The role of time preferences in explaining the long-term pattern of international trade

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Abstract

Globalization is accompanied by increasing current account imbalances. They can undermine the positive impacts of increasing international cooperation and trade on economic growth. By applying an economic growth model that requests for long-term compensation of short-term current account deficits, we derive patterns of international trade. Model output, however, is challenged by empirical data - which is related to the Lucas-Paradox. This paper demonstrates how, based on the assumption of differentiated time preferences, model results and empirical data are reconciled with each other. The method presented here yields an indirect estimate of the rates of time preference across regions. Our results suggest that the time preference rate is low in emerging Asian countries, while the USA and Europe are characterized by above world-average rates. Based on the applied model that differentiates between trade in energy resources and a composite good, simulated trade patterns of these three world regions significantly differ from each other and also from trade patterns that occur in resource exporting countries.

JEL classification: F11, F21, E21, D90, O41

keywords: global analysis, international trade, time preference, economic growth model, Lucas Paradox, current account imbalance

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1 Introduction

The output of economic models applied for policy analyses is sometimes challenged by empirical data. This applies to capital and trade flow patterns simulated by applied models that are based on Ramsey-type economic growth models. This paper demonstrates how the problem can be tackled based on a concept that is rooted in economic theory but hardly adopted by applied models. Starting with the conceptual perspective, this study is approaching the problem by first asking: What drives trade in an economic growth model? In following economic literature, trade and capital flows between countries can be explained by differences in three economic fundamentals - factor endowments, technologies and preferences (cf. Ten Raa and Mohnen, 2001). While differences in endowments and productivities are broadly discussed and applied features of economic models, the role of time preferences in explaining international trade patterns is rarely highlighted. This study will provide some insights which then will be used by an applied economic growth model to simulate long-term trade patterns.

Economic growth models are represented by a broad range of different economic models (for a classification - see Arnold, 2007) that aim to explain the dynamics of economic development. While international capital mobility is often represented in economic growth models, international trade is usually not in the focus of this model type. In its most simple form, represented by a single-factor, two-country economic growth model, where the representative agents have no preferences on consuming domestic compared to foreign goods, trade is only meaningful as intertemporal trade. Intertemporal trade is meant as exchange of the composite good today against the composite good in the future. It can simultaneously be conceived as capital trade or as borrowing and lending (cf. Obiols-Homs, 2011). Intertemporal trade helps to balance capital needs of countries with different demographic dynamics or at different stages of development, hence contributes to economic growth.

Even in more complex economic growth models that also include trade as ex-

change of different commodities, intertemporal trade plays a role. Integrated Assessment (IA) models are such a class of models centered around an economic growth model, e.g. RICE (Nordhaus and Yang, 1996) and MERGE (Manne et al., 1995). Within these models a composite good exists that aggregates the majority of each countries' tradeable goods. Commonly in IA models, trade in the composite good balances trade in energy resources and emission permits. If intertemporal trade is not modeled, capital inflows, current account deficits and therefore a part of real-world dynamic do not occur in such a setting.

The issue of intertemporal trade is weakly represented in applied economic modeling studies. With respect to IA models, it has hardly been addressed since Manne and Rutherford (1994) and Nordhaus and Yang (1996) - on the one hand, because of the numerical demands on solving large-scale models with intertemporal trade, on the other hand, because of the peculiarity of resulting trade flow patterns. In a model with perfect competition and free trade, simulated trade flows may deviate in an order of magnitude from empirically observed data. Ten Raa and Mohnen (2001) report this for a multi-product model. With the intertemporal dimension of trade a similar effect can be observed. The standard theory predicts capital flows from rich to poor countries which is in contrast to existing patterns of international current accounts and which is known as the Lucas-Paradox (Lucas, 1990). While Lukas himself suggested modifications of the standard neoclassical theory to solve the Paradox, empirical research has permanently investigated into this issue.

Studies which approach this problem can rely on empirical literature that tries to identify and explain determinants of current account imbalances (e.g. Chinn and Prasad, 2003; Milesi-Feretti and Razin, 1998; Aizenman and Sun, 2010; Gruber and Kamin, 2007; Coi et al., 2008; Campa and Gavilan, 2011). Among these determinants are expectations about future incomes and relative prices (Campa and Gavilan, 2011), savings behaviour (Choi et al., 2008), financial crises and institutional quality (Gruber and Kamin, 2007), government budget balances, financial deepening and trade openness (Chinn and Prasad, 2003). In reversed perspective,

Shoham and Pelzman (2011) discuss the role of current account imbalances for the global financial crisis. Alfaro et al. (2008) explicitly focus on the Lucas Paradox, highlighting again the institutional quality as leading explanation. The sustained rise of the US current account deficits, in particular, challenges economic theory and economic models. Highfill and McAsey (2010) address the relation between the US current account deficit and the state of technology. There is no agreement in the economic literature whether these deficits are sustainable or not. Caballero et al. (2008) and Mendoza et al. (2009) present models that explain this phenomenon based on the heterogeneity of domestic financial markets. The model of Mendoza et al. (2009) even predicts a current account deficit if all countries have identical preferences, endowments and technologies.

In this paper, we discuss how this problem manifests in an applied economic model and demonstrate how by means of differentiated regional time preferences trade flows will be contained and redirected and the Lucas-Paradox is resolved. This approach is supported by the study of Choi et al. (2008) who found that international differences in subjective discounting display increasing relative U.S. impatience and create current account imbalances that match patterns observed in the data. Subject and tool of investigation is the large-scale IA model REMIND-R (Leimbach et al., 2010b) which allows for an indirect estimation of time preference rates and the simulation of future trade patterns.

The paper is structured as follows. In section 2, we analyze the drivers of trade in a stylized economic growth model analytically and summarize contributions from the literature with respect to the role of time preferences. In section 3, we present the trade module of the global multi-region model REMIND-R and its integration in an intertemporal welfare-maximizing model framework. Laying open the nature of trade as control variable and the meaning of the intertemporal budget constraint is crucial. An improved algorithm to finding the equilibrium solution is presented. Empirical data and model outcomes from REMIND-R simulations are compared in section 4. According to the simulations, the future trade pattern of each world region can be assigned to one of four clusters. We end with some

conclusions.

2 Trade in an economic growth model

While we recognize the development of new trade models that extended the explanation of international trade based on the concept of heterogenous firms (Melitz, 2003; Bernard et al., 2003; Arkolakis et al., 2012), we focus on the representation of trade in economic growth models. While the assumption of representative firms and households is a weakness, the long-term perspective represents a strength of growth models. Eaton et al. (2011) provide an anatomy of international trade based on a model with firm heterogeneity. In deriving changes in trade patterns they assume that each country hold its trade deficit in a constant proportion to the world GDP. With the growth model as conceptual tool, however, we investigate long-term trade patterns which explicitly request for a change of trade balances.

What drives trade in an economic growth model? In order to answer this question based on simple analytical reasoning, we consider a single-factor, two-country economic growth model. Both countries produce just one composite good. Utility U is a function of consuming this good over a time $t = 0, ..., T$. The representative agents of each country have no preferences on consuming domestic compared to foreign goods. This yields the following fairly standard optimization problem for each country i=1,2:

$$max \int_{t=0}^{T} e^{-\rho_i t} U_i(C_i(t)) dt \tag{1}$$

$$s.t. \quad C_i(t) = f(A_i(t), K_i(t)) - I_i(t) - X_i(t) \tag{2}$$

$$\dot{K}_i(t) = I_i(t) + (1 - \delta) K(t) \tag{3}$$

$$\dot{D}_i(t) = X_i(t) + r(t) \cdot D_i(t) \tag{4}$$

$$D_i(T) = 0, \tag{5}$$

including additional initial and terminal conditions for the stock variables K_i and D_i. Control variables I_i, X_i represent investments and net exports, parameter A_i represents total factor productivity, and variables C_i, K_i and D_i represent consumption, capital and net foreign assets, respectively. f is a neoclassical constant-return-to-scale production function. Utility is discounted based on the pure rate of time preference ρ, capital is depreciated with the rate δ, and net foreign assets yield interest by the amount $r \cdot D_i$. Eq. 5 ensures that all debts are cleared, i.e. all accumulated current account deficits are balanced at the end of the time horizon, while trade in the composite good is balanced in each period:

$$\sum_i X_i(t) = 0. \tag{6}$$

From the economic theory we know that for the marginal product of capital at the optimum growth path $\hat{K}$ it holds (Cass, 1965):

$$f'(\hat{K}_i(t)) = \rho + \delta. \tag{7}$$

In an open economy with unrestricted capital trade the marginal products in each country become equal:

$$f'(\hat{K}_1(t)) = f'(\hat{K}_2(t)). \tag{8}$$

In following the classical Heckscher-Ohlin and Ricardian model (Flam and Flanders, 1991), trade between countries (or regions) is induced by differences in three economic fundamentals - factor endowments (K), technologies (A) and preferences (ρ). While this was originally derived from a two-product static case, it can analogously be applied to a multi-product case (cf. Ten Raa and Mohnen, 2001) and to the one-product intertemporal case. The present study investigates the latter. We are interested in transitional effects and in resulting trade patterns that not only take into account that marginal products of capital can be equalized

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by initial trade shocks but also that the trade interaction is only completed if initial export (import) is balanced by future import (export) as ensured by eq. 5.

Assuming the common properties of the neoclassical welfare and production functions, and otherwise symmetric countries, trade is induced by differences in initial capital endowments

$$K_1(0) > K_2(0) \Rightarrow f'(K_1(t)) < f'(K_2(t)) \Rightarrow D_1(t) > D_2(t). \qquad (9)$$

Differences in initial productivities have the same effect in the opposite direction:

$$A_1(0) > A_2(0) \Rightarrow f'(K_1(t)) > f'(K_2(t)) \Rightarrow K_1(t) > K_2(t) \Rightarrow D_1(t) < D_2(t). \qquad (10)$$

In order to meet eq. 8, capital always flows to the country with higher marginal productivity. This holds irrespective of opportunities for domestic capital accumulation. In both previous cases, trade is induced as part of an instantaneous transition towards a new steady state (in particular an optimal capital output ratio).

From the perspective of a dynamic model, directed trade can also be triggered by differences of productivity growth in the following way:

$$\dot{A}_1(t) > \dot{A}_2(t) \Rightarrow \frac{f'(K_1(t))}{f'(K_2(t))} > \frac{f'(K_1(t-1))}{f'(K_2(t-1))} \Rightarrow$$
$$\frac{K_1(t)}{K_2(t)} > \frac{K_1(t-1)}{K_2(t-1)} \Rightarrow D_1(t) > D_2(t). \qquad (11)$$

Analogous to the trade pattern induced by comparative advantages in a static multi-product world, capital moves towards the more productive country in times when productivity differences are expected to be highest and towards the less productive country otherwise.

The present study focus on time preferences as crucial element for explaining international trade patterns. Starting analytically, we refer to eq. 7. According to this optimality condition, a higher marginal product of capital can be assumed for

the country with the higher rate of time preference. This implies transitional trade
flows (here from country 2 to country 1):

$$\rho_1 > \rho_2 \Rightarrow f'(K_1(t)) > f'(K_2(t)) \Rightarrow K_1(t) > K_2(t) \Rightarrow D_1(t) < D_2(t). \quad (12)$$

In an open economy with perfect international capital market, the neoclassical
model predicts that capital moves quickly to equalize marginal products. This can
lead to huge initial capital flows. In most applied economic models, like Integrated
Assessment models, by default, equal time preferences are assumed[1], as well as
capital endowments and technology differences that imply capital flows from North
to South.

Unlike the differentiation of preferences across commodities (a typical assump-
tion in computable general equilibrium models), the assumption of interacting rep-
resentative agents with different time preferences is uncommon in applied eco-
nomic models but also in standard economic theory (Lengwiler, 2005). The major-
ity of the relevant literature examines the existence of different preferences in the
context of individuals or agents that represent less than countries or entire world
regions. Apart from that, Barro et al. (1995) bring forward the argument of differ-
ent preferences when explaining growth patterns of countries. They, furthermore,
introduced human capital to allow for an imperfect capital mobility. In this frame-
work only the accumulation of physical capital can be financed by borrowing.

In an economic growth model, the pure rate of time preference and the savings
behavior are strongly linked to each other. A strong argument in favor of a differ-
entiation of time preferences is the fact that the savings behavior is not unique in
the world. Differences are rooted in the stage of economic development and in so-
cioeconomic and cultural characteristics of respective regions. Marchiori (2011),

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[1] While most integrated assessment studies do not consider regionally differentiated time prefer-
ences, the level of chosen time preferences rates varies between different studies. Moreover, there is
a huge debate in the climate economics literature whether to follow a positive or normative approach
in selecting the time preference rate for climate policy assessments (cf. Schneider et al., 2012).

for example, analyzed in an overlapping generations model internationally different savings behavior based on demographic trends. Furthermore, Aizenman and Sun (2010) noted that habit formation make consumers reluctant to change consumption behavior quickly (see also Caroll et al., 2000). This implies a sustained high level of savings in countries with high economic growth.

The assumption of regionally differentiated time preference rates can be combined with the assumption of either being constant or varying over time. While the former is consistent with the hypothesis that successive generations are motivated by the same system of preferences (Ramsey, 1928), it creates another unappealing characteristic. If agents discount future utility and use different constant discount rates, then, at any future state, all the capital will be owned by agents with the lowest discount rate (Barro et al., 1995; Bliss, 2004).

Optimal growth with endogenously determined rates of time preferences is examined by Das (2003) and Uzawa (1996). Das (2003) adopts the idea that the time preference varies with increasing income. While previous theoretically based argumentation is in favor of increasing marginal impatience, as it ensures stability of the steady state, Das (2003) demonstrates that a stable steady state can also be consistent with decreasing marginal impatience.

As the discussion above shows, the theoretical literature provides a sound foundation for experiments based on the assumption of regionally differentiated and time-variant rates of time preferences. The formulation and application of the numerical model described in the next section will adopt the possibility of regionally differentiated rates of time preferences, while assuming time invariance. It is nevertheless in contrast to most other applied models that address economic growth and trade issues. Another example that deal with differentiated time preferences is given by Hof et al. (2010) in the context of Integrated Assessment modeling.

3 The trade module of REMIND-R

While the previous section reveals the basic drivers of trade in an economic growth model, the next sections will address which of these mechanisms drive trade simulation output in an applied economic model. This will help to identify in how far theoretical economic concepts can assist in explaining and in overcoming deviations of model outputs from empirical data.

Subject of investigation is the multi-region model REMIND-R. For the purpose of this paper we will focus on those parts of the model that are most relevant for the discussion of trade issues.[2]

REMIND-R is used to assess climate policies (Leimbach et al. 2010a,b; Bauer et al. 2012, Luderer et al. 2012). It couples an economic growth model with an energy system model and a simple climate model (see Fig. 1). Technological change in the energy sector is embedded in a macroeconomic environment that by means of investment and trade decisions as well as assumptions on technical progress (in particular labor efficiency growth) governs long-term regional development. REMIND-R is suited to analyze long-term trade patterns as it allows for intertemporal trade and current account imbalances. It furthermore separates a component of the current account that can be expected to have a sustained impact in a number of countries - trade in fossil resources.

The applied version of REMIND-R includes eleven world regions:

1. USA - USA

2. EUR - EU27

3. JPN - Japan

4. CHN - China

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[2]For comprehensive and detailed technical description of the model we refer to http://www.pik-potsdam.de/research/research-domains/sustainable-solutions/models/remind/remind-code and http://www.pik-potsdam.de/research/sustainable-solutions/models/remind/description-of-remind-v1.5.
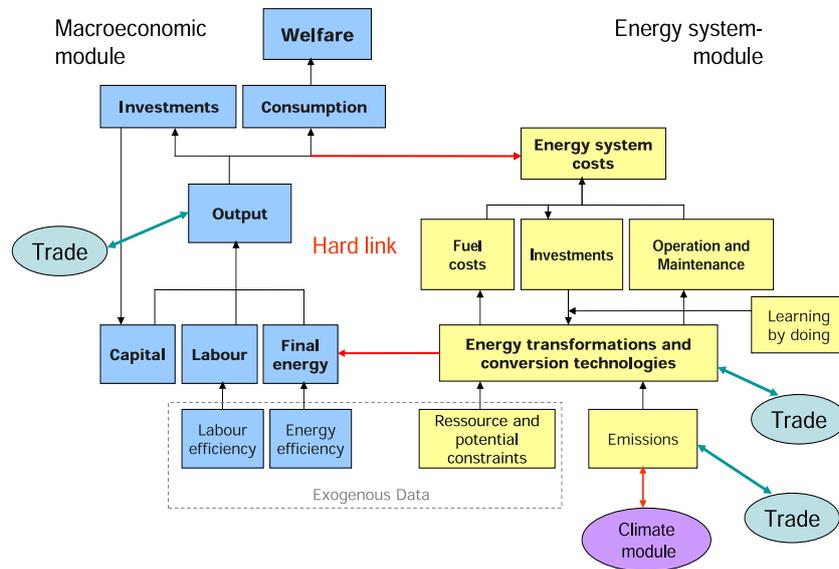
Figure 1: Structure of REMIND-R

5. IND - India

6. RUS - Russia

7. AFR - Sub-Saharan Africa (excl. Republic of South Africa)

8. MEA - Middle East and North Africa

9. LAM - Latin America

10. OAS - Other Asia (Central and Pacific Asia)

11. ROW - Rest of the World (Canada, Australia, South Africa and Rest of Europe).

World-economic dynamics over the time horizon 2005 to 2150 is simulated with five-year time steps in REMIND-R. Each region is modeled as a representative household with a utility function $U(r)$ that depends upon the per capita consumption. With assuming the intertemporal elasticity of substitution of per capita consumption to be close to 1 it holds:

$$U(r) = \sum_{t=t_0}^{T} \left(G(t,r) \cdot L(t,r) \cdot \ln \left(\frac{C(t,r)}{L(t,r)} \right) \right) \quad \forall r. \tag{13}$$

with

$$G(t,r) = e^{-\rho(r) \cdot (t-t_0)} \quad \forall t, r. \tag{14}$$

$C(t,r)$ represents consumption in time-step t and region r, $L(t,r)$ represents labor (equivalent to population), $G(t,r)$ the discount factor and $\rho(r)$ the pure rate of time preference. Each region generates macro-economic output (i.e. GDP) based on a calibrated and nested "constant elasticity of substitution" (CES) production function of the production factors labor, capital, and final energy. GDP is available for consumptiion, investments into the macroeconomic capital stock, energy system expenditures and for the export of composite goods. Macro-economic investments as control variable enter a common capital stock equation (cf. eq. 3) with assumed depreciation rate of 5%.

While the above formulation of the welfare function considers regionally differentiated time preference rates, the original version of REMIND-R assumes them to be the same across regions. Trade between regions is first of all induced by differences in factor endowments and technologies. Trade is considered in different primary energy sources, in a composite good and in emission permits. This is supplemented by the possibility of intertemporal trade. Capital mobility is represented by free trade in the composite good. It is weak capital mobility as only new capital, i.e. investment goods, is mobile. Capital mobility and intertemporal trade cause price equalization and guarantee an intertemporal and interregional equilibrium. There is no bilateral trade, but export in and import from a common pool. With $X_j(t,r)$ and $M_j(t,r)$ as export and import of good j of region r in period t, the following trade balance equation holds:

$$\sum_r (X_j(t,r) - M_j(t,r)) = 0 \quad \forall\, t, j \tag{15}$$

Both trade variables represent control variables. A procedure of reconciling trade decisions of actors (i.e. regions) is needed. In searching for the respective equilibrium solution we apply a sequential joint maximization algorithm (Manne and Rutherford, 1994) which is also called Negishi approach (Negishi, 1972). In this iterative approach, the objective functions of the individual regions are merged to a global objective function W by means of welfare weights w:

$$W = \sum_r \left(w(r) \cdot U(r) \right) \tag{16}$$

A distinguished pareto-optimal solution, which in the case of missing externalities also corresponds to a market solution, is obtained by adjusting the welfare weights according to the intertemporal trade balances $B^i(r)$:

$$B^i(r) = \sum_t \sum_j \left(p_j^i(t) \cdot [X_j^i(t,r) - M_j^i(t,r)] \right) \quad \forall\, r, i \tag{17}$$

where i represents the iteration index, which is skipped from the equations above, and $p_j^i(t)$ represents present value world market prices derived as shadow prices from eq. 15.

A new set of weights is derived iteratively:

$$w^{i+1}(r) = w^i(r) + \frac{B^i(r)}{\sum_t e^{-\rho(r)\cdot(t-t_0)} L(t,r)} \quad \forall\, r, i \tag{18}$$

We compute a new solution from which we derive $B^{i+1}(r)$. It holds that

$$\mid B^{i+1}(r) \mid \;\; < \;\; \mid B^i(r) \mid \quad \forall\, r, i \tag{19}$$

and

$$\lim_{i \to \infty} B^i(r) = 0 \quad \forall\, r, \tag{20}$$

i.e. the intertemporal trade balance has to converge to zero for each region. Hence, the higher the intertemporal trade balance deficit of a region, the more its welfare weight needs to be lowered to induce exports from this region to other regions.

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In going beyond the general presentation of the Negishi algorithm given by Manne and Rutherford (1994), with eq. 18 we provide an explicit formulation. Analytical foundation is given in the Appendix. This implementation of the Negishi algorithm is more efficient than the heuristic approach by Leimbach and Toth (2003). Convergence is quite fast. Usually, 3 to 4 iterations are sufficient.

The trade patterns resulting from model simulations are highly impacted by the intertemporal trade balance constraint. Each export of the composite good qualifies the exporting region for a future import (of the same present value), but implies for the current period a loss of consumption. Imports increase current consumption but imply the accumulation of debts that have to be cleared in the long run according to the intertemporal trade balance constraint that takes effect like an additional budget constraint. While the Negishi weights have only an impact on the trade patterns in combination with this constraint, hence cannot be considered as a freely chosen parameter, the selection of the time horizon for clearing all debts is arbitrary and will likely have an impact on the resulting trade patterns. We decided to use the models' time horizon as reference.

If we accept that indebtedness is part of the real-world dynamics that should be represented in such kind of economic growth model, two additional alternatives in balancing intertemporal trade exist in principle. The first alternative would be to follow the historic trend of the current account pattern which in essence would imply to assume sustained current account surplus for China and increasing debts of the USA. Within the literature that tries to explain current account imbalances, there is some indication (e.g. Aizenman and Sun, 2010; Chen, 2011) that this cannot be a sustainable pattern. The second alternative is to dispense for balancing at all. This, however, would completely shift the meaning of the Negishi weights from a positive to a normative parameter linked to a number of distributional and even ethical questions.

4 Simulation results vs. empirical data

While REMIND-R is more complex than the stylized model presented in section 2, major drivers of trade, in particular intertemporal trade, are similar. Based on empirical data, factor endowments are not equal among the regions. Technology characteristics, which are represented by factor efficiency parameters and which result from model calibration, are even more diverse. As section 3 highlights, the intertemporal trade balance equation is expected to have a significant impact on trade patterns. Also this feature is in correspondence with the stylized model. The intertemporal trade balance (eq. 17) and its terminal condition (eq. 20) take effect like the net foreign asset constraints (eq. 4 and 5) in the stylized growth model.

In first simulations with REMIND-R, based on the assumption of equal time preference rates of 3% across all regions, an international trade pattern arises that is characterized by oversized trade flows compared to empirically observed figures. This is illustrated in Fig. 5 at the end of this section. As we did not restrict trade flows by artificial bounds (cf. Manne and Rutherford, 1994), differences in the marginal productivities and utilities between regions are equalized quickly by capital trade (i.e. trade in the composite good). This leads to initial spikes in current account balances and an overestimation of trade flows (cf. Nordhaus and Yang, 1996). Ten Raa and Mohnen (2001) reported on deviations in the same order of magnitude for a free trade model based on the economic fundamentals only.

Deviations from the empirics do not only apply to the level of trade but also to the direction of trade. In accordance with the theory, capital is flowing from North to South in the model, whereas empirical data indicate trade flows in the opposite direction. This is known as the Lucas Paradox (Lucas, 1990). This effect is most significant for China and the USA. High trade deficits and trade surpluses, respectively, are simulated for these regions in the model experiments.

A first conceptual approach in correcting the trade flow level is to capture the home bias effect (cf. Obstfeld and Rogoff, 2000). Most standard computable general equilibrium models apply Armington elasticities to model the home bias.

While capturing the home bias is suited to adjust the level of trade flows, it is not likely to help in tackling the Lucas Paradox, which request for a shift in the direction of initial trade. The same limitation applies to the inclusion of trade costs, barriers (e.g. tariffs) and risk premia for capital transfers. Institutions certainly play a role. However, Gruber and Kamin (2011) reported that they were not able to explain the large U.S. current account deficit based on a model with standard determinants and augmented by measures of institutional quality. We, therefore, followed another approach that similar to the Armington elasticities affects regional preferences, but is more radical.

Starting from the assumption that international trade is caused by regional differences in economic fundamentals as discussed in section 2, and given that differences in endowments and technologies are almost captured in the model, we consider regional time preferences to have a corrective impact on the deviation between model data and empirical data. Differences in time preferences primarily represent empirically well founded differences in the international patterns of saving, investing and consuming.

We propose to correct the observed deviation by introducing regionally differentiated time preference rates instead of equal time preferences rates as assumed in the original model. Estimates for regional time preference rates are derived indirectly. Within an iterative process we manually adjusted the time preference rates such that subsequent simulations yield initial trade flows that sufficiently match empirical data. Table 1 shows the original and the adjusted set of time preferences assumed in REMIND-R. The latter range from 1.2% (China) to 4.7% (USA). [3] Whereas comparatively high values are indicated for developed countries, low values show up in the revised model for most developing world regions. Africa is the exception for which a medium value of 3.4% is estimated. While we assume that the preferences remain constant over time in each single region to maintain inter-

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[3]This range is comparable with what can be found in the literature. While macro-economic estimates for the pure rate of time preference are hardly available, Schneider et al. (2012) report on a range between zero and 10% by referring to studies that consider household data.

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Region	Unadjusted model	Revised model
USA	0.03	0.0475
JPN	0.03	0.038
EUR	0.03	0.0415
RUS	0.03	0.024
MEA	0.03	0.025
LAM	0.03	0.027
OAS	0.03	0.0145
CHN	0.03	0.012
IND	0.03	0.015
AFR	0.03	0.034
ROW	0.03	0.0325

Table 1: Parameter values for the rate of time preference

generational consistency, we recognize a long-term regional spread in consumption growth rates (cf. discussion in section 2).

The shift of the parameter values from the unadjusted to the revised REMIND-R version changes the model output. Simulated regional GDP paths are affected only slightly, but regional consumption paths become quite different. As known from the theory, a higher rate of time preference results in a short-term increase and a long-term decrease of consumption. This pattern holds for Europe and the USA (see Fig. 2). An opposite pattern occurs for most other regions. In contrast to standard growth models, this model allows to simulate different consumption growth rates across different world regions - something which is likely to represent real-world characteristics more adequately. While the changes in the simulated growth pattern are substantial, consumption in the most impatient region (i.e. USA) is still growing until 2100.

Fig. 3 shows changes in the trade pattern, represented by the trade flows in the base year. Positive values indicate more net export/import in the revised REMIND-
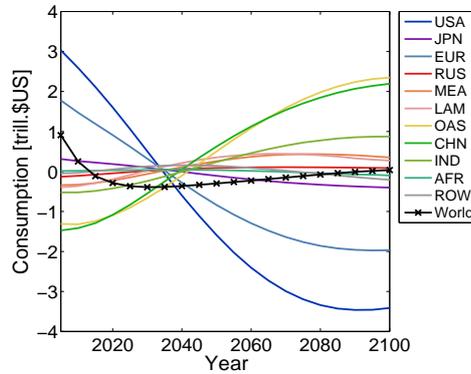
Figure 2: Consumption differences between revised and unadjusted model version (net present value)

R version, while negative values denote less net export/import in the revised compared to the unadjusted version. Mainly driven by a change in regional time preference rates initial exports and imports decrease. The former applies to the developed world regions for which the time preference rates were increased, while the latter applies to the developing regions for which the preference rates were lowered. For a number of regions (e.g. USA, CHN, OAS) initial trade changes the direction. Overall, this provides an improved correspondence to empirical data for the revised model version.

This is supported by Fig. 4 which demonstrates the deviation of observed and simulated current account data in 2005 [4]. As control variables like trade are endogenously chosen already for the base year, deviation between simulated and empirically observed values for those variables are likely to appear. However, simulated figures within the initial periods are expected to be in a broadly defined empirical range. While this does not hold for the unadjusted model version with respect to the current account, it holds for the revised model version. Moreover, with the revised model version sustained trade deficits and surpluses as empirically

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[4]Current account data are subject to significant short-term changes. We therefore use the average of IMF data between 2003 and 2007 as empirical benchmark for 2005. This includes a correction aiming to balance the global sum of regional current accounts.
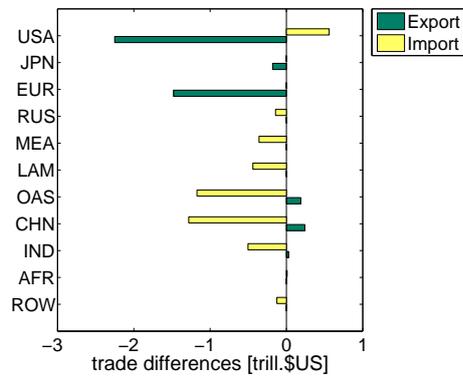
Figure 3: Trade differences between revised and unadjusted version in 2005 (composite good only)
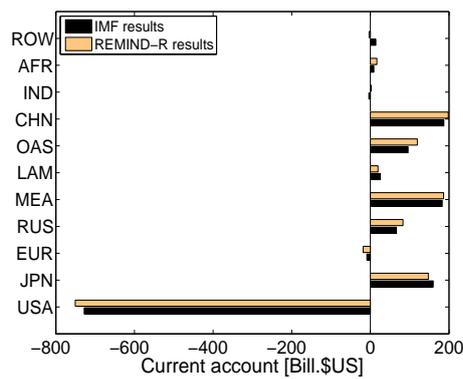
Figure 4: Current account in 2005, empirical data from International Monetary Fund (IMF) database

observed are reproduced, hence the Lucas-Paradox is resolved. This is demonstrated for the most extreme examples USA and China in Fig. 5. In the respective subfigures, model results for the time horizon 2005-2100 and empirical current account data (WDI, 2005) for 1960-2003 are put together.

The composition of the current accounts of all regions as simulated by the

(a) China unadjusted   (b) China revised

(c) USA unadjusted   (d) USA revised
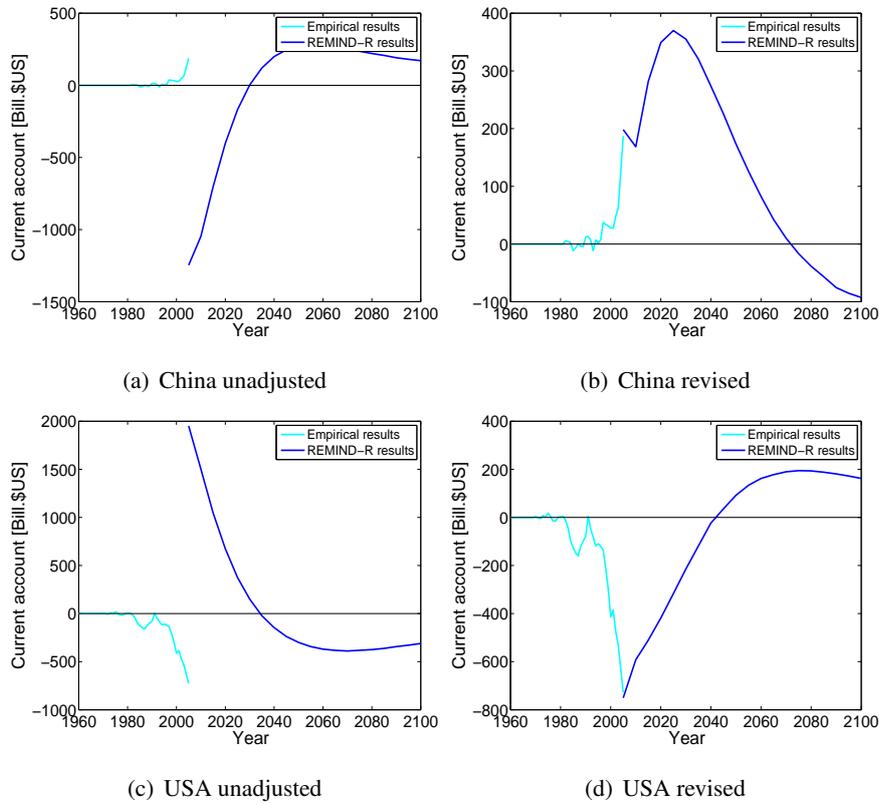
Figure 5: Current account of China and USA of unadjusted and revised version; Empirical data based on WDI (2005)

revised version of REMIND-R is shown in the Appendix [5]. While the results presented do not claim for high predictive power, which in particular applies to the time and the level when the current accounts turn around, they provide a possible qualitative pattern of future development. Four regional clusters can be identified. The first group comprises the resource owners (RUS, MEA, LAM, AFR, ROW). Their current accounts are characterized by energy resources exports and composite good imports. Intertemporal trade plays a minor role, i.e. the current accounts are quite in balance over time. This, however, depends on a sustained future de-

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[5]The contribution to the current account that is labeled as foreign asset indicates the implicit transfers of revenues from net foreign assets.

mand on resources and may change if climate change will request for a reduction of the fossil-fuel intensive way of global energy production. The fast growing Asian regions (CHN, IND, OAS) form the second group. A pronounced intertemporal structure of their current accounts is associated with short-term export surpluses and long-term import surpluses. These regions generate a large amount of foreign assets. The third group, composed of Europe and Japan, is characterized by high energy resources imports that in the short term are balanced by composite good exports. In the mid term, imports will dominate even for the composite good, while this is turned around again in the long term. The earlier these regions shift from a net exporter of goods to a net importer of goods the larger the amount of debts they accumulate. Finally, the USA represents a group for which intertemporal trade is very important. Part of current economic growth and consumption is based on capital inflow and goods imports. Favorable institutional conditions support this way of growth, but it is questionable that it can be sustained over the century (cf. Aizenman and Sun, 2010; Chen, 2011). A pattern as simulated by the model is more likely. Huge initial current account deficits have to be cut back in the long run.

5 Conclusions

In this paper, we analyzed capital and trade flow patterns that result from economic growth-type models. Intertemporal trade, which is a feature that helps to capture real-world dynamics in such type of model, shapes the overall trade pattern. We analytically discussed the role that different drivers play in explaining overall trade patterns. The theoretical literature mentions the three fundamentals - factor endowments, technologies and preferences.

Simulations with the large-scale Integrated Assessment model REMIND-R, that features intertemporal trade in a composite good and trade in different energy resources, indicate a dominant impact of time preferences. We demonstrated how trade in the composite good can be controlled by altered assumptions on time pref-

erence rates. Based on a new set of indirectly derived time preference rates, simulated trade and capital flows have been harmonized with empirical data. Moreover, we were able to tackle the Lucas Paradox by generating capital flows from South to North in a neoclassical growth model. This implies rates of time preferences lower than 2% for emerging Asian countries and higher than 4% for Europe and the USA.

The pursued approach includes two key elements: first, the adjustment of regional time preferences in such a way that initial current account levels are approximated, and second, the assumption that regions completely level off their cumulated trade balance deficits until a finite point in time. Based on these assumptions, we can estimate the development of regional current accounts and future trade and capital flows. We identified four clusters of future regional trade pattern. The most significant shifts can be expected in the Asian regions (switching from capital exporters to capital importers) and the USA (switching from capital importer to a capital exporter). This will requests for long-term structural change governed by domestic economic policies.

Trade in the composite good and intertemporal trade, respectively, primarily represent a welfare-increasing redistribution of global GDP. A sensitivity analysis showed that results are robust against variation of a key assumption - the constancy of the time preference rates over time. This, however, turned out from simulations in a model setting that ignores market imperfections like trade barriers and institutional constraints. It is subject of future research to investigate to what extent the impact of intertemporal trade on long-term growth increases and the role of time preferences changes in model settings with market imperfections, externalities and limited anticipation of shocks.

6   Acknowledgement

References

[1] Aizenman, J., Sun, Y. (2010), Globalization and the sustainability of large current account imbalances: Size matters. Journal of Macroeconomics 32, 35-44.

[2] Alfaro, L., Kalemli-Ozcan, S., Volosovych, V. (2008), Why doesn't capital flow from rich to poor countries? An empirical investigation. The Review of Economics and Statistics 90, 347-368.

[3] Arkolakis, C., Costinot, A., Rodriguez-Clare, A. (2012), New Trade Models, Same Old Gains? American Economic Review 102, 94-130.

[4] Arnold, L.G. (2007), A generalized multi-country endogenous growth model. International Economics and Economic Policy 4, 61-100.

[5] Bauer, N., Baumstark, L., Leimbach, M. (2012), The REMIND-R model: the role of renewables in the low-carbon transformation - first-best vs. second-best worlds. Climatic Change 114, 145-168, DOI: 10.1007/s10584-011-0129-2.

[6] Barro, R.J., Mankiw, N.G., Sala-i-Martin, X. (1995), Capital Mobility in Neo-classical Models of Growth. The American Economic Review 85, 103-115.

[7] Bernard, A.B., Eaton, J., Jensen, J.B., Kortum, S. (2003), Plants and Productivity in International Trade. American economic Review 98, 1268-1290.

[8] Bliss, C. (2004), Koopmans recursive preferences and income convergence. Journal of Economic Theory 117, 124-139.

[9] Caballero, R. J., Farhi, E., Gourinchas, P.-O. (2008), An equilibrium Model of "Global Imbalances" and Low Interest Rates. American Economic Review 98, 358-393.

[10] Campa, J.M., Gavilan, A. (2011), Current accounts in the euro area: An intertemporal approach. Journal of International Money and Finance 30, 205-228.

[11] Caroll, C., Overland, J., Weil, D.N. (2000), Saving and growth with habit formation. American Economic Review 90, 341-355.

[12] Cass, D. (1965), Optimum growth in an Aggregated Model of Capital Accumulation. Review of Economic Studies 32, 233-240.

[13] Chen, S. (2011), Current account deficits and sustainability: Evidence from OECD countries. Economic Modelling 28, 1455-1464.

[14] Chinn, M.D., Prasad, E.S. (2003), Medium-term determinants of current accounts in industrial and developing countries: an empirical exploration. Journal of International Economics 59, 47-76.

[15] Choi, H., Mark, N.C., Donggyu, S. (2008), Endogenous discounting, the world saving glut and the U.S. current account. Journal of International Economics 75, 30-53.

[16] Das, M. (2003), Optimal growth with decreasing marginal impatience. Journal of Economic Dynamics & Control 27, 1881-1898.

[17] Eaton, J., Kortum, S., Kramarz, F. (2011), An anatomy of international trade: evidence from French firms. Econometrica 79, 1453-1498.

[18] Gruber, J.W., Kamin, S.B. (2007), Explaining the global pattern of current account imbalances. Journal of International Money and Finance 26, 500-522.

[19] Highfill, J., McAsey, M. (2010), Will Technological Progress Cure the "Advanced Technology Products" Trade Account Deficit? Global Economy Journal, Vol. 10, Article 7.

[20] Hof, A.F., den Elzen, M.G.J., van Vuuren, D.P. (2010), Including adaptation costs and climate change damages in evaluating post-2012 burden sharing regimes. Mitigation and Adaptation Strategies for Global Change 15, 19-40.

[21] Leimbach, M., Toth, F. (2003), Economic development and emission control over the long term: The ICLIPS aggregated economic model. Climatic Change, 56, 139-165.

[22] Leimbach, M., Bauer, N., Baumstark, L., Lüken, M., Edenhofer, O. (2010a), Technological Change and International Trade - Insights from REMIND-R, The Energy Journal 31 (SI), 109-136.

[23] Leimbach, M., Bauer, N., Baumstark, L., Edenhofer, O. (2010b), Mitigation costs in a globalized world: climate policy analysis with REMIND-R, Environmental Modeling and Assessment 15, 155-173. DOI 10.1007/s10666-009-9204-8.

[24] Lengwiler, Y. (2005), Heterogenous Patience and the Term Structure of Real Interest Rates. The American Economic Review, 95, 890-896.

[25] Lucas, R.E. (1990), Why Doesn't Capital Flow from Rich to Poor Countries? The American Economic Review 80, 92-96.

[26] Luderer, G., Pietzcker, R.C., Kriegler, E., Haller, M., Bauer, N. (2012), Asia's role in mitigating climate change: A technology and sector specific analysis with ReMIND-R. Energy Economics 34, S378-S390.

[27] Marchiori, L. (2011), Demographic trends and international capital flows in an integrated world. Economic Modelling 28, 2100-2120.

[28] Manne, A.S., Mendelsohn, M., Richels, R. (1995), MERGE - A Model for Evaluating Regional and Global Effects of GHG Reduction Policies. Energy Policy 23, 17-34.

[29] Manne, A.S., Rutherford, T. (1994), International trade, capital flows and sectoral analysis: formulation and solution of intertemporal equilibrium models. In: Cooper, W. W. and Whinston, A. B. (eds.), New directions in computational economics, Kluwer Academic Publishers, Dordrecht, The Netherlands, 191-205.

[30] Mas-Colell, A., Whinston, M.D., Green J.R. (1995), Microeconomic Theory. Oxford University Press, New York.

[31] Melitz, M.J. (2003), The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. Econometrica 71, 1695-1725.

[32] Mendoza, E. G., Quadrini, V., Rios-Rull, J.-V. (2009), Financial Integration, Financial Development, and Global Imbalances. Journal of Polictical Economy 117, 371-416.

[33] Milesi-Ferretti, G.M., Razin, A. (1998), Sharp reductions in current account deficits: An empirical analysis. European Economic Review 42, 897-908.

[34] Negishi, T. (1972), General Equilibrium Theory and International Trade. North-Holland, Amsterdam.

[35] Nordhaus, W.D., Yang, Z. (1996), A Regional Dynamic General-Equilibrium Model of Alternative Climate-Change Strategies. American Economic Review 86, 741-765.

[36] Obiols-Homs, F. (2011), On borrowing limits and welfare. Review of Economic Dynamics 14, 279-294.

[37] Obstfeld, M., Rogoff, K. (2000), The Six Major Puzzles in International Macroeconomics: Is There a Common Cause? In: Bernanke, B. S., Rogoff,

K. S. (ed.), NBER Macroeconomics Annual 2000. Cambridge (USA), MIT Press.

[38] Ramsey, F.P. (1928), A Mathematical Theory of Saving. The Economic Journal, No.152 - Vol. XXXVIII, 543-559.

[39] Schneider, T.M., Traeger, C.P., Winkler, R. (2012), Trading off generations: Equity, discounting, and climate change. European Economic Review 56, 1621-1644.

[40] Shoham, A., Pelzman, J. (2011), A Review of the Crises. Global Energy Journal, Vol.11, Article 5.

[41] Ten Raa, T., Mohnen, P. (2001), The Location of Comparative Advantages on the Basis of Fundamentals Only. Economic Systems Research 13, 93-108.

[42] Uzawa, H. (1996), An endogenous rate of time preference, the Penrose effect, and dynamic optimality of environmental quality. Proceedings of the National Academy of Sciences 93, 5770-5776.

[43] World Development Indicators (2005), World Bank. Washington, DC.

7 Appendix

7.1 Derivation of Negishi Algorithm

In order to derive a relationship between the Negishi weights and regional per-capita consumption levels, we consider the global objective function

$$W = \sum_r \sum_{t=t_0}^{T} \left(w(r) \cdot e^{-\rho(r) \cdot (t-t_0)} L(t,r) \cdot \ln\left(\frac{C(t,r)}{L(t,r)}\right)\right). \qquad (21)$$

Free international capital trade gives rise to the arbitrage condition that at any given period t the marginal utility of consumption is equalized across regions r and s, and equals the present value price of the composite good $p(t)$:

$$p(t) = \frac{\partial W}{\partial C(t,r)} = \frac{\partial W}{\partial C(t,s)} \qquad \forall t. \qquad (22)$$

Evaluating the partial derivative yields the condition

$$p(t) = w(r) \cdot e^{-\rho(r) \cdot (t-t_0)} \cdot \frac{L(t,r)}{C(t,r)}, \qquad (23)$$

which can be rearranged to

$$C(t,r) = w(r) \cdot e^{-\rho(r) \cdot (t-t_0)} \cdot \frac{L(t,r)}{p(t)}. \qquad (24)$$

The fixed point of the Negishi iteration is characterized by the intertemporal trade balance vanishing to zero for all regions:

$$\hat{B}(r) = \sum_t \sum_j \left(\hat{p}_j(t) \cdot [\hat{X}_j(t,r) - \hat{M}_j(t,r)] \right) = 0 \quad \forall\, r. \qquad (25)$$

The optimization performed within each Negishi iteration yields a maximization of the globally and intertemporally aggregated consumption. Based on the Second Fundamental Theorem of Welfare Economics (cf. Mas-Colell at al. 1995, p.28), separability of efficiency and distribution holds. Correspondingly, an adjustment of Negishi weights results in a redistribution of consumption across regions, but does not change the way in which the composite good is produced:

$$\hat{C}(t,r) - C^i(t,r) \approx \left(X_k^i(t,r) - M_k^i(t,r) \right) - \left(\hat{X}_k(t,r) - \hat{M}_k(t,r) \right) \quad (26)$$

where the index k refers to the composite good.

Moreover, we can assume that the different prices of goods and trade in intermediate goods are independent of the Negishi weights:

$$p_j^i(t,r) \quad \approx \quad \hat{p}_j(t) \qquad \forall\, t, j; \quad (27)$$

$$X_j^i(t,r) \quad \approx \quad \hat{X}_j(t,r) \qquad \forall\, t, r, j \neq k; \quad (28)$$

$$M_j^i(t,r) \quad \approx \quad \hat{M}_j(t,r) \qquad \forall\, t, r, j \neq k, \quad (29)$$

Subtracting Eq. (25) from the Eq. (17) and combining it with Eq. (26) thus yields

$$
\begin{aligned}
B^i(r) \quad &\approx \quad \sum_t p^i(t) \left(\left(X_k^i(t,r) - M_k^i(t,r) \right) - \left(\hat{X}_k(t,r) - \hat{M}_k(t,r) \right) \right) \\
&\approx \quad \sum_t p^i(t) \left(\hat{C}(t,r) - C^i(t,r) \right) \qquad \forall\, r, \quad (30)
\end{aligned}
$$

where $p^i(t)$ refers to the price of the composite good.

This finding is in line with intuition, as it indicates that for each region the intertemporal trade balance is an approximation of the difference between the discounted stream of consumption in the fixed point and the the discounted stream of consumption achieved in iteration i. Based on Eq. (24) we can establish a condition for the revised Negishi weights $\hat{w}(r)$:

$$
\begin{aligned}
B^i(r) \quad &\approx \quad \sum_t p_k^i(t) \left(\hat{w}(r) \cdot e^{-\rho(r) \cdot (t-t_0)} \cdot \frac{L(t,r)}{p(t)} - w^i(r) \cdot e^{-\rho(r) \cdot (t-t_0)} \cdot \frac{L(t,r)}{p(t)} \right) \\
&\approx \quad \left(\hat{w}(r) - w^i(r) \right) \cdot \sum_t e^{-\rho(r) \cdot (t-t_0)} \cdot L(t,r) \qquad \forall\, r, \quad (31)
\end{aligned}
$$

where we make use of the property that $p^i(t) \approx \hat{p}(t) \approx p(t)$ (Eq. 27). Resolving for $\hat{w}(r)$, we get

$$\hat{w}(r) \approx w^i(r) + \frac{B^i(r)}{\sum_t e^{-\rho(r) \cdot (t-t_0)} \cdot L(t,r)}. \quad (32)$$

This approximation is used to establish the iteration procedure described in Eq. (18).

7.2 Current accounts
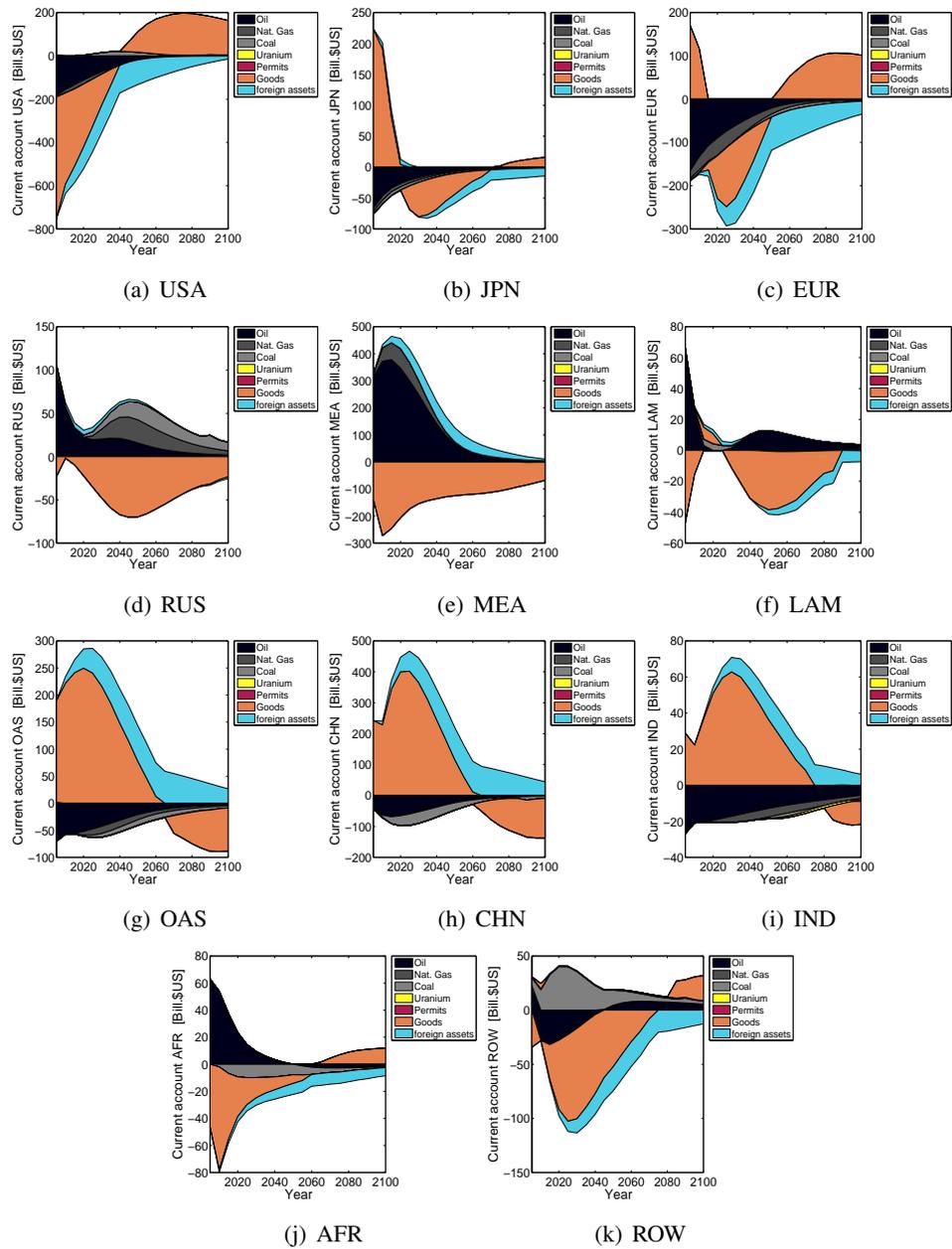
Figure 6: Regional current accounts; Baseline scenario of revised model version