightarrow P_U = \left(\frac{P_N^U}{P_T^U}\right)^{\gamma-1}\left[\alpha_U + \alpha_E\tau_{U,E}^{1-\eta} + \alpha_A\tau_{U,A}^{1-\eta} + \alpha_O\tau_{U,O}^{1-\eta}\right]^{\frac{\gamma-1}{1-\eta}}. \tag{A.45}$$

In general, the exchange rates between two countries i and j ($E_{i,j}$) are defined as:

$$E_{i,j} = q_{i,j} \times \frac{P_C^i}{P_C^j}$$

Therefore, we have for the various nominal exchange rates:

$$E_{U,E} = q_{U,E} \times \frac{P_C^U}{P_C^E} = q_{U,E} \times \frac{P_U^{\gamma}\left(P_N^U\right)^{1-\gamma}}{P_E^{*\gamma}\left(P_N^{E*}\right)^{1-\gamma}} = q_{U,E} \times \frac{\left(P_T^U/P_U\right)^{\gamma}}{\left(P_T^{E*}/P_E^{*}\right)^{\gamma}} =$$

$$= q_{U,E} \times \frac{\left(\alpha_U + \alpha_E\tau_{U,E}^{1-\eta} + \alpha_A\tau_{U,A}^{1-\eta} + \alpha_O\tau_{U,O}^{1-\eta}\right)^{\frac{\gamma}{1-\eta}}}{\left(\beta_E + \beta_U\tau_{E,U}^{1-\eta} + \beta_A\tau_{E,A}^{1-\eta} + \beta_O\tau_{E,O}^{1-\eta}\right)^{\frac{\gamma}{1-\eta}}}, \tag{A.46}$$

$$E_{U,A} = q_{U,A} \times \frac{\left(\alpha_U + \alpha_E\tau_{U,E}^{1-\eta} + \alpha_A\tau_{U,A}^{1-\eta} + \alpha_O\tau_{U,O}^{1-\eta}\right)^{\frac{\gamma}{1-\eta}}}{\left(\chi_A + \chi_E\tau_{A,E}^{1-\eta} + \chi_U\tau_{A,U}^{1-\eta} + \chi_O\tau_{A,O}^{1-\eta}\right)^{\frac{\gamma}{1-\eta}}}, \tag{A.47}$$

$$E_{U,O} = q_{U,E} \times \frac{\left(\alpha_U + \alpha_E\tau_{U,E}^{1-\eta} + \alpha_A\tau_{U,A}^{1-\eta} + \alpha_O\tau_{U,O}^{1-\eta}\right)^{\frac{\gamma}{1-\eta}}}{\left(\delta_O + \delta_E\tau_{O,E}^{1-\eta} + \delta_A\tau_{O,A}^{1-\eta} + \beta_O\tau_{O,U}^{1-\eta}\right)^{\frac{\gamma}{1-\eta}}}, \tag{A.48}$$

and of course

$$E_{E,A} = \frac{E_{U,A}}{E_{U,E}}, \tag{A.49}$$

$$E_{E,O} = \frac{E_{U,O}}{E_{U,E}}, \tag{A.50}$$

$$E_{O,A} = \frac{E_{E,A}}{E_{E,O}}. \tag{A.51}$$

Effective Nominal Exchange Rates

Using the solutions above, we can define the nominal effective exchange rates as:

$$E^U = \left(E_{U,E}\right)^{\frac{\alpha_E}{1-\alpha_U}}\left(E_{U,A}\right)^{\frac{\alpha_A}{1-\alpha_U}}\left(E_{U,O}\right)^{\frac{\alpha_O}{1-\alpha_U}}, \tag{A.52}$$

$$E^E = \left(\frac{1}{E_{U,E}}\right)^{\frac{\beta_U}{1-\beta_E}}\left(E_{E,A}\right)^{\frac{\beta_A}{1-\beta_E}}\left(E_{E,O}\right)^{\frac{\beta_O}{1-\beta_E}}, \tag{A.53}$$

$$E^A = \left(\frac{1}{E_{U,A}}\right)^{\frac{\chi_U}{1-\chi_A}}\left(\frac{1}{E_{E,A}}\right)^{\frac{\chi_E}{1-\chi_A}}\left(E_{A,O}\right)^{\frac{\chi_O}{1-\chi_A}}, \tag{A.54}$$

$$E^O = \left(\frac{1}{E_{U,O}}\right)^{\frac{\delta_U}{1-\delta_O}}\left(\frac{1}{E_{E,O}}\right)^{\frac{\delta_E}{1-\delta_O}}\left(\frac{1}{E_{A,O}}\right)^{\frac{\delta_A}{1-\delta_O}}. \tag{A.55}$$