Trade, persistent habits and development – a dynamic CGE model analysis

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Abstract

This paper presents a recursively dynamic CGE model of international trade with an alternative specification of imports demand and trade substitution elasticities, building on theoretical models of habit persistence and habit formation. We test and demonstrate with illustrative policy simulations how different imports demand specifications affect the short-run and long-run outcomes of trade policy shocks, focussing on imports and exports of food products in selected developing countries. Our results show that the inclusion of habit persistence can have significant effects on the expected trade policy outcomes, and hence the functional form of import demand in a global trade CGE model is not a trivial choice.

Introduction

Imperfect substitution between domestic and foreign goods is one of the key features used in analysing international trade policies. In computable partial (PGE) and general equilibrium (CGE) models, it used to be standard practice to assume a substitution structure between domestic and imported goods reflecting perfectly competitive "Armington (1969) theory of trade". As changes in import flows for products from different origins are conditioned by pre-existing trade shares, these models typically only capture intensive margins resulting from a trade policy change. More recent empirical trade literature underlines the importance of extensive margin in the expansion of trade, i.e. the number of exporting firms or contribution of new varieties in export markets, in line with Melitz (2003) trade model. This aspect along with monopolistic competition and economies of scale already present in Krugman (1980) has been incorporated in international trade CGE models such as GTAP-HET (Akgul et al. 2016) and GTAP-A2M (Dixon & Rimmer 2018).

This paper addresses the response time to price shocks as an additional dimension to import demand. Empirical evidence suggests that trade substitution elasticities depend on time: while the observed immediate responses to price changes are often rather small, a persistent price difference tends to continue affecting trade volumes for longer periods. This implies that the long-term substitution elasticities can be considerably higher that the short-term ones (McDaniel and Balistreri 2002). In comparative static CGE models, different short-run and long-run impacts can be accounted for by running multiple simulations with elasticity parameters adjusted for desired time horizon – even if this is does not seem to be done as a standard practice. Typical simulations employ elasticity parameters calibrated to reflect medium-run (5 to 10 years). These same parameters are frequently used also in dynamic models, and due to most commonly used log-differential model formulation, any price changes only have effect in the time period they occur. As a matter of fact, this applies not only to the prices in foreign trade, but to all domestic prices as well.

We suggest a recursively dynamic CGE model of international trade with an alternative specification of trade substitution elasticities, building on theoretical models of habit persistence and habit formation. This approach complements the approaches focussing on intensive and extensive margins, taking into account consumer habit formation and institutional changes, and can in some cases provide simplified model yielding similar results as monopolistic competition or firm heterogeneity. To test and demonstrate the impact of the habit persistence specification of trade substitution elasticities, a set of simulations is conducted using the standard version of the Dynamic GTAP (Global Trade Analysis Project) model and data base, and a modified version with habit persistence of trade. The analysis focusses on imports and exports of food products in selected developing countries.

For developing countries, there are two distinct implications of particular interest related to habit persistence in trade. The first and intuitively more apparent implication is that the actual magnitude of long-run trade substitution elasticities seem particularly relevant to developing countries whose welfare gains from trade may on one hand be substantial from access to new markets, and on the other hand depend heavily on their ability to utilise potential new imported foreign products. The second implication is related to the income distribution and welfare of the poor resulting from price changes of basic food items: Atkin (2013) shows in general equilibrium setting with intergenerational habit formation that trade liberalisation systematically induces price increases on locally produced crops. As household tastes have developed to favour these local crops, these price increases erode the short-run (caloric) welfare gains.

The next section elaborates on the background and reasons for applying habit persistence in imports demand. Section 3 presents the theoretical structure of demand in the GTAP model and the effect of habit persistence on substitution elasticity parameters. Section 4 introduces the data used and outlines the required changes to the model to incorporate persistent trading habits and to calculate welfare effects in dynamic model simulations. Section 5 presents illustrative scenarios and their results. Section 6 concludes.

2. Habit persistence and imports demand from different sources

Potential explanations on the imperfect substitution between goods from different origins have gained some attention already since Linder (1961), who suggested that elasticities of substitution be higher between goods from countries with similar income levels, as the consumer tastes, and hence goods produced, in those countries are likely to be similar. Nielsen & Yu (2002) find strong evidence in international rice market that the different varieties of rice typical for different countries are indeed far less than perfect substitutes for one another. Yang and Koo (1994) have estimated the structure of meat imports in Japan with habit formation.

There are (at least) four distinctive reasons behind the observed Armington elasticities that warrant different kinds of approaches to properly understand their significance and implications. First of all, the substitutability between goods from different origins can be imperfect for the simple reason that those goods are not, in fact, identical. This is the underlying idea in Armington's original work and empirically relevant especially when dealing with actual trade statistics based on tariff lines, which furthermore are typically aggregated into product groups that may be highly heterogeneous. The second reason arises from private consumption preferences and can be tracked down to individual behavioural factors. Thirdly, there are factors that mainly affect firm behaviour (though can also influence consumers) related to trading practices. Among these, non-tariff barriers (NTB) and measures (NTM) have gained a lot of attention in recent literature as they have become the main focus of multilateral trade negotiation since the tariff measures have largely been abolished. Finally, though overlapping with the other explanations, institutions both in formal and informal sense play a role in maintaining and incentivising behavioural choices.

A study by Welsch (1989) analyses the commodity structure of foreign trade in nine industrialised countries through an expenditure system that allocates total trade expenditures to various commodity groups with prevalent habit persistence assumptions. Welsch notes as potential causes for habit persistence such phenomena as continuity of trade relations among countries due to the international division of labour and long-lasting contracts, long-term trade decisions subsequent to delivery lags as well as transaction costs and past experiences. Habit persistence, or 'habit formation' in its most common representation, is a preference specification according to which the period utility function depends on a quasi-difference of consumption. Under habit persistence, an increase in current consumption lowers the marginal utility of consumption in the current period and increases it in the next period. Intuitively, the more the consumer eats today, the hungrier he wakes up tomorrow.

A common variant of the habit persistence, which is used as a reference for the CGE model presented in this paper, is to treat habits as external to the consumer, hence implying that the stock of habit depends on the history of aggregate past consumption as opposed to the consumer's own past consumption. In international trade context, it should be noted that while the original habit formation model is drawn from consumer preferences, the resulting functional form also allows alternative interpretations, such as rigidities imposed by institutional constraints, which may for some traded commodities be more relevant than consumer preferences.

While rooted in consumer theory, we can extend trading habits at industry level to incorporate a number of institutional factors such as continuity of trade relations among countries due to the international division of labour and long-lasting contracts, long-term trade decisions subsequent to delivery lags, and transaction costs and past experiences. This approach is also partly overlapping and consistent with Melitz theory of trade and can in some cases provide simplified model yielding similar results as monopolistic competition or firm heterogeneity. The low initial responses can actually reflect extensive and intensive margins, which in turn can be regarded as part of institutions driven trading habits.

3. Source structure of commodity demand

The basic functional form behind the import demand system used in most multi-country, multi-product CGE models, including GTAP, is represented in a triple nested form, where the top tier consists of the utility derived from quantities of K varieties of goods consumed.

$$U = (Q_1, Q_2, \dots, Q_K) \quad (1)$$

The exact form of the utility function (e.g. Cobb-Douglas, CES, different non-homothetic forms) can vary. The middle tier splits the consumption of each commodity Q within sector k according to source into home (H) and foreign (F). Regularly, this is written in CES form with some additional terms B that represent non-price factors such as tastes, quality and variety:

$$Q_k = \left(B_{kH}{Q_{kH}}^{\theta_k^D} + B_{kF}{Q_{kF}}^{\theta_k^D}\right)^{1/\theta_k^D}, \theta_k^D = \left(\sigma_k^D - 1\right)/\sigma_k^D \tag{2}$$

The bottom tier then aggregates the consumption of each imported commodity Q_{kF} from different sources i, again in CES form:

$$Q_{kF} = \left(\sum_i B_{ki}{Q_{ki}}^{\theta_k}\right)^{1/\theta_k}, \theta_k = (\sigma_k - 1)/\sigma_k \tag{3}$$

The source-specific preference weights B in the bottom and middle tier are critical for any simulation results and in calibrating observed trade flows. While the preference weights can for example reflect the number, quality or variety of goods in line with Krugman (1980) and Melitz (2003) theories of trade, they are most often still simply taken as deep parameters in the utility function.

This three-tier demand system, which has long been the standard formulation in multi-country trade CGE models, is primarily a practical and convenient solution driven by statistical reporting standards for international trade and national accounts data. Indeed, there is no commonly agreed theoretical framework – nor empirical evidence –supporting the idea that final users first decide between domestic and foreign goods, and then eventually between different foreign sources. Nevertheless, traditionally the input-output tables in national accounting only report the inputs as domestic or foreign, whereas customs data that form the basis for international trade statistics does not necessarily contain information on the sector where the imported goods are going.[2]

Bearing in mind these caveats, we retain this conventional model structure of demand for imports, and look at both tiers import substitution in this paper. Writing out the total expenditure E for each commodity (for notational convenience we suppress the commodity index k)from sources i we have

$$Q_i = (B_i)^\sigma \left(\frac{p_i}{P}\right)^{-\sigma} E \tag{4}$$

where P_k is the CES price index over imports of k from different sources. Dividing by total import expenditures, this can be written as import shares from each source

$$s_i = (B_i)^\sigma \left(\frac{p_i}{P}\right)^{-\sigma} \tag{5}$$

[2] This is still the case for large number of countries, though for example European Union's external trade statistics do record the broad importing sector (private, government, intermediate etc.)

Taking logs of (4) and (5) we get

$$\ln Q_i = \sigma \ln B_i - \sigma(\ln p_i - \ln \bar{P}) + \ln E_k \quad (6)$$

$$\ln s_i = \sigma \ln B_i - \sigma(\ln p_i - \ln \bar{P}) \quad (7)$$

Recent studies with emphasis on firm heterogeneity and monopolistic competition issues re-specify preference weights B to represent e.g. number of firms in each country. In econometric studies it is common to take preference weights B as exogenous constants, which yields equations that are similar to demand shares in linear expenditure system (LES). In line with Blanciforti and Green (1983), in a framework of Almost Ideal Demand System (AIDS), the import share of the source i can be presented as

$$\ln s_i = \alpha_i + \sum_j \gamma_j (\ln p_i - \ln \bar{P}) \quad (8)$$

where α is a mandatory "base consumption" level below which the consumer gets no utility. Thus, total expenditures on imports of each commodity are assumed to be allocated to different source countries so as to maximise an objective function that is affine homothetic in the quantities of these imported goods. The actual demand of commodity from source country i, denoted q_i, depends on a base quantity $\bar{q}_i$, which is independent of price and total expenditure. For the quantities in excess over $\bar{q}_i$, the objective function is homothetic. The consumption decisions over these 'excess quantities' are made within a budget constraint that equals the total expenditure minus the value of the base quantities of all commodities, i.e. $Y - \sum \bar{q}_i$. This setting avoids the implausible unitary expenditure elasticity implied by homothetic utility functions.

As our primary interest in this paper is the difference between the short-term and long-term elasticities, we give the preference weights a different interpretation that ties them to the temporal elasticity variation.

Introducing habit persistence

Pollak and Wales (1969) present an early formulation of the habit formation model cast in the external form in context of a dynamic demand system, the habit formation art of which is discussed in detail in Pollak (1970). In this dynamic Linear Expenditure System, the base quantities $\bar{q}_i$ are not assumed constant, but to follow a habit formation process. More precisely, the base quantities in each period are modelled as linear functions of the actual quantities in the previous period. Inserting further structure, let us specify $\bar{q}_{it}$ as a proportion of the lagged observed quantity:

$$\bar{q}_{it} = \lambda_i q_{i,t-1}\,, \quad (9)$$

where $\lambda_i \geq 0$ is a habit formation coefficient. Re-specifying the constant parameter α_i in (8) to reflect persistence in consumption patterns as including the linear relationship to previous consumption levels given in equation (8):

$$\alpha_i = \alpha_i^* + \lambda_i q_{i,t-1}. \quad (10)$$

The resulting imports expenditure system to can then be presented as (for notational convenience, the asterisks from the 'new' alphas are subsequently omitted):

$$s_i = \alpha_i + \lambda_i b_j + \sum_j \gamma_j (\ln p_i - \ln \bar{P}) \quad (11)$$

where $b_{it} = \frac{p_{it} q_{i,t-1}}{m_t}$, which is equal to the share of the expenditure of good from source i that it would have on present period with the present period price but no change in quantity from previous period. This implies that for the length of T periods, price elasticity of imports σ_{iT} can be expressed as

$$\sigma_{ijT} = \gamma_{ij} \frac{1-\lambda_i^T}{1-\lambda_i}, \text{ if } \lambda_i \neq 1. \quad (12)$$

The short-term (one period) elasticity is thus γ_{ij} and long-term elasticity $\sigma=\gamma/(1-\lambda)$ if $|\lambda|<1$.

4. The model and data

The Global Trade Analysis Project (GTAP) model and database have been applied in numerous studies on regional and bilateral trade agreements. A recursive dynamic CGE model based on the GTAP model and database are used in this paper. The model builds on the GTAP-Dyn model (Ianchovichina and McDougall 2001) and is further to incorporate habit persistence of international trade. The GTAP Database 9 (Aguiar et al. 2016) includes disaggregated data on 140 countries and regions, hence allowing the analysis of several countries of interest.

The database comprises several types of data: behavioural parameters that include elasticities of substitution between domestic and imported goods, and elasticities of substitution between sources of imports via Armington (1969) elasticities. The database represents the world economy as flows of goods and services measured in millions of 2007 US dollars. Additional data are provided for capital stocks, population and savings. The database includes five endowments (i.e. production factors) – land, skilled labour, unskilled labour, natural resources, and capital – with 129 countries/regions and 57 commodities/sectors. In this study, the database is aggregated into 20 countries/regions and 29 commodities/sectors, including 16 agricultural commodities/food sectors. Trade policy instruments are represented in the GTAP database as ad valorem taxes and subsidies. Thus, the GTAP database and model are widely used, particularly in research concerning international trade.

In the more recent versions of GTAP database, from version 7 released in 2008 (Badri Narayanan et al 2008) onwards, the trade elasticity parameters have been updated to account for the generally higher long-term elasticities than used in earlier database versions, and greater degree of variation between differences product groups. between the foreign-foreign Armington elasticities for grains range between -2.6 and -10.1. The low substitution elasticity for other grains also reflects the heterogeneity of this product category, which makes the grains from different sources imperfect substitutes by nature.

Table 1: Price elasticity of substitution between import sources in GTAP database versions

	GTAP v. up to 6		GTAP v. from 7	
	domestic-imported (σ)	foreign-foreign (2σ)	domestic-imported (σ)	foreign-foreign (2σ)
Rice	-2.2	-4.4	-5.05 -2.6	-10.1 (paddy) -5.2 (processed)
Wheat	-2.2	-4.4	-4.45	-8.9
Other grains	-2.2	-4.4	-1.3	-2.6

We have estimated foreign-foreign substitution elasticities with habit persistence specification for selected food products (ref), and short-term elasticity estimates ranging typically from −0.5 to −3.0 with a lot of variation between importing countries. Coefficients for habit persistence are in most cases between 0.3 and 0.6, which implies that the long-term elasticities are on average comparable to the parameters in the GTAP database, though slightly lower.

Regions and commodities for scenario simulations

The commodity grouping and regional focus is motivated by welfare and poverty reduction implications of trade reforms, as especially on short-run they may depend heavily on the degree to which traditional consumption patterns can accommodate the potential gains from international trade.

Table 2 shows the regional aggregation used in this study, with the Sub-Saharan African focus countries highlighted. Important South and South-East Asian rice producing countries are also kept as individual regions, and a raising wheat producing area Black Sea region (Kazakhstan, Russia, Ukraine) is also included separately. The rest of the world countries are included as aggregated regions with geographical and income level considerations.

Table 2: Country or region aggregation scheme implemented in the GTAP model

1	China	8	High income Asia and Oceania	15	Ghana
2	Indonesia	9	North America	16	Nigeria
3	Thailand	10	Latin America (excl NAFTA)	17	Ethiopia
4	Viet Nam	11	European Union 28	18	Kenya
5	Bangladesh	12	Black Sea Producers	19	Mozambique
6	India	13	Rest of Europe and Centaral Asia	20	Tanzania
7	Rest of Asia (excl high inc)	14	North Africa	21	South Africa
				22	Rest of Sub-Saharan Africa
				23	Rest of the World

Source: GTAP Database 9: https://www.gtap.agecon.purdue.edu/databases/regions.asp?Version=9

Commodity aggregation (Table 3) reflects the paper's focus on cereal grains trade. Three cereal commodity groups are all important globally traded commodities and also potential export products for many developing countries. However, the characteristics of each commodity groups are distinct.

Rice: The world trade on rice is dominated by only five exporter countries – Thailand, Viet Nam, India, the USA, and Pakistan – accounting for over 70 percent of the total international rice trade. However, at regional level, some other countries also become important players, occupying very high shares in imports of one or few individual trading partners. Namely in South America, imports from Brazil, Argentina or Uruguay constitute over half of the total rice imports for some neighbouring countries. The share of other South American countries of total rice imports is between 75 and 98 percent in Paraguay, Bolivia, Argentina, Brazil and Chile, and over 50 percent also in Uruguay and Peru. Conversely, rice imports from South America to countries outside the region are below five percent of the total, with the exception of Portugal, Turkey, Switzerland, Senegal, Spain and the Netherlands, where between 9 and 26 percent of rice imports originate from South America. To a lesser extent, a regional rice trade pattern can be observed in Europe and some countries in the Eastern Mediterranean, where especially Italy (and in a few cases also Spain and Greece) is an important source of rice imports in many countries. However unlike in South America, all European countries source significant amounts of rice also from outside the region.

Wheat: The international wheat market is concentrated to a few players in similar way as rice market. However, for wheat the exports and total production are closely associated, and bilateral trading patterns are not as pronounced as at the rice market. Traditionally, major wheat exporters have been Australia, Canada, the European Union (most notably France and Germany), and the United States. A recent trend that is not yet fully present in the data base used in this study shows the emergence of Black Sea region – Kazakhstan, Russia, and Ukraine – as a strong player in the global wheat market. While also quality differences play lesser role than at rice market, the recent success of the wheat from the Black Sea region can be partly attributed to lower price.

Other grains: This commodity group aggregates several grains that have very different characteristics. In international trade the vast majority share in this group consists of maize, markedly dominated by the United States, which account for nearly a third of world total exports, reflecting its even greater share of global maize production. Brazil, Argentina and Ukraine each have a share between 10 and 15 per cent of world exports, followed by Russia, European Union and Paraguay with 2 to 3 percent shares. While maize comes in several different varieties, the differences in the bulk of traded commodity are insignificant for quality considerations. Globally in this commodity group, maize is followed by rye, but in Sub-Saharan Africa sorghum holds the second most important place and in terms of regional production is in some countries is even more important than maize.

Table 3: Commodity or sector aggregation scheme implemented in the GTAP model

	Aggregated sectors	Included sectors and commodities
1	Rice	Paddy rice, Processed rice
2	Wheat	Wheat
3	Other grains	Cereal grains nec
4	Other food	Other primary agriculture, and processed food
5	Manufacture	All manufactured products, excl. food
6	Services	All services

Source: GTAP Database 8: https://www.gtap.agecon.purdue.edu/databases/v8/v8_sectors.asp

Implementing habit persistence in the CGE model

The trade substitution elasticities used in the standard version of GTAP model have been refined in two ways: (i) The top-level substitution: the elasticities are defined separately according to the final user – private consumption, government consumption or intermediate use; (ii) All trade elasticities, including the top-level substitution and substitution between different regional sources, have been calculated separately for each importing country, using the GTAP database standard elasticities for disaggregated commodities weighted by each commodity's share in the aggregate import commodity.

International trade module of the model has been modified to enable habit persistence formulation of trade flows and corresponding short term elasticities computed (See appendix for the code). For the illustrative simulations, we keep the GTAP 9 database foreign-foreign substitution parameters (ESUBM) but re-specify them as the *long-run* elasticities. Short-run elasticities are implicitly defined in the demand system that accounts for the habit persistence parameter λ. The term $1-\lambda$ can be interpreted as a rate of adjustment from base demand towards the long-run target demand. Corresponding transformation is also made to domestic-imported substitution parameters. Habit persistence parameters λ_D for domestic-imported and λ_M for foreign-foreign are set to either 0, which implies the standard model with no adjustment time, or 0.5 depending on scenario options as described in the next section.

The long-run equilibrium log percentage change in (target) demand q^{LR} from each source is equal to standard model demand

$$q_i^{LR} = \bar{q} - \sigma(\ln p_i - \ln \bar{P}) \tag{13}$$

where $\bar{q}$ is the average percentage change in commodity demand from all sources. The short run (one-year period) demand level Q^{SR} is defined by habit persistence λ (adjustment speed $1-\lambda$), base quantity, and long-run target demand

$$Q_t^{SR} = \lambda Q_{t-1} + (1-\lambda) Q_t^{LR} \tag{14}$$

The base quantities that depend on the parameter λ are derived from the GTAP base data header VIMS – bilateral imports at market prices. Initial values for this coefficient are the same as the original VIMS, but are only updated with the price change. This corresponds to the base quantity term $p_{it}q_{i,t-1}$ in the habit persistence demand system. The model code for implementing these features in the Dynamic GTAP model is presented in the appendix I.

Measuring welfare

The standard, comparative-static GTAP model incorporates the calculation of regional equivalent variation (EV) for the single representative consumer based on the model's private consumption utility function and expenditures on government consumption and savings. It also provides a detailed decomposition of the EV allowing to track for example the contributions of productivity changes, taxes and tariffs, allocative efficiency effects and terms of trade effects. The calculation method is not, however, usable as such in recursive dynamic simulations for both theoretical and technical reasons.

Ianchovichina and Walmsley (2012) address some of these problems and propose a solution for welfare measurement in the Dynamic GTAP model. They recognise the problems related to the assessment of the aggregate differently timed benefits and losses over time in absence of a theoretically sound discount factor. The technical issues arise from the model's way of recording the simulated data only as values, which are subsequently used as base for the following period simulation. Essentially, the information of the commodity volumes consumed and price changes are lost, and EV calculations for different simulations become incomparable as the results are not normalise with regard to prices. As a solution, the authors suggest running a comparative static simulation for a single period reconstructed from the differences between base and policy simulation shocks.

While this method does provide accurate results for a single year, it is cumbersome to apply and does not address the benefits and losses timing and discounting issues. Furthermore, they do not discuss the inclusion of savings in the household utility. In a comparative static setting, the savings can be considered to reflect the utility from anticipated future consumption, but in a dynamic simulation this is not necessarily feasible, as there is a risk of double counting both the utility from savings and from the subsequent effect on consumption.

To arrive at a more satisfactory and comparable measurement of welfare, changes are made to the model, and a separate GEMPACK simulation program for calculating the EV-decomposition is constructed. Data file with quantities (volumes) is included in the model, which means that all data are also recorded at initial base year prices. The raw regional EV measure is modified to use these volume data, which already produces more comparable results between simulations. The separate simulation programme uses the simulated data files to compute EV decomposition between two simulations for each individual period. Finally, while an option to apply a user-specified discount rate is included, the programme calculates for each region an internal discount rate that would result in equal aggregate over time welfare for both simulations. The details of the welfare decomposition are presented in annex II.

5. Illustrative scenarios and results

We study how different imports demand specifications affect the short-run and long-run outcomes of trade liberalisation under three illustrative policy scenarios. All these scenarios are implemented as trade facilitation shock with 50 percent reduction in "hidden" trading costs of cereal grains (rice, wheat, other grains), which can imply for example a decrease in non-tariff trade barriers. In the first scenario, "Unilateral", only exports originating from Sub-Saharan Africa low income countries to the European Union benefit from trade cost reduction. The second scenario "Multilateral" is a global, multilateral liberalisation round where the trade facilitation shock is applied uniformly across all countries of the world. The third scenario "Temporary" is otherwise the same as the "Multilateral" scenario, but the trade facilitation policy only lasts for three years after which the hidden trading costs are brought back to the original levels.

To keep the analysis as simple as possible, we do not apply any baseline shocks (such as growth of population, productivity, labour force) in the scenarios nor do we allow for accumulation of. All these scenarios are simulated for ten years with one year intervals. For simulations without habit persistence or other dynamics, this is equivalent to comparative static model results: all changes happen within a single period where the policy shocks are implemented. Simulations with habit persistence can be regarded as showing the convergence paths towards the long term equilibrium state, which is comparable though not necessarily equal to the results obtained from a comparative static simulation.

In usual dynamic CGE applications a baseline scenario is first constructed and simulated and one or more policy scenarios are evaluated against this baseline. While we employ this functionality in the RunDynam GEMPACK program, the baseline and policy distinction is not applicable. In these illustrative scenario simulations we are not interested in the impact of a particular policy as such – indeed the policy experiments are constructed so that the results and interpretations would be as straightforward as possible – but the difference in the results with different model specifications. Thus, our "base scenario" is the simulation with the standard dynamic GTAP model, while the "policy scenarios" are simulations with exactly the same policy shocks as the base scenario but with different model specifications.

Technically, we implement the different model specifications by adding an extra before the actual scenario time. In the base scenario, there are no shocks in this year, which means that the next period data is exactly the same as the first period data. In the "policy" scenarios shocks are given to the parameters that control foreign trade habit persistence so that the parameter values are as desired already in the beginning of the period we are actually observing. These shocks to the parameter values do not affect any other variables or data headers, so the "base" and "policy" data in the beginning are the same.

Table 4: Policy scenario features

	Unilateral	Multilateral	Temporary
Treated commodities	Rice, Wheat, Other grains		
Treated importing regions	EU28	All	All
Treated exporting regions	Low-income Sub-Saharan Africa	All	All
Policy duration	Indefinite		3 years

All policy scenarios are simulated with four different sets of assumptions on import demand elasticities and habit persistence (see Table 5). The "Base" set of options constitutes the reference for each policy scenario, and is identical to standard GTAP model in both import demand nests (domestic-imported, between import sources) without habit persistence (i.e. long-run and short-run elasticities are equal) and price elasticity of substitution (2s, database parameter ESUBM) between import sources two times that between domestic and imported (s, database parameter

ESUBD). Scenario options "M" and "D" have habit persistence coefficient of 0.5 imposed on between import sources nest and domestic-imported nest respectively. Scenario option "M+D" has habit persistence in both nests.

Table 5: Scenario options on import demand elasticity and habit persistence

	Scenario options			
	Base	**M**	**D**	**M+D**
Substitution between different sources of imports				
Habit persistence λ_M	0	.5	0	.5
Long-run elasticity σ_M	2s	2s	2s	2s
Short-run elasticity γ_M (implied)	2s	s	2s	s
Substitution between domestic and imported goods				
Habit persistence λ_D	0	0	.5	.5
Long-run elasticity σ_D	s	s	s	s
Short-run elasticity γ_D (implied)	s	s	.5 s	.5 s

s = GTAP 9 database substitution elasticity between domestic and imported (ESUBD); elasticity between sources of imports ESUBM = 2 × ESUBD for all commodities.

Baseline results for the main policy scenarios

Following from the scenario options, the implications of the policy shock take place immediately on the period they are implemented, and thus the short-run and long-run results are identical. In Figure 6 - Figure 9 (Multilateral) and Figure 2 - Figure 5 (Unilateral) the global results of the policy scenarios with base options show as dotted horizontal line. "Multilateral" liberalisation increases world trade volume, GDP and investments, but has a slightly negative impact on consumer expenditure. "Unilateral" liberalisation only increases trade while the effect on GDP, investments and consumer expenditure is negative. As shown in Figure 10 – Figure 13 temporary shocks that are reversed after three years have no effect on the long-run results and economies return back to their pre-policy states

(Multilateral) and Figure 15 (Unilateral) show the changes in selected six Sub-Saharan Africa countries. These results show that the benefits and losses form policy change are unevenly distributed between countries, and the relative winners and losers are also different between the policies. In the "Multilateral" policy scenario all countries have e positive effect on the GDP and investments, trade increases in all countries except Kenya, while the impact on consumption is negative for Ghana, Nigeria and Ethiopia but positive for Kenya, Mozambique and Tanzania. As the

"Unilateral" scenario is designed to benefit Sub-Saharan economies exclusively, effects on all these countries are all positive with the exception of total exports from Kenya and investments in Tanzania. However, benefits for Ethiopia and Tanzania are clearly higher than for the other countries.

In welfare terms, the utility based on GTAP model's consumption function increases in the Multilateral scenario between 0.0 and 1.4 per cent depending on the country, translating into annual per capita equivalent variations from USD 0 to USD 52. Such big differences between countries for a uniform policy change are mostly explained by the differences of the importance of the agricultural crops. Welfare gains from the Unilateral liberalisation are very small, though as expected, the Sub-Saharan African countries that face improved trading conditions, as well as the EU that benefits from the subsequently lower prices, show modestly positive welfare changes.

Effects of introducing habit persistence

Generally, the specification of imports demand elasticities and habit persistence make significant differences to the outcomes of policy change in the short-run, and some of these changes persists on the long run, too. Moreover, the effects of the specification options differ between "Multilateral" and "Unilateral" policy scenarios.

Introduction of habit persistence in the between imported sources nest (Scenario options "M") in the Multilateral scenario has an impact that follows straightforward from the mathematical formulation: Compared to the baseline, the short-run response on exports is smaller but the difference fades out on the long run. Other global variables follow similar convergence pattern towards baseline response either from a greater (GDP, investment) or smaller (consumption) initial short run effect. (Figure 6 - Figure 9)

In the Unilateral scenario, however, while the short-run response goes to same direction as in the Multilateral case, the effect on exports volumes exceeds the baseline on the long run. GDP and consumption are at higher level compared to the baseline during the whole simulation period, and investments conversely at lower level. (Figure 2 - Figure 5)

When habit persistence is introduced to the domestic-imported nest (Scenario options "D"), we observed a nearly mirror image of the options "M" results discussed above. The export volume follows the mathematical convergence pattern in the Unilateral policy scenario (Figure 2), and GDP, investment and consumption again reflect that (Figure 3 - Figure 5). In the Multilateral policy scenario, short-run differences to the baseline are significant. The immediate impact on trade volume is negligible but exceeds the baseline in the long run. GDP and investments impact are clearly smaller than in the baseline, and remain at the same level in the long-run. The private consumption effect is slightly below the baseline initially, but increases in the long run.

The explanation for the different results between scenario options can be characterised as "Ricardian" since they follow from classical comparative advantage. When the equal trade enhancing shock in the multilateral scenario with foreign-foreign habit persistence is implemented to all traders, the only effect is on the global prices compared to domestic ones. With habit persistence, the adaptation takes longer, but since there are no changes to relative prices between different exporters the trading patterns do not change and the long-run increase in global trade is equal to the comparative static results. In the Unilateral scenario with domestic-imported persistence the policy change driving the results takes place in the foreign-foreign nest, where the elasticity parameters are equivalent to the standard model (i.e. no persistence) and since the impact on global commodity prices is only negligible there is little observable long-run change between domestic and imported goods. A globally more important bilateral policy could have different results as it would affect the domestic-imported substitution more significantly.

Conversely, in the multilateral scenario the relative domestic-imported prices change significantly and trigger trade creation effects that continue to increase the demand for imports in the long run with domestic-imported persistence. In the Unilateral scenario with foreign-foreign substitution, similar trade creation effects are observed for the countries that benefit from the trade policy liberalisation. Thus, the specification of trade persistence matters in the long run if it is associated to changes in trade patterns.

The combined effects of habit persistence in the two import demand nests (Scenario options M+D) are not separable when looking at the convergence paths, suggesting that the specification of demand elasticities and habit persistence in one of the nests affects the other in the short run. In the long run, the "D" option seems to dominate the impact on trade volume in both Multilateral and Unilateral policy scenarios while the "M" option has more weight on the long run. Other global variables follow the "D" option in the whole simulation period in the Multilateral scenario, and the "M" option in the Unilateral scenario.

If the policy measure is introduced only to a limited time period, here in the "Temporary" (multilateral) scenario for three years, long-run results differ from the comparative-static ones in those model options that affect the implications from changing trade patterns as discussed above. Global trade and private consumption expenditure remain in higher level compared to the standard model results, even when the policy is removed. However, the impact on investment compared to the standard model actually turns negative in the long run, which also leads to slightly negative effect on the GDP.

Regional differences

Figure 16 - Figure 23 present the impacts of different scenario options on exports and consumption in the three Sub-Saharan African countries – Ethiopia, Kenya and Tanzania (and Mozambique in the Multilateral scenario) – which overall are most affected by the policy changes in the scenarios explored in this paper. The differences to the baseline are shown both as an average of the 10 year simulation period and as cumulative change at the final simulation year to account for the differences in the adjustment paths. The average tells the difference compared to the baseline during the simulation period whereas the final year figure represent the permanent (equilibrium) difference due to the policy change.

In the Multilateral policy scenario, results on long-run exports decrease compared to the baseline with introduction of habit persistence, especially on the domestic-imported nest. Altering the domestic-imported substitution elasticities, on the other hand, have an increasing effect on exports. Consumption increases with domestic-imported habit persistence in all countries while between imported sources habit persistence has only a negligible effect.

In the Unilateral policy scenario, impacts vary between countries, but generally consumption decreases on the long term when habit persistence is increased.

Effects on welfare over time

The choice of model options has significant effects on welfare effects expressed in terms of equivalent variation. Focussing on the Multilateral scenarios with both permanent and temporary policy changes and model options D and M+D which affect the long-run results we see that bot timing of the welfare gains (or losses) and the distribution of gains and losses between countries changes with model options. Table 6 shows the difference of annual average (non-discounted) per capita EV to the standard model ("baseline") results for the aggregated scenario regions. While the world averages are 3 to 4 percent, or USD 0.33 to 0.45, higher, regional results vary from 77 percent better (USD 1.42, Ethiopia, Temporary D and M+D) to 47 percent worse (USD 0.20, India, Multilateral M+D).

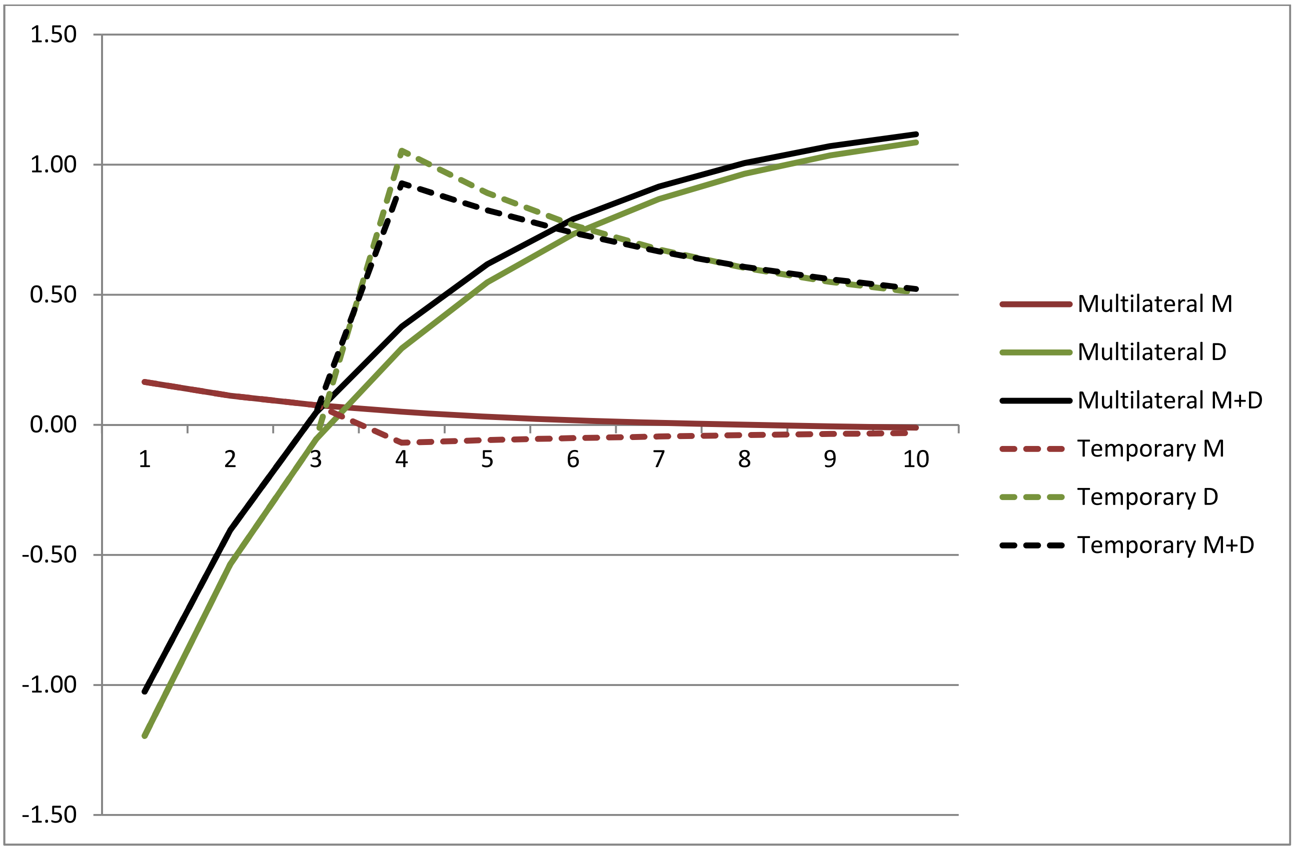
Table 6: Annual per capita EV, diffrence to standard model results, USD

	Unilateral			Multilateral			Temporary		
	M	D	M+D	M	D	M+D	M	D	M+D
China	0.00	0.00	0.00	0.09	-0.53	-0.41	0.00	-0.67	-0.58
Indonesia	0.00	0.00	0.00	0.15	2.35	2.69	0.06	3.02	3.31
Thailand	0.02	0.00	0.02	-1.75	-1.76	-3.84	-0.03	4.71	3.79
Viet Nam	0.00	0.00	0.00	-1.20	-1.28	-2.58	-0.07	1.64	1.16
Bangladesh	0.00	0.00	0.00	0.05	1.86	2.05	0.03	2.47	2.66
India	0.00	0.00	0.00	-0.02	-0.18	-0.20	0.00	-0.05	-0.06
Rest of Asia (excl high inc)	0.00	0.00	0.00	-0.31	0.50	0.27	0.02	0.83	0.86
High income Asia and Oceania	0.00	0.00	0.00	2.56	-5.61	-2.94	0.23	-4.91	-4.68
North America	0.00	0.00	0.00	0.26	-2.10	-1.88	-0.02	-2.35	-2.28
Latin America (excl NAFTA)	0.00	0.00	0.00	-0.14	-0.15	-0.26	-0.01	-0.41	-0.47
European Union 28	-0.01	0.00	0.00	-0.07	2.56	2.45	-0.03	1.34	1.25
Black Sea Producers	0.00	0.00	0.00	-0.06	-0.38	-0.47	-0.01	-0.22	-0.30
Rest of Europe and Central Asia	0.00	0.00	0.00	-0.21	1.41	1.23	-0.02	0.57	0.52
North Africa	-0.01	0.00	-0.01	0.02	8.15	8.47	0.01	5.85	5.96
Ghana	-0.04	0.00	-0.04	0.15	3.18	3.42	0.00	3.37	3.42
Nigeria	0.00	0.00	0.00	0.05	2.21	2.45	0.03	3.82	4.06
Ethiopia	-0.03	0.00	-0.03	-0.01	1.34	1.37	0.00	1.42	1.42
Kenya	-0.04	-0.01	-0.04	0.22	0.07	0.26	-0.03	0.26	0.04
Mozambique	0.00	0.00	0.00	0.01	0.93	0.97	-0.01	1.04	1.06
Tanzania	-0.11	-0.02	-0.13	-0.09	0.78	0.72	-0.03	1.12	1.10
South Africa	-0.01	0.00	-0.01	0.17	-0.80	-0.63	-0.03	-1.70	-1.66
Rest of Sub-Saharan Africa	-0.01	0.00	-0.01	0.06	1.35	1.46	-0.03	1.10	1.12
Rest of the World	-0.01	0.00	-0.01	-0.20	2.96	2.84	-0.03	1.82	1.76
World	0.00	0.00	0.00	0.04	0.37	0.45	0.00	0.33	0.35

In line with the other results discussed earlier, the welfare is typically lower than in the standard model results in the first years of the simulations, but higher in the later periods, as illustrated in Figure 1. The total EV difference over time in both scenarios with model options D and M+D becomes clearly positive unless a very high internal discount rate is applied.

In the Unilateral scenario, EV differences are very modest even for the directly affected regions. These regions typically show slightly smaller welfare gains compared to the standard model results.

Figure 1: World annual per capita EV, difference to standard model results, USD



6. Discussion

To test and demonstrate the impact of the habit persistence specification of trade substitution elasticities, a set of stylised trade policy scenarios is constructed and simulated using the standard version of the Dynamic GTAP (Global Trade Analysis Project) model and data base, and a modified version with habit persistence of trade. The analysis focusses on imports of food products in six countries in Sub-Saharan Africa. The commodity group and regional focus is motivated by welfare and poverty reduction implications of trade reforms, as especially on short-run they may depend heavily on the degree to which traditional consumption patterns can accommodate the potential gains from international trade. The results show that the inclusion of habit persistence can have significant effects on the expected trade policy outcomes. While this study does not evaluate which demand specification best reflects the reality, other studies have found evidence of at least some degree of habit persistence in imports.

Thus, the functional form of import demand in a global trade CGE model is not a trivial choice. The imports demand modelling solutions presented in this paper offer a relatively simple way to account for long and short run elasticities that can differ significantly for varying reasons, such as consumer habits, institutional constraints (intensive and extensive margin of trade), and non-tariff barriers.

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Table of Figures

Figure 2: Unilateral; world trade volume index, cumulative %-difference

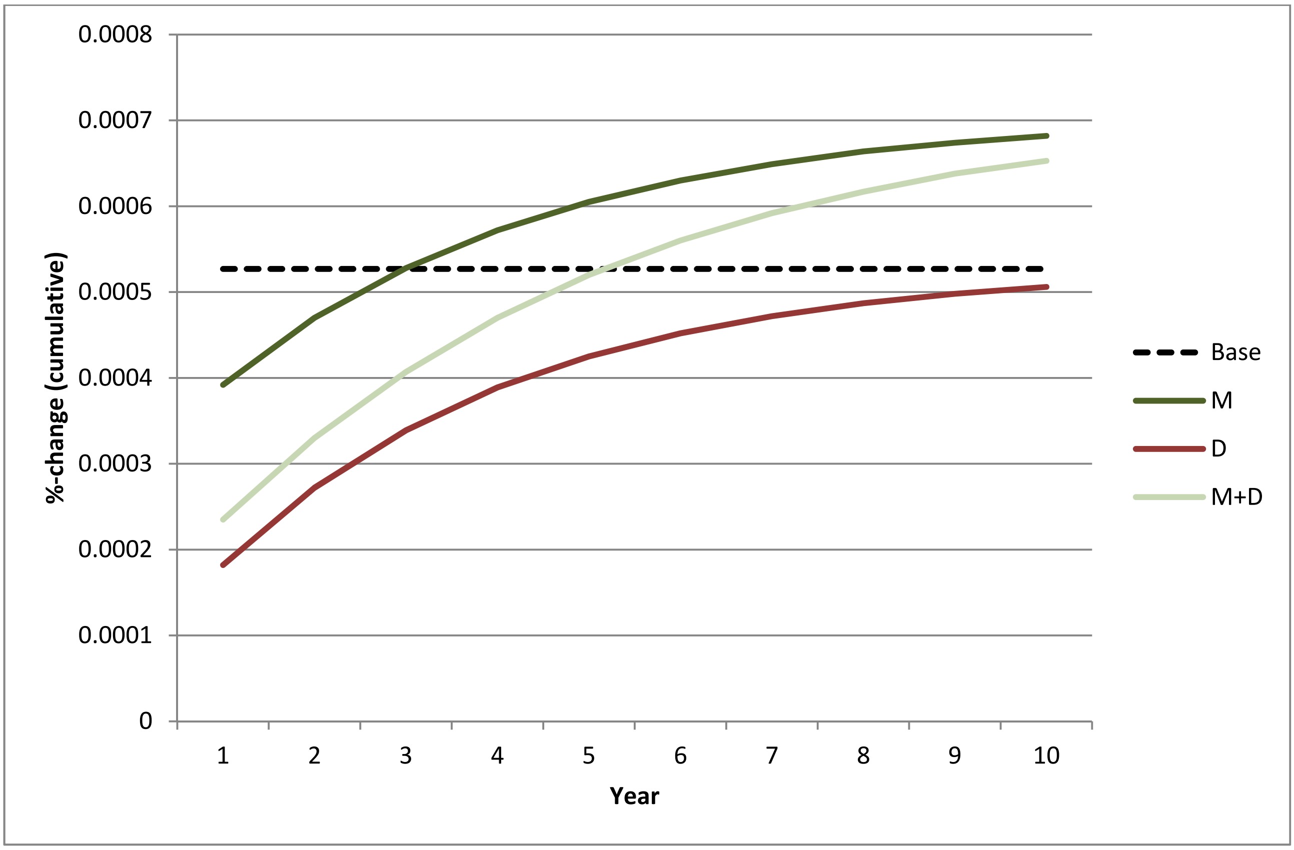


Figure 3: Unilateral; world combined gdp volume index, cumulative %-difference

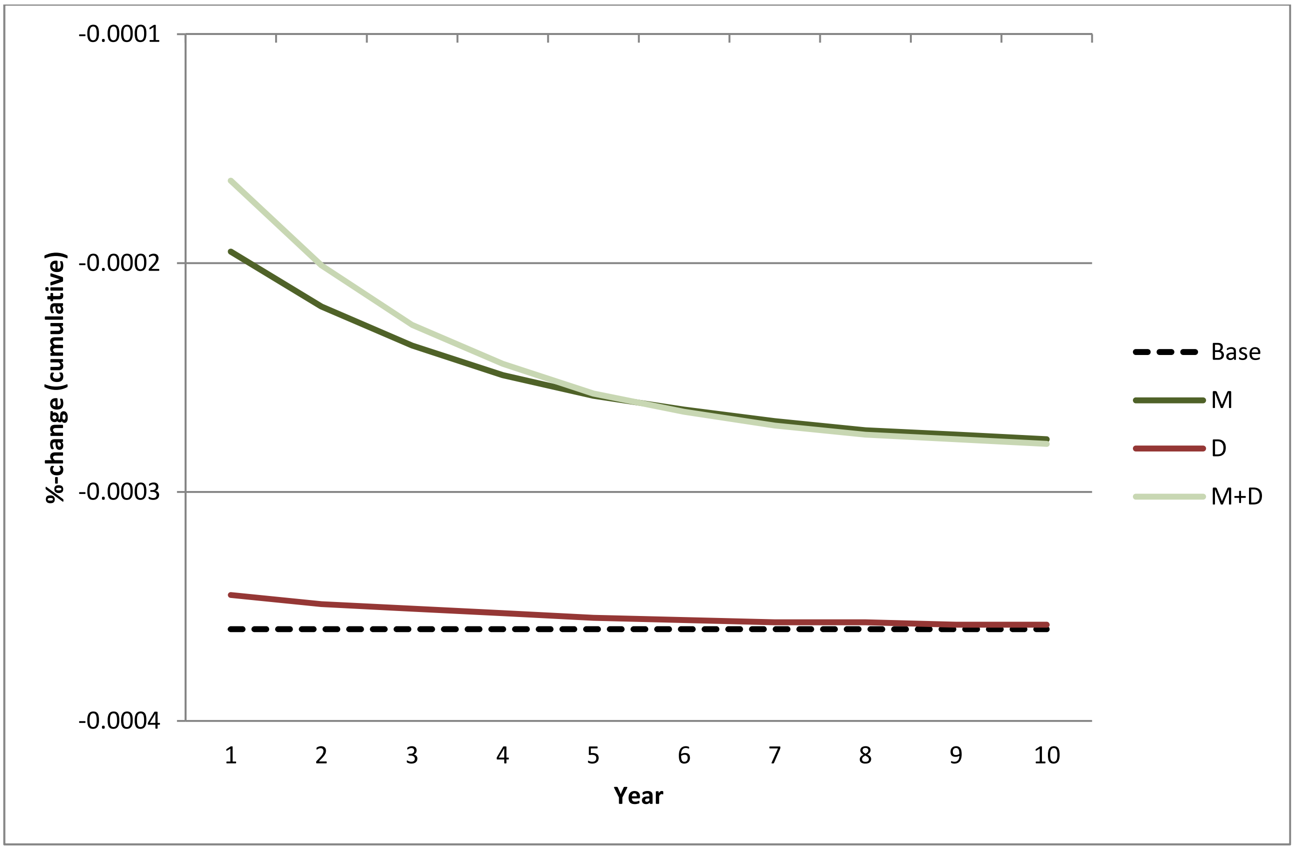


Figure 4: Unilateral; world combined private consumption expenditure, cumulative %-difference

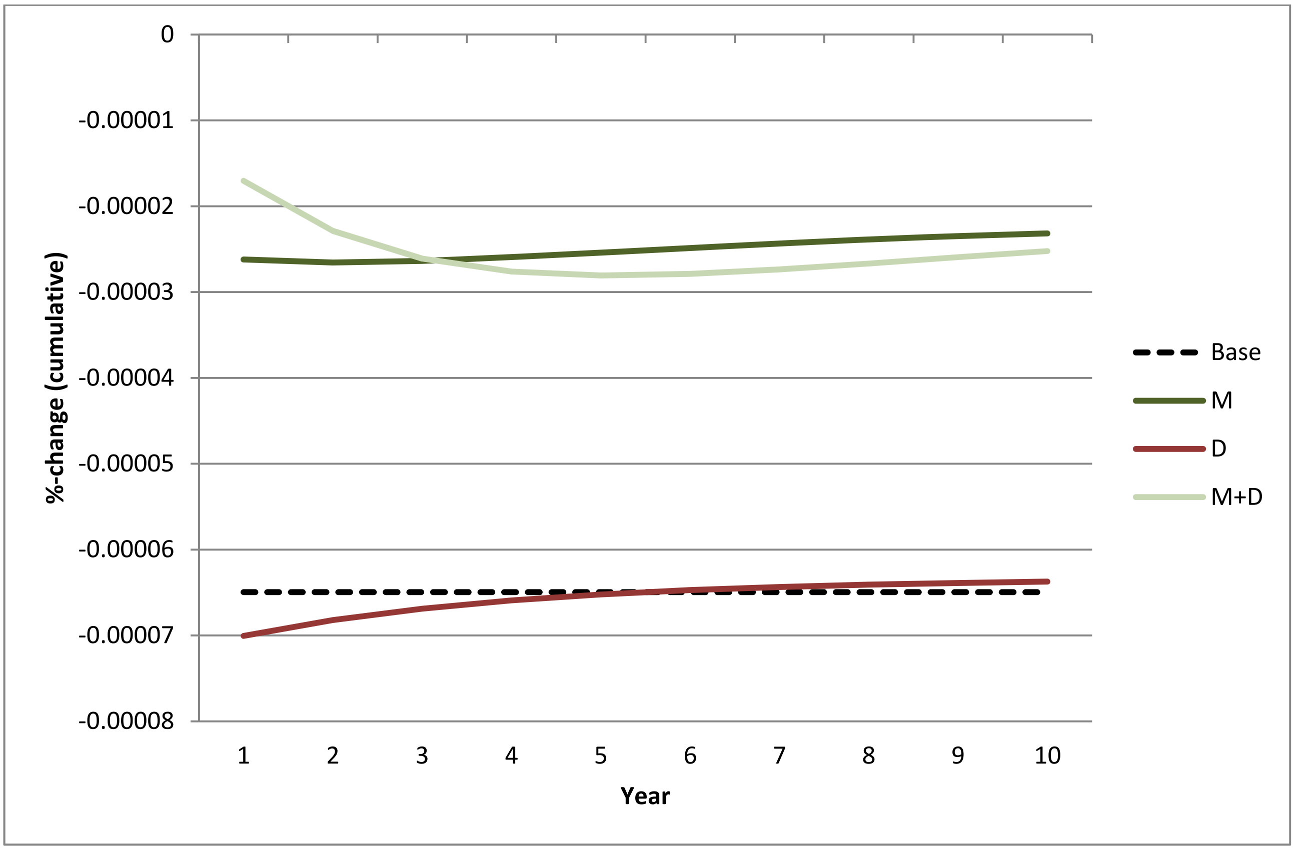


Figure 5: Unilateral; world combined investments volume index, cumulative %-difference

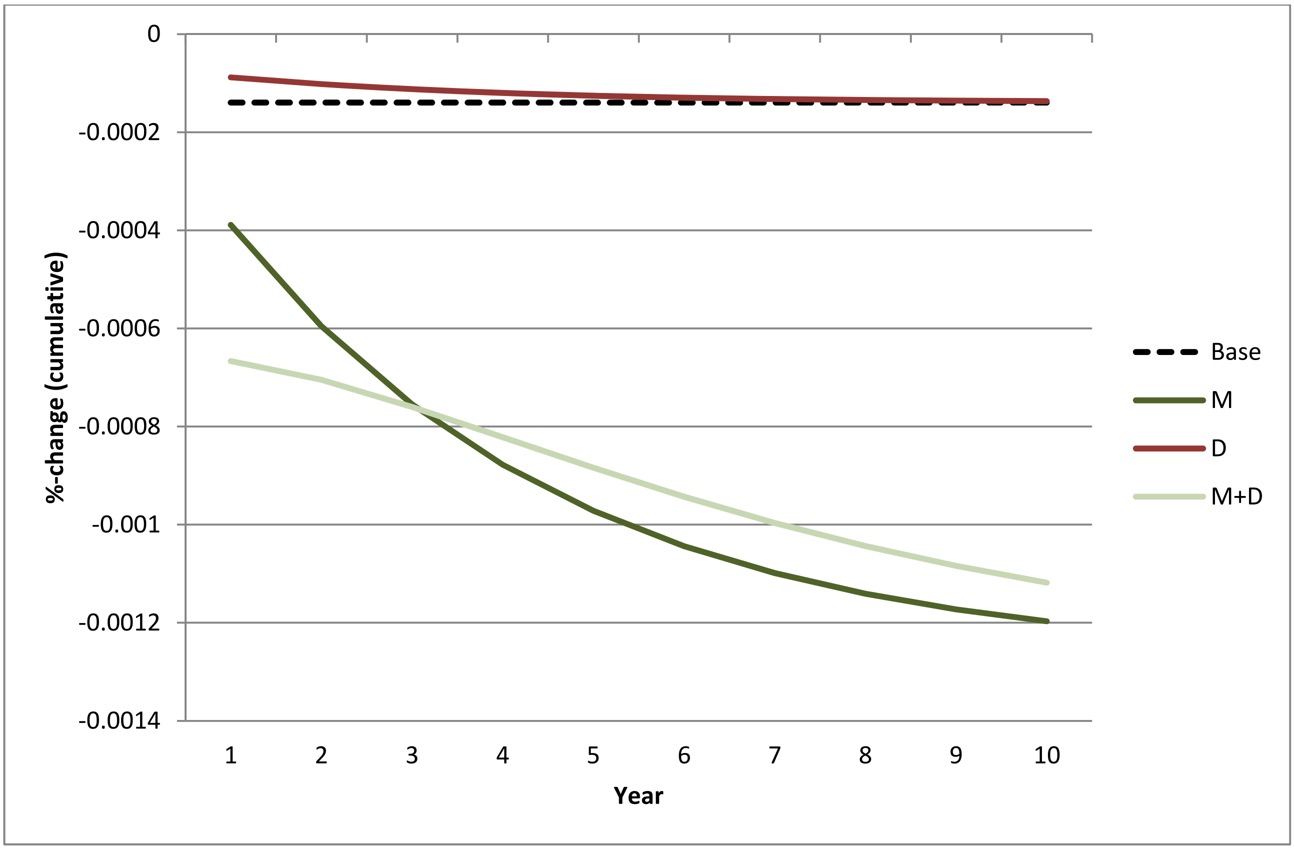


Figure 6: Multilateral; world trade volume index, cumulative %-difference

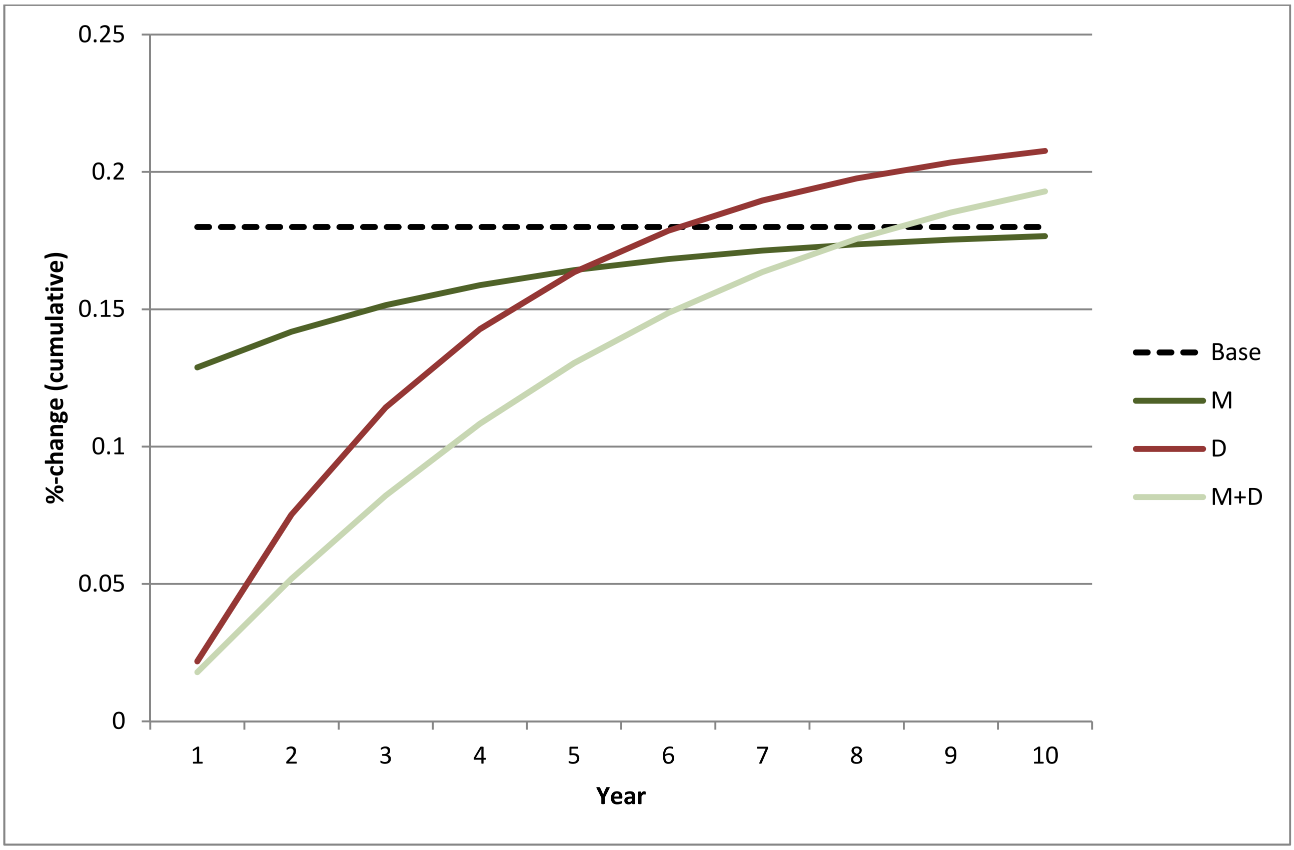


Figure 7: Multilateral; world combined gdp volume index, cumulative %-difference

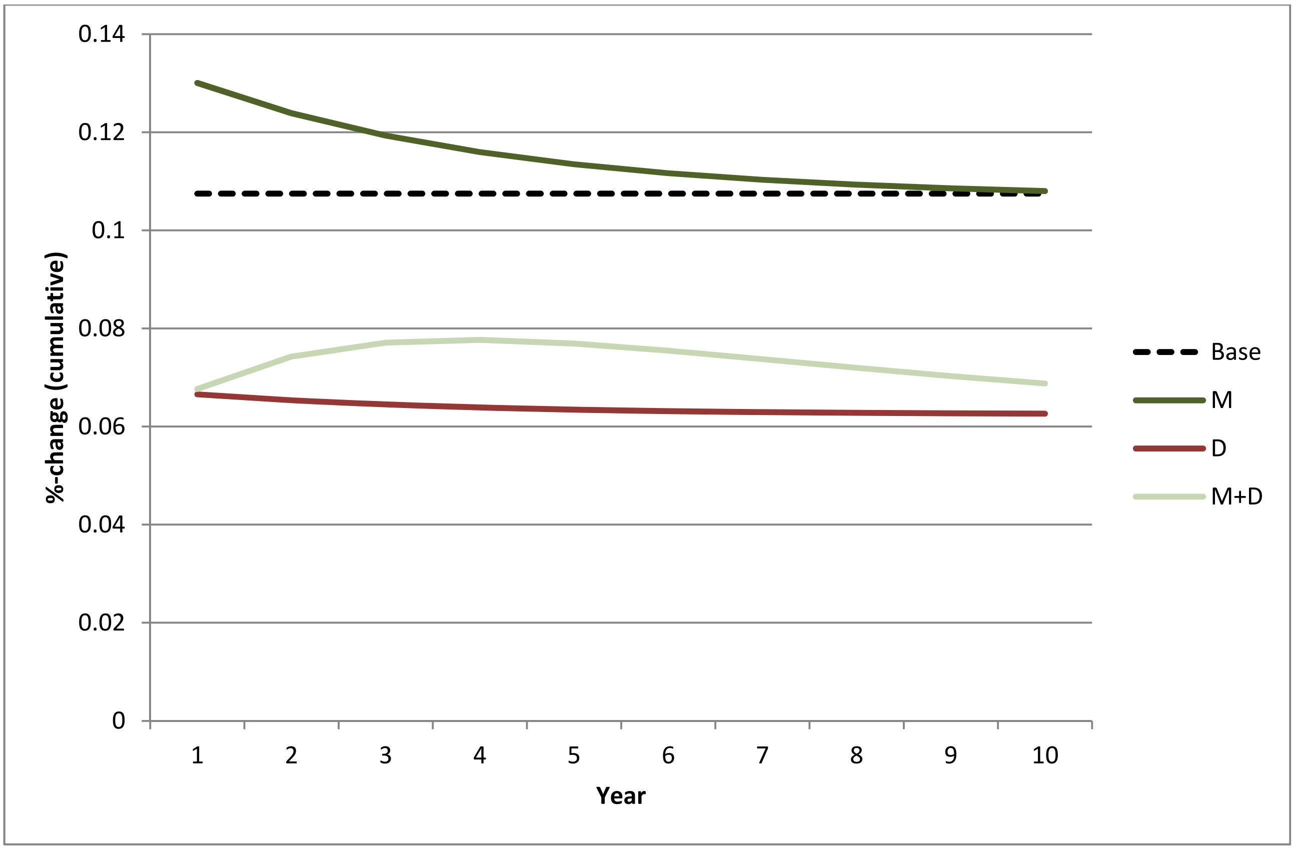


Figure 8: Multilateral; world combined private consumption expenditure, cumulative %-difference

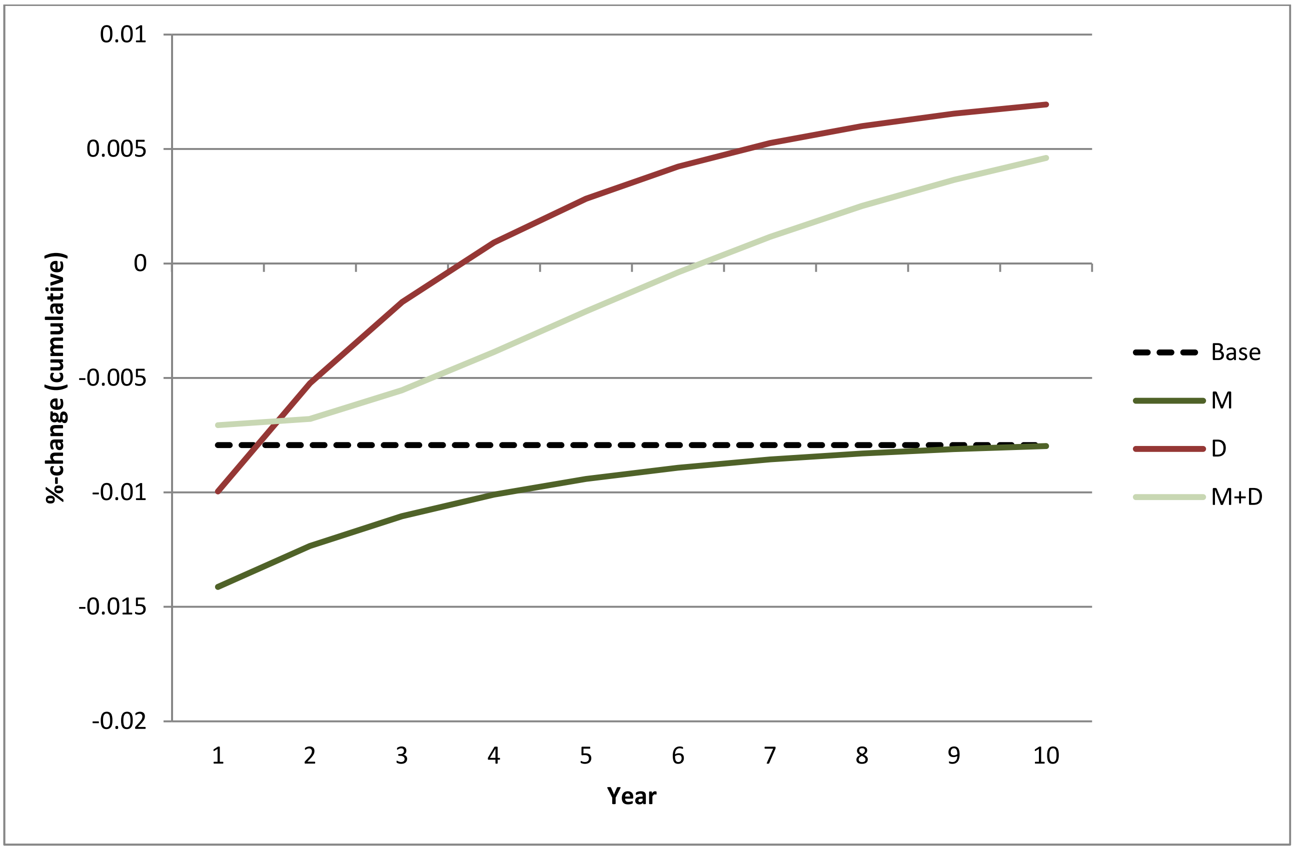


Figure 9: Multilateral; world combined investments volume index, cumulative %-difference

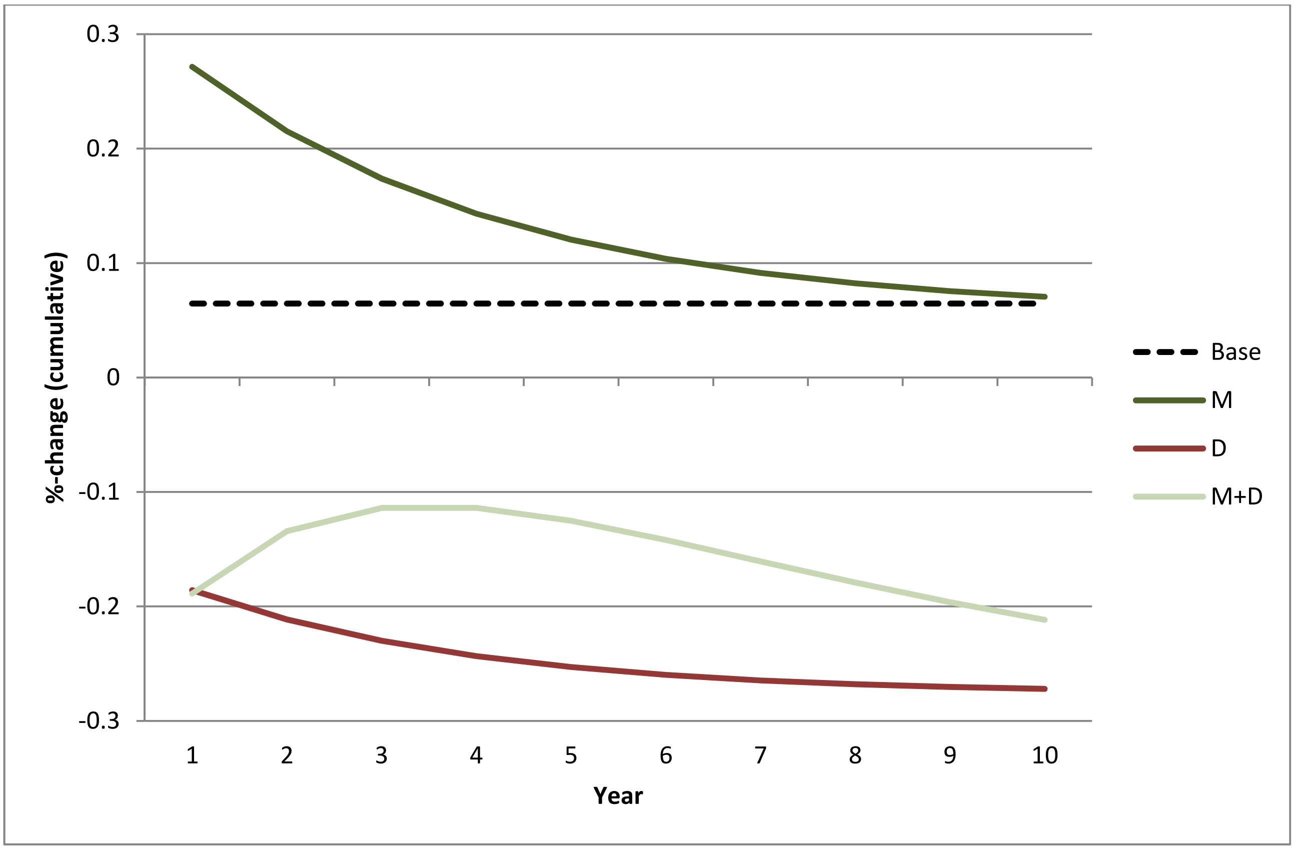


Figure 10: Temporary; world trade volume index, cumulative %-difference

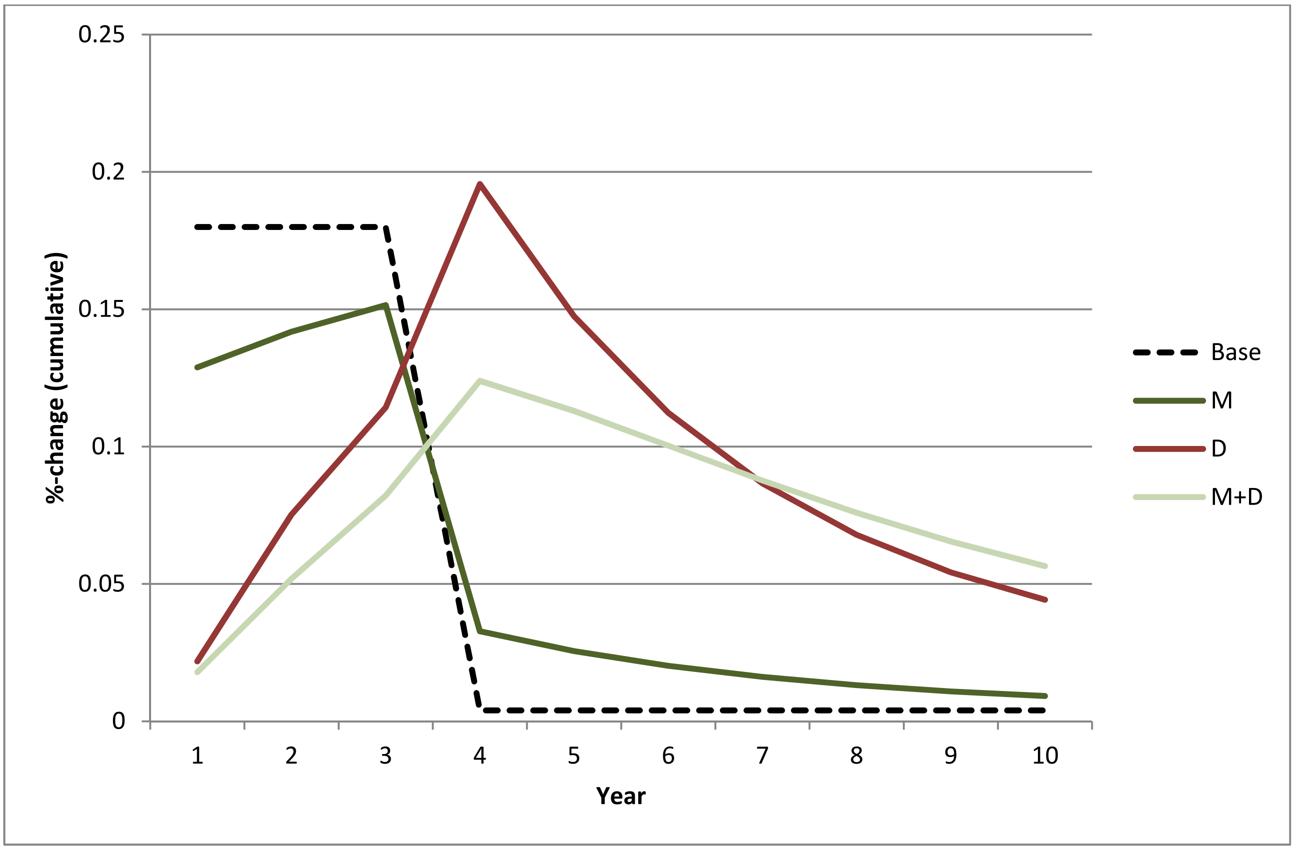


Figure 11: Temporary; world combined gdp volume index, cumulative %-difference

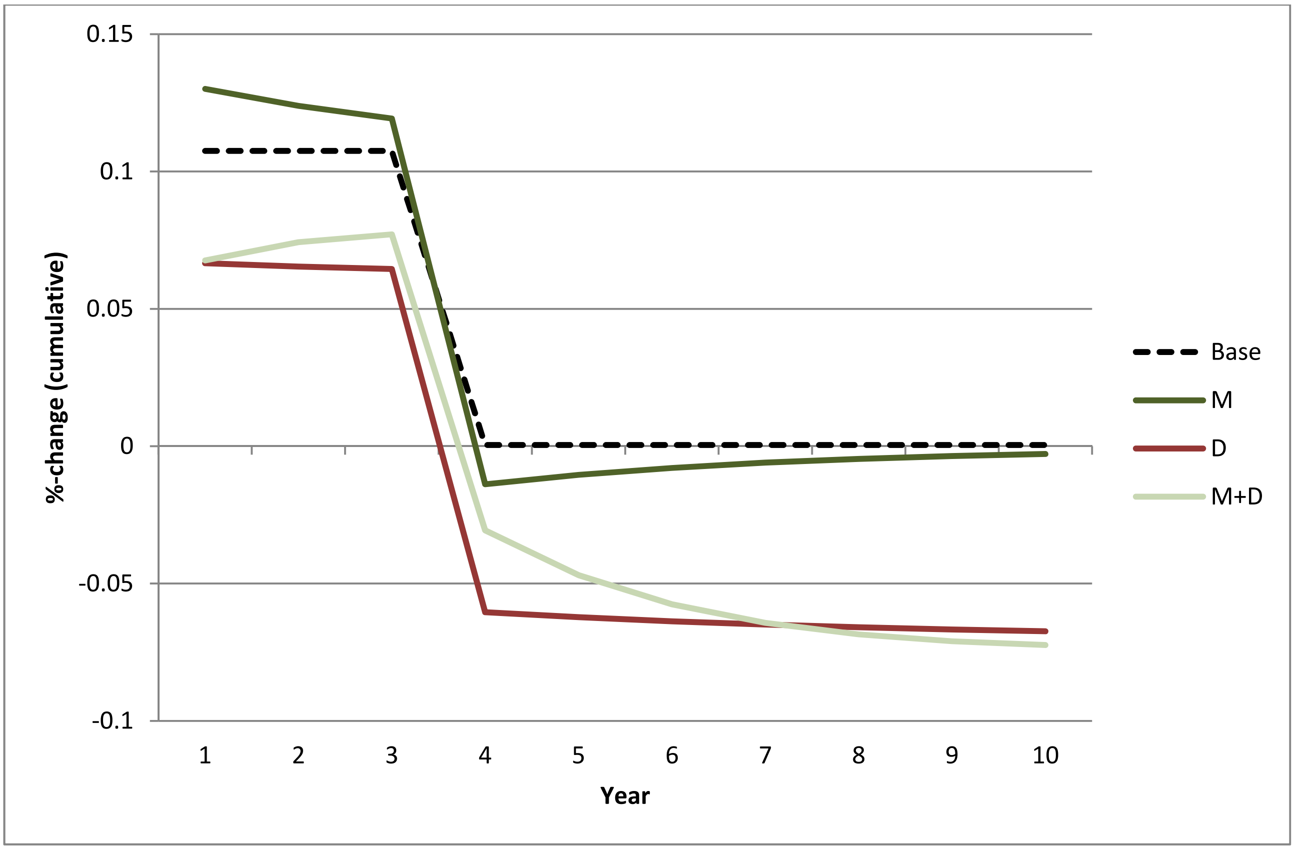


Figure 12: Temporary; world combined private consumption expenditure, cumulative %-difference

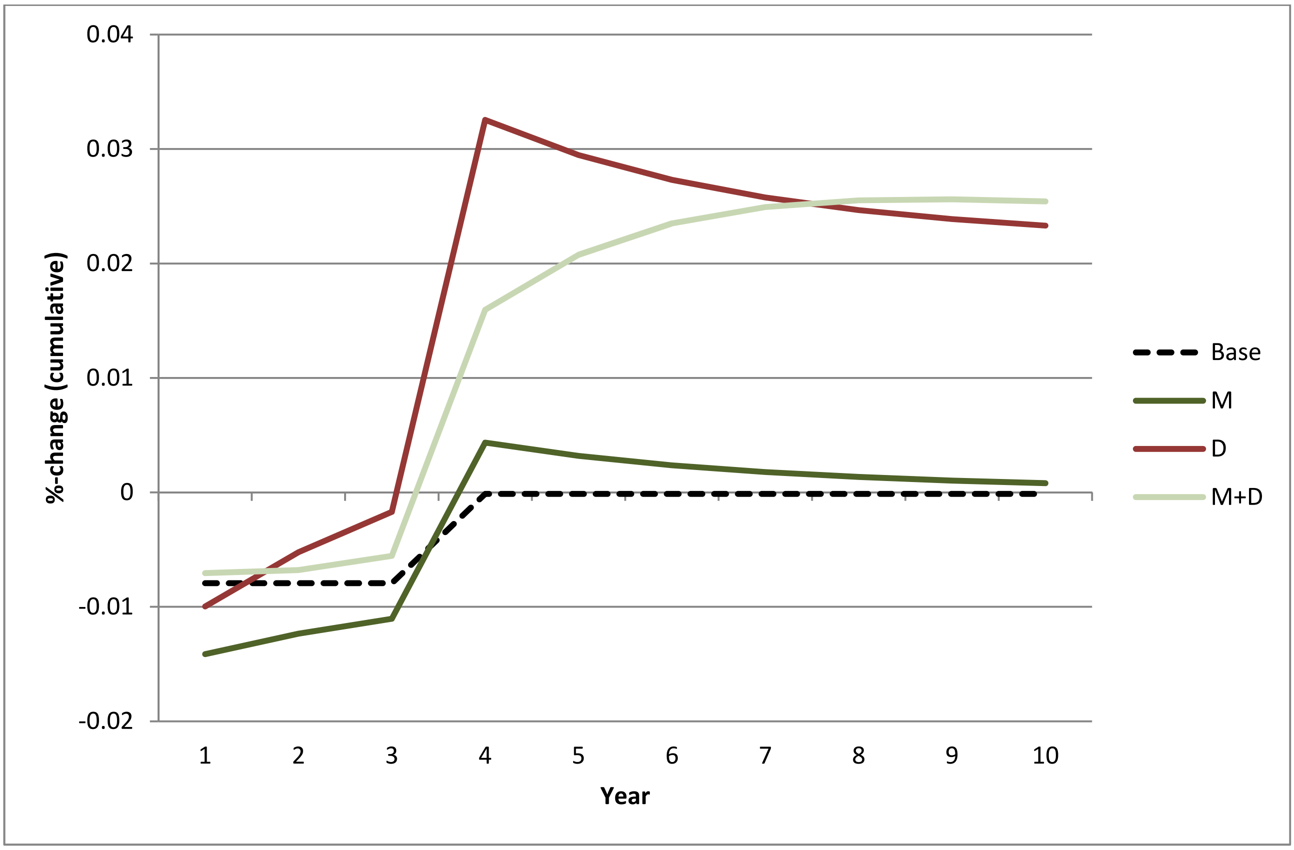


Figure 13: Temporary; world combined investments volume index, cumulative %-difference

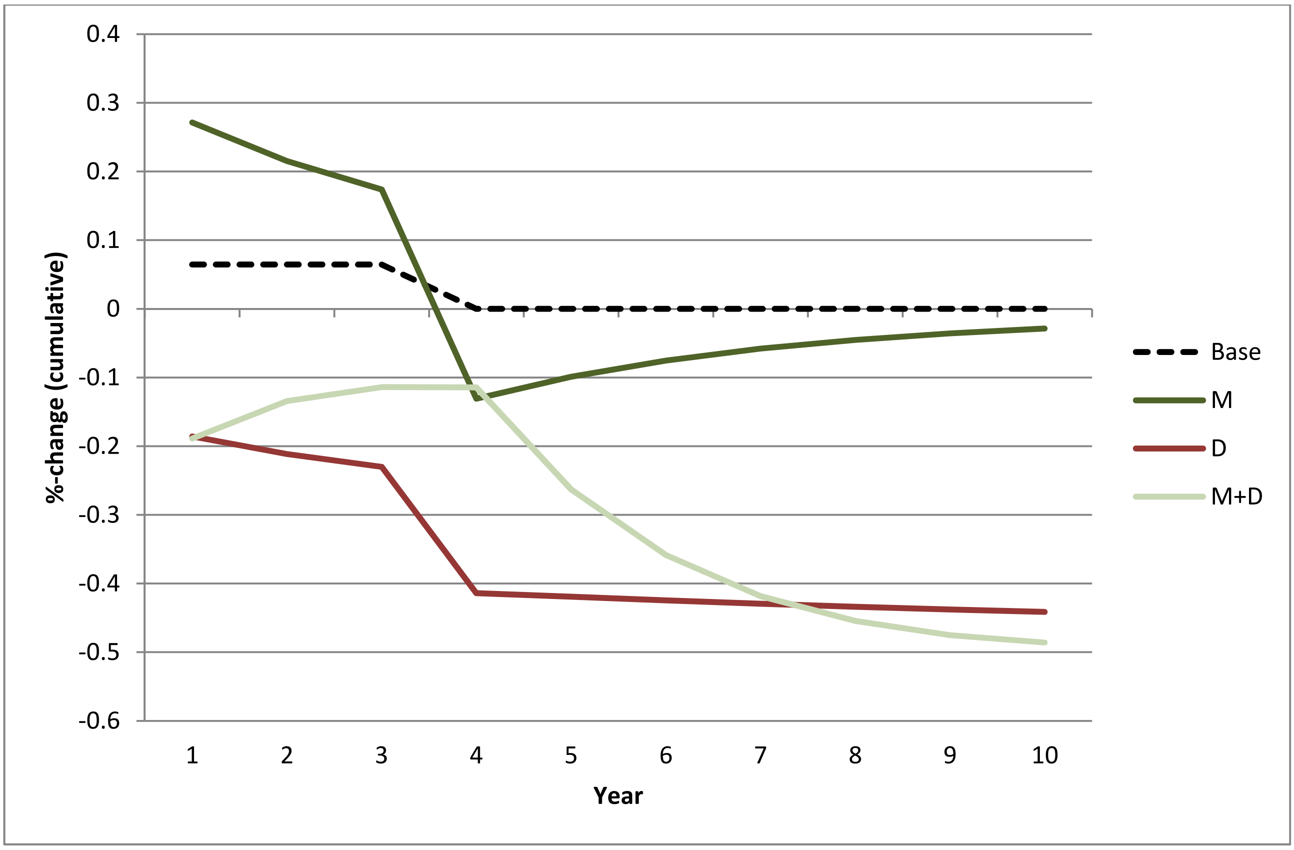


Figure 14: Multilateral; Baseline macros, cumulative %-change from year 0 to 10, selected regions

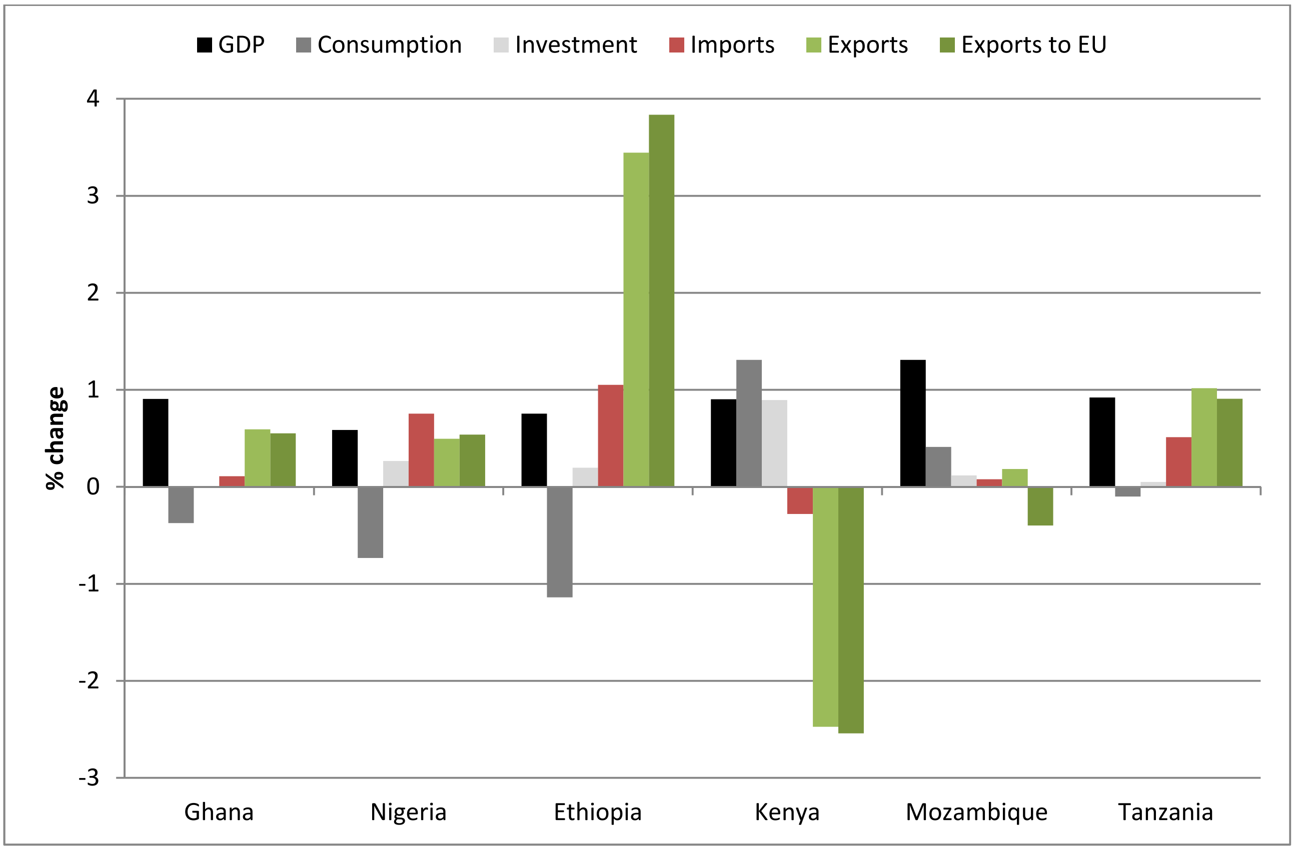


Figure 15: Unilateral; Baseline macros, cumulative %-change from year 0 to 10, selected regions

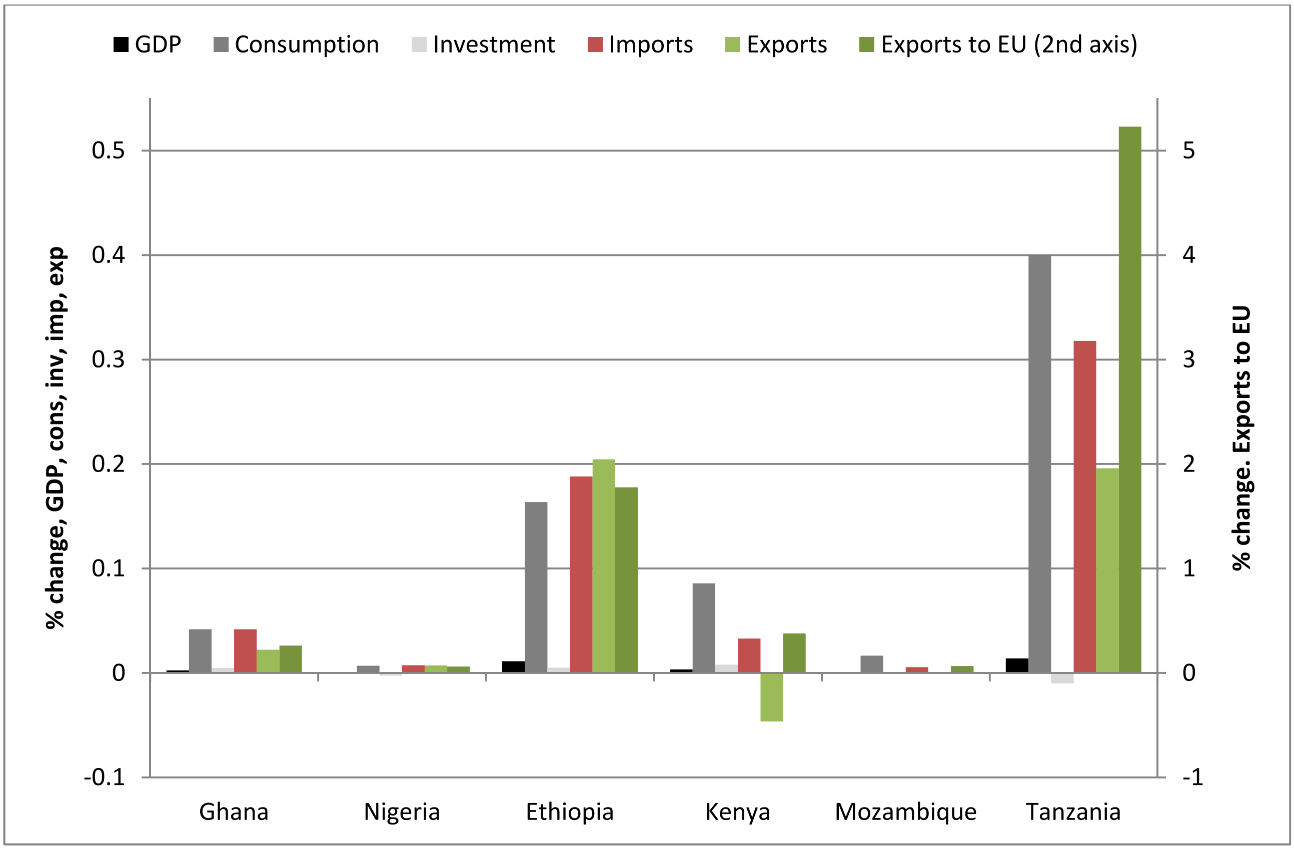


Figure 16: Multilateral; Exports – Cumulative, average difference to the base

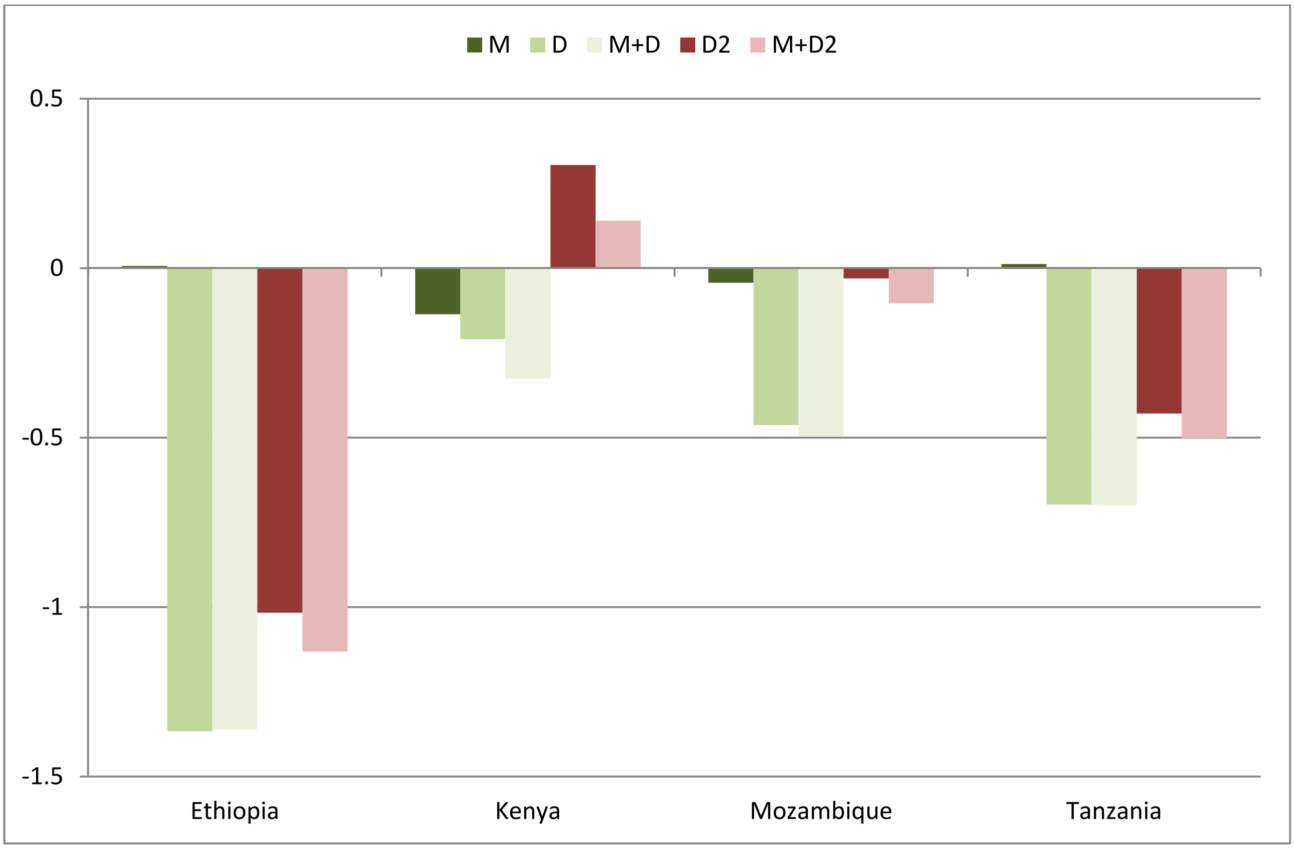


Figure 17: Multilateral; Exports – Cumulative, end difference to the base

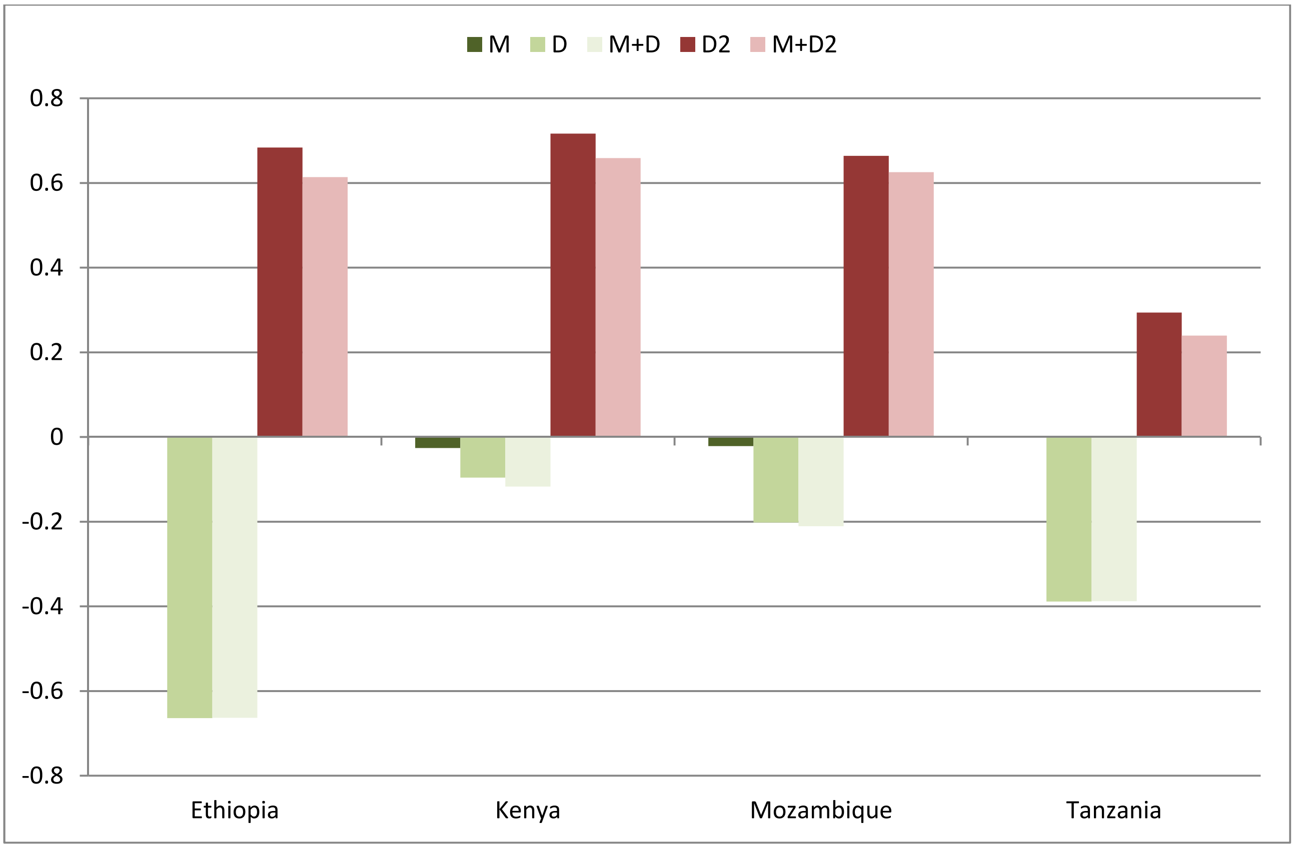


Figure 18: Multilateral; Consumption – Cumulative, average difference to the base

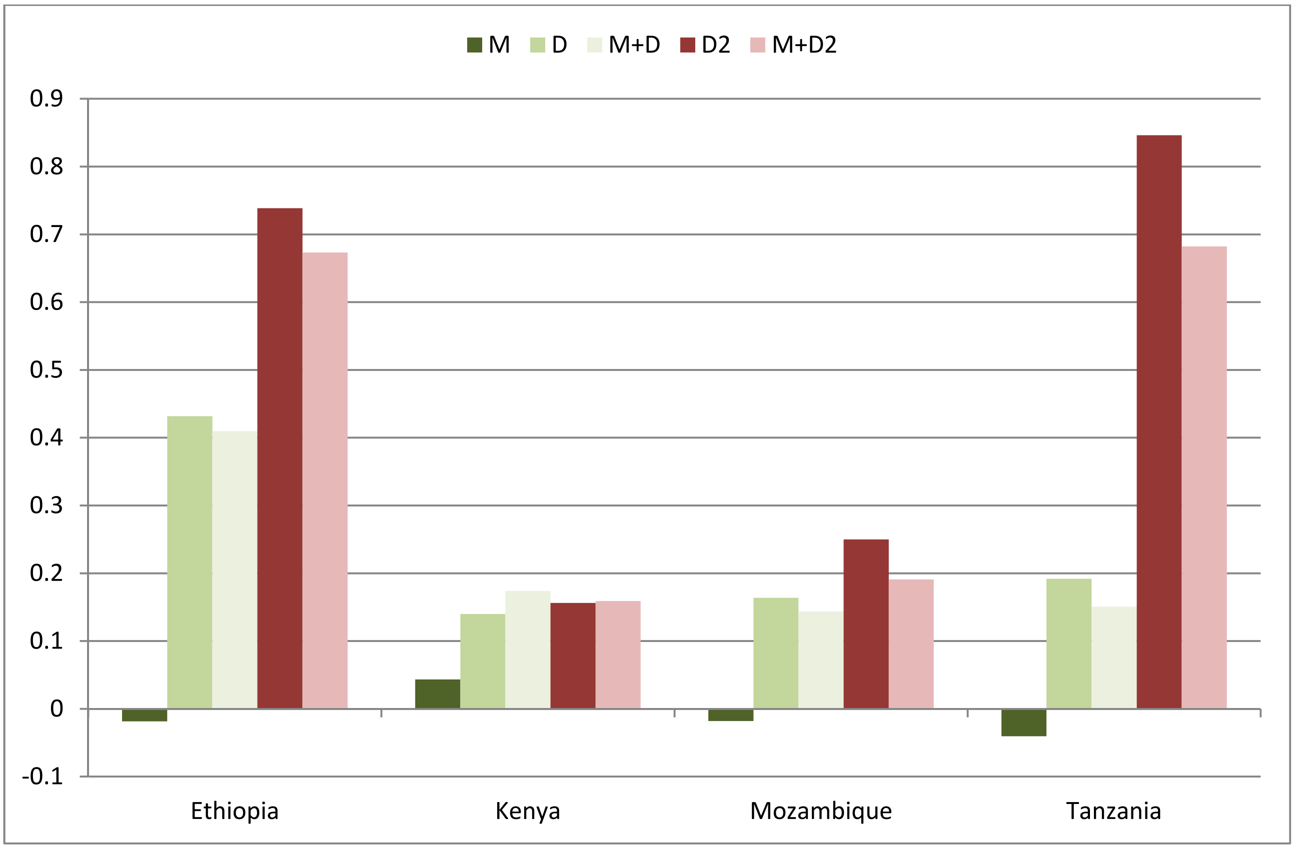


Figure 19: Multilateral; Consumption – Cumulative, end difference to the base

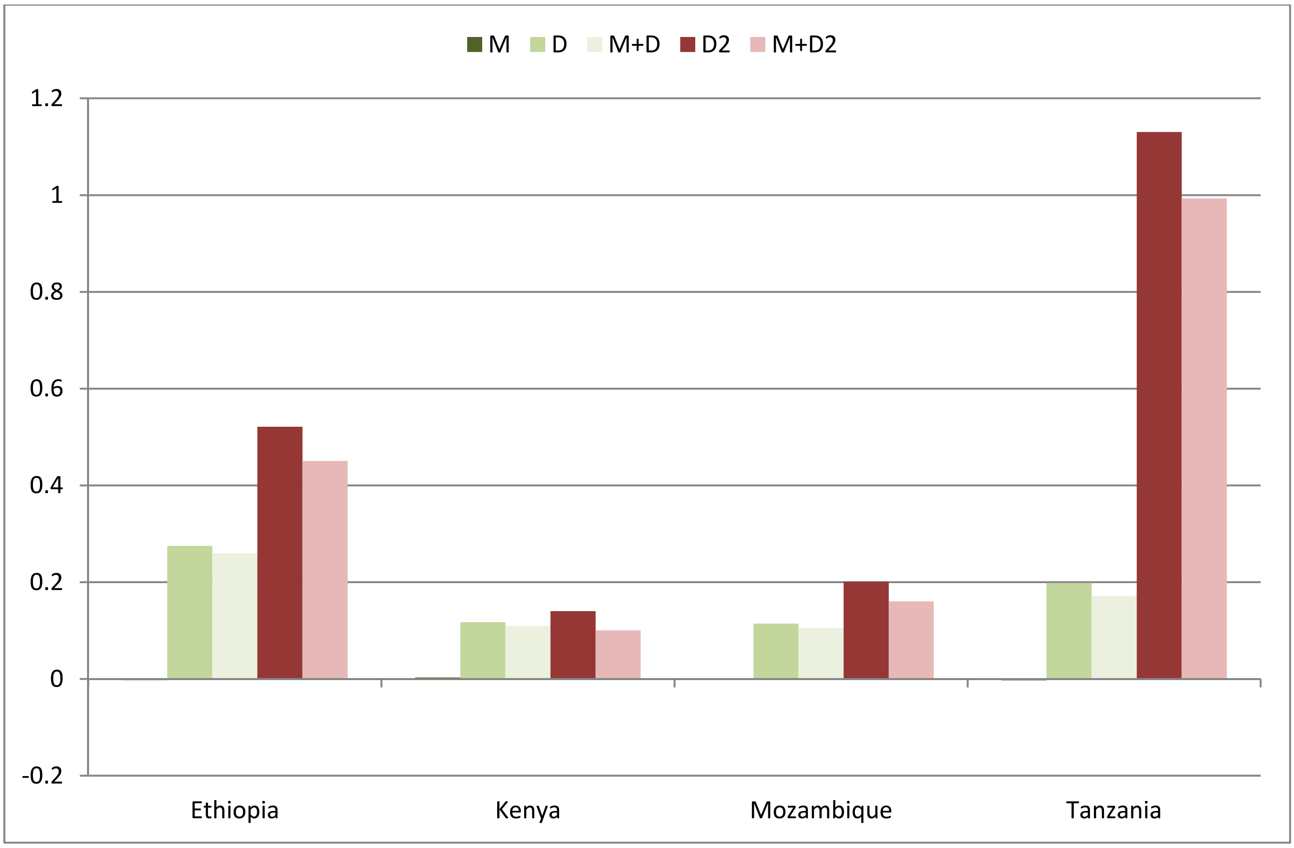


Figure 20: Unilateral; Exports – Cumulative, average difference to the base, selected regions

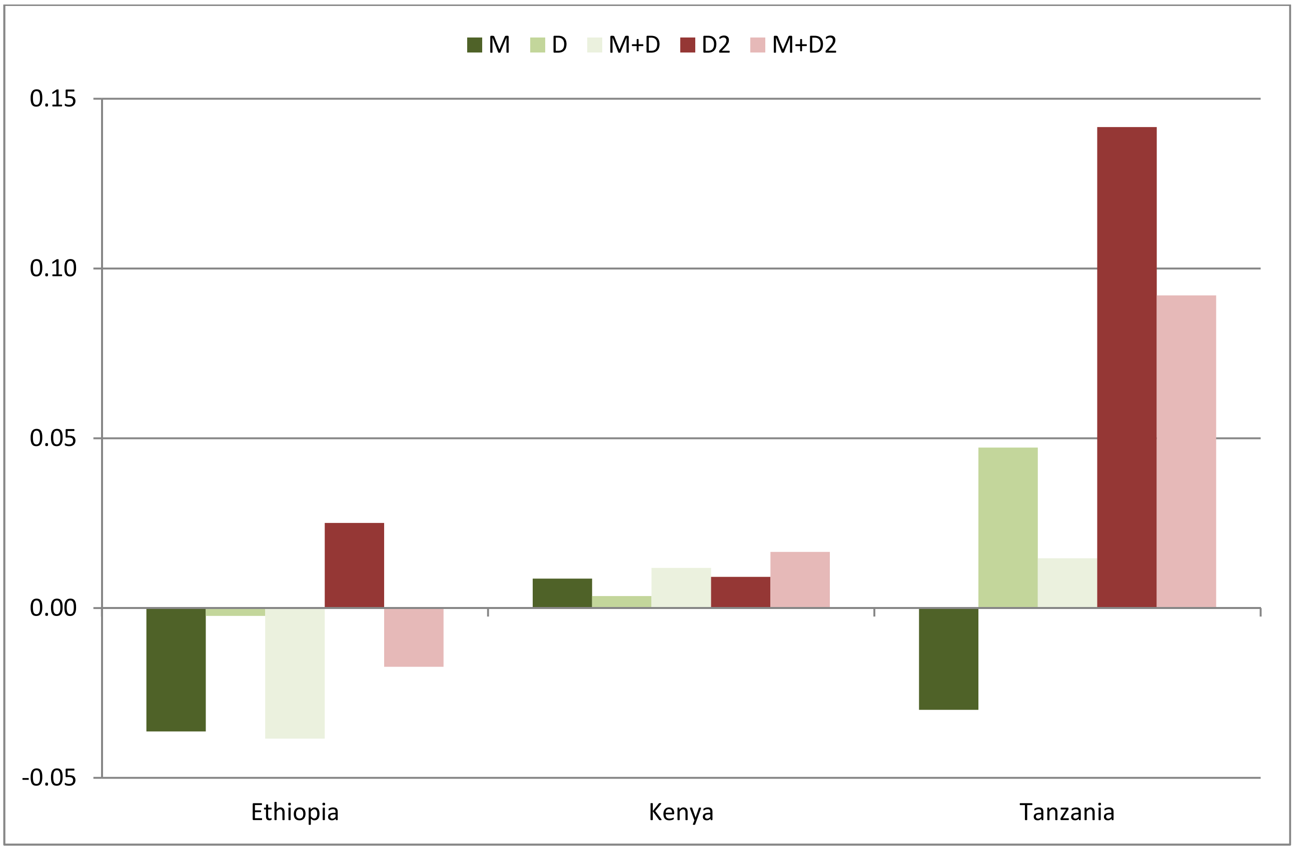


Figure 21: Unilateral; Exports – Cumulative, end difference to the base

Figure 22: Unilateral; Consumption – Cumulative, average difference to the base

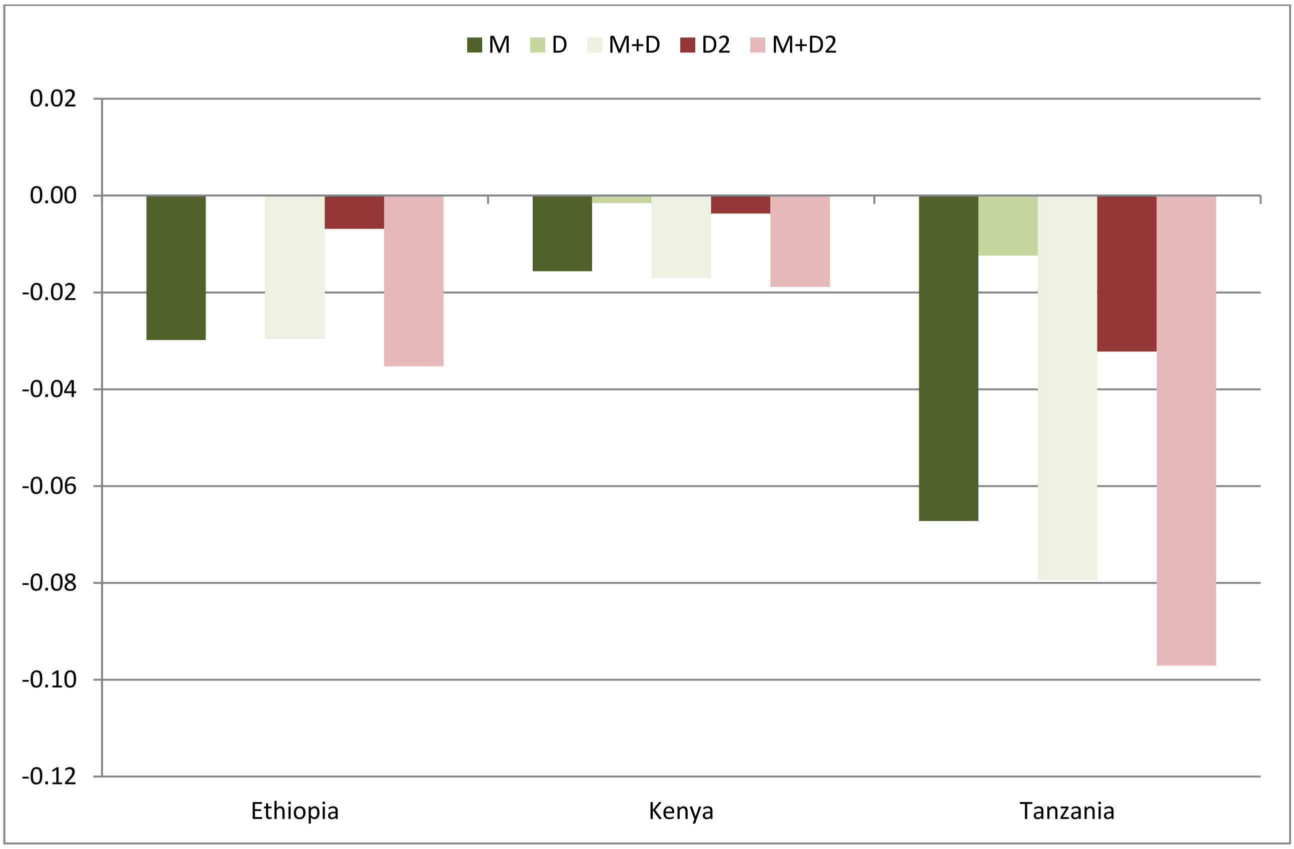


Figure 23: Unilateral; Consumption – Cumulative, end difference to the base

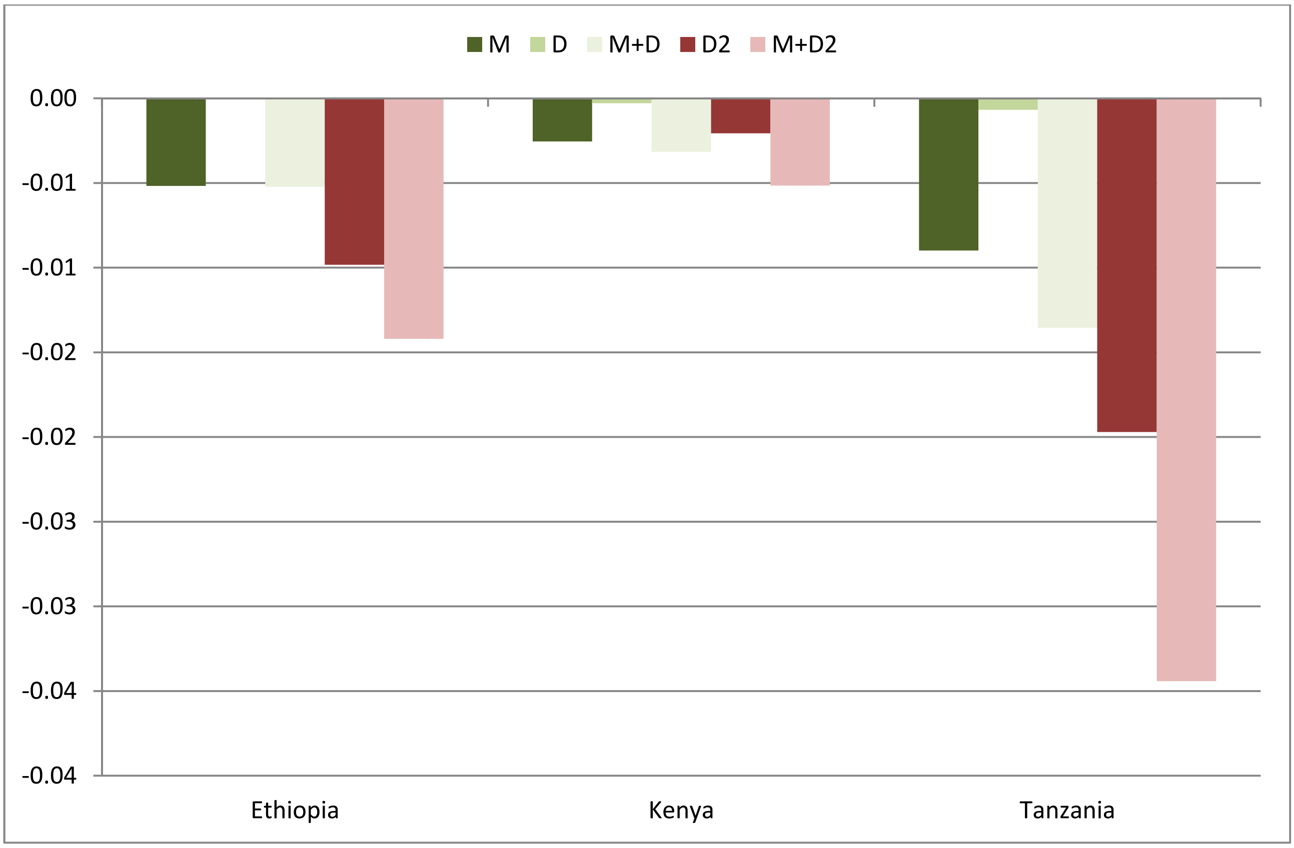
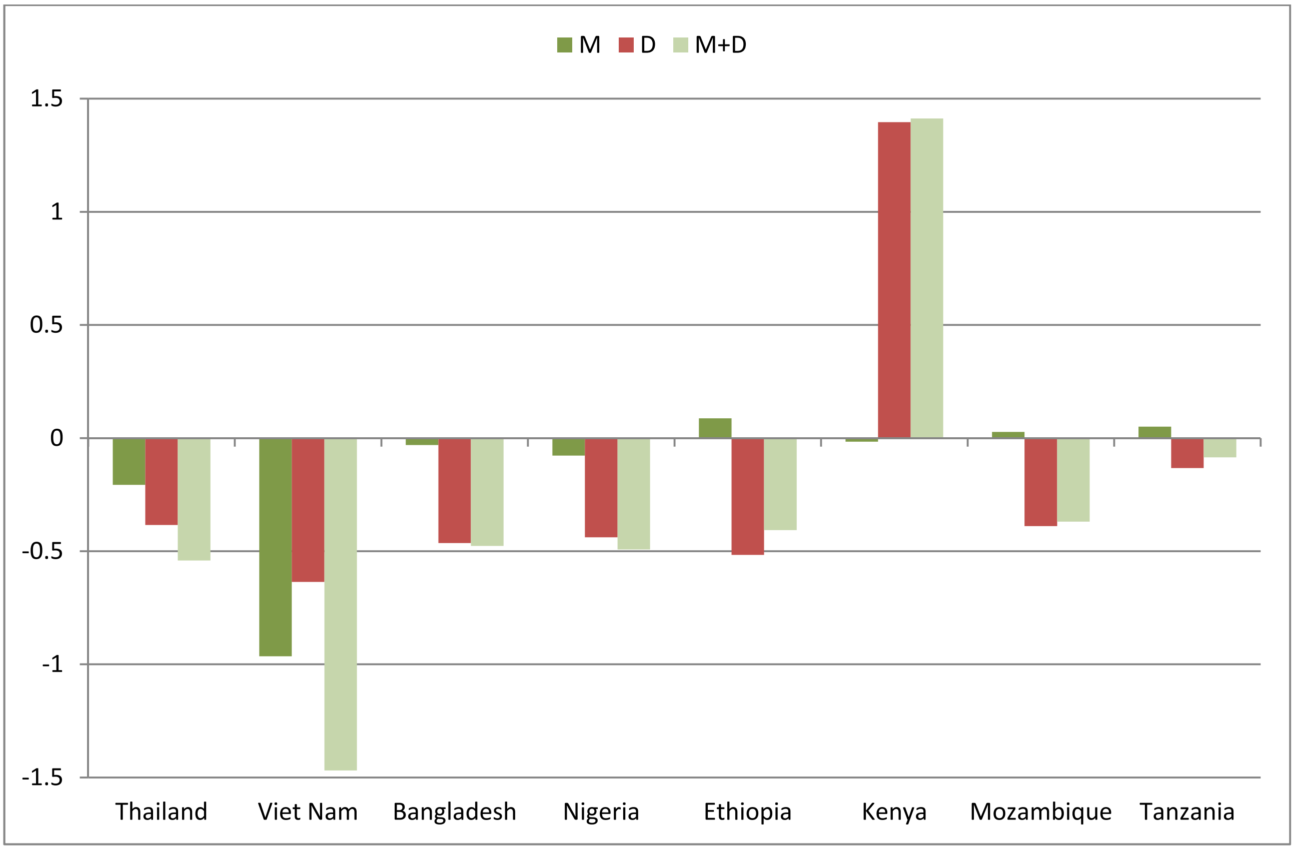


Figure 24: Unilateral & Capital; difference in regional household income



Appendix 1: Model code to be added to standard dynamic GTAP model:

```
!<
<
    ====================
    HABITS MODULE
    ====================
>!
Variable centum # 100 % #;

! Imports demand from different sources !

Coefficient (all,i,TRAD_COMM)(all,r,REG)
    ESUBML(i,r)
    # long-run el. of sub. among imports of i in Armington structure #;
Formula (initial)(all,i,TRAD_COMM)(all,r,REG)
    ESUBML(i,r) = ESUBM(i);
Read (ifheaderexists)
    ESUBML from file GTAPDATA header "ESBL";
Variable (all,i,TRAD_COMM)(all,r,REG)
    p_ESUBML(i,r) # Change in long-run el. of sub. among imports #;
Update (all,i,TRAD_COMM)(all,r,REG)
    ESUBML(i,r) = p_ESUBML(i,r);


Coefficient (all,i,TRAD_COMM)(all,r,REG)
    LAMBDAM(i,r)
    # Habit persistence coefficient for imports of i in Armington structure #;
Formula (initial)(all,i,TRAD_COMM)(all,r,REG)
    LAMBDAM(i,r) = 0.0;
Read (ifheaderexists)
    LAMBDAM from file GTAPDATA header "LAMB";
Variable (change) (all,i,TRAD_COMM)(all,r,REG)
    c_LAMBDAM(i,r) #Change in long-run el. of sub. among imports #;
Update (change)(all,i,TRAD_COMM)(all,r,REG)
    LAMBDAM(i,r) = c_LAMBDAM(i,r);

Coefficient (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
    VIMS_B(i,r,s)
    # Base imports of i from r to s valued at domestic mkt prices #;
Formula (initial)(all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
    VIMS_B(i,r,s) = VIMS(i,r,s);
Update (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
    VIMS_B(i,r,s) = pms(i,r,s);

Coefficient (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
    VIMS_LR(i,r,s)
    # Long-run target imports of i from r to s valued at domestic mkt prices #;
Formula (initial) (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
    VIMS_LR(i,r,s)= VIMS(i,r,s);
Read (ifheaderexists)
    VIMS_LR from file GTAPDATA header "IMLR";
Variable (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
    qxs_lr(i,r,s)
    # Change in LR target imports of i from r to s valued at domestic mkt prices #;

Update (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
    VIMS_LR(i,r,s) = pms(i,r,s) * qxs_lr(i,r,s);

Update (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
    VIMS(i,r,s) = pms(i,r,s) * qxs(i,r,s);

!The long-run import demand qxs_lr is identical to the standard GTAP model import demand qxs!
Equation LR_IMPORTDEMAND
# regional long-run demand for disaggregated imported commodities by source (HT 29) #
(all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
    qxs_lr(i,r,s)
        = -ams(i,r,s) + qim(i,s)
        - ESUBML(i,s) * [pms(i,r,s) - ams(i,r,s) - pim(i,s)];

!The short-run import demand qxs is now dependent on parameter LAMBDA, which defines the "base
 demand" and adjustment speed towards the long-run demand !
Equation IMPORTDEMAND
# regional short-run demand for disaggregated imported commodities by source #
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```
(all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
    VIMS(i,r,s) * [centum+qxs(i,r,s)+pms(i,r,s)]
        = LAMBDAM(i,s) * VIMS_B(i,r,s) * [centum+pms(i,r,s)]
        + [1-LAMBDAM(i,s)] * VIMS_LR(i,r,s) * [centum+pms(i,r,s) + qxs_lr(i,r,s)];


Equation TIMPRATIO
# change in ratio of import tax payments to regional income #
(all,r,REG)
    100.0 * INCOME(r) * del_taxrimp(r) + TIM(r) * y(r)
        = sum(i,TRAD_COMM, sum(s,REG,
            VIMS(i,s,r) * [tm(i,r) + tms(i,s,r)]
            + MTAX(i,s,r) * [pcif(i,s,r) + qxs(i,s,r)]));

! Demand of domestic and aggregate imported goods !

! We introduce auxillary set and variables to write the original GTAP model equations (below)
  in a more simple and concise form !
![[!
Equation GHHLDAGRIMP
# government consumption demand for aggregate imports (HT 43) #
(all,i,TRAD_COMM)(all,s,REG)
    qgm(i,s) = qg(i,s) + ESUBD(i) * [pg(i,s) - pgm(i,s)];

Equation GHHLDDOM
# government consumption demand for domestic goods (HT 44) #
(all,i,TRAD_COMM)(all,s,REG)
    qgd(i,s) = qg(i,s) + ESUBD(i) * [pg(i,s) - pgd(i,s)];

Equation PHHLDDOM
# private consumption demand for domestic goods (HT 48) #
(all,i,TRAD_COMM)(all,s,REG)
    qpd(i,s) = qp(i,s) + ESUBD(i) * [pp(i,s) - ppd(i,s)];

Equation PHHLDAGRIMP
# private consumption demand for aggregate imports (HT 49) #
(all,i,TRAD_COMM)(all,s,REG)
    qpm(i,s) = qp(i,s) + ESUBD(i) * [pp(i,s) - ppm(i,s)];

Equation INDIMP
# industry j demands for composite import i (HT 31) #
(all,i,TRAD_COMM)(all,j,PROD_COMM)(all,s,REG)
    qfm(i,j,s) = qf(i,j,s) - ESUBD(i) * [pfm(i,j,s) - pf(i,j,s)];

Equation INDDOM
# industry j demands for domestic good i (HT 32) #
(all,i,TRAD_COMM)(all,j,PROD_COMM)(all,s,REG)
    qfd(i,j,s) = qf(i,j,s) - ESUBD(i) * [pfd(i,j,s) - pf(i,j,s)];
!]]!

Set
  SRC # Source (dom/imp) # (domestic,imported);
  FINDEM  # Final consumption demand # (cons,gov);
  TOTDEM  # All demand # = PROD_COMM + FINDEM;

Variable
  (all,i,TRAD_COMM)(all,j,TOTDEM)(all,d,SRC)(all,r,REG) qdem(i,j,d,r) # All demand for traded commodities by
source (dom/imp) # ;
  (all,i,TRAD_COMM)(all,j,TOTDEM)(all,d,SRC)(all,r,REG) pdem(i,j,d,r) # Demand price for traded commodities
by source (dom/imp) #;
  (all,i,TRAD_COMM)(all,j,TOTDEM)(all,r,REG) qdem_s(i,j,r) # Average demand for traded commodities # ;
  (all,i,TRAD_COMM)(all,j,TOTDEM)(all,r,REG) pdem_s(i,j,r) # Average demand price for traded commodities # ;

Equation
 E_qgd (all,i,TRAD_COMM)(all,s,REG)      qgd(i,s) = qdem(i,"gov","domestic",s);
 E_qgm (all,i,TRAD_COMM)(all,s,REG) qgm(i,s) = qdem(i,"gov","imported",s);
 E_qpd (all,i,TRAD_COMM)(all,s,REG) qpd(i,s) = qdem(i,"cons","domestic",s);
 E_qpm (all,i,TRAD_COMM)(all,s,REG) qpm(i,s) = qdem(i,"cons","imported",s);
 E_qfd (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,s,REG) qfd(i,j,s) = qdem(i,j,"domestic",s);
 E_qfm (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,s,REG) qfm(i,j,s) = qdem(i,j,"imported",s);
 E_pgd (all,i,TRAD_COMM)(all,s,REG)      pgd(i,s) = pdem(i,"gov","domestic",s);
 E_pgm (all,i,TRAD_COMM)(all,s,REG) pgm(i,s) = pdem(i,"gov","imported",s);
 E_ppd (all,i,TRAD_COMM)(all,s,REG) ppd(i,s) = pdem(i,"cons","domestic",s);
 E_ppm (all,i,TRAD_COMM)(all,s,REG) ppm(i,s) = pdem(i,"cons","imported",s);
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 E_pfd (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,s,REG) pfd(i,j,s) = pdem(i,j,"domestic",s);
 E_pfm (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,s,REG) pfm(i,j,s) = pdem(i,j,"imported",s);
 E_qg (all,i,TRAD_COMM)(all,s,REG) qg(i,s) = qdem_s(i,"gov",s);
 E_qp (all,i,TRAD_COMM)(all,s,REG) qp(i,s) = qdem_s(i,"cons",s);
 E_qf (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,s,REG) qf(i,j,s) = qdem_s(i,j,s);
 E_pg (all,i,TRAD_COMM)(all,s,REG) pg(i,s) = pdem_s(i,"gov",s);
 E_pp (all,i,TRAD_COMM)(all,s,REG) pp(i,s) = pdem_s(i,"cons",s);
 E_pf (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,s,REG) pf(i,j,s) = pdem_s(i,j,s);


Coefficient (all,i,TRAD_COMM)(all,j,TOTDEM)(all,r,REG)
    ESUBDL(i,j,r)
    # Long-run el. of sub. domestic/imported  #;
Formula (initial)(all,i,TRAD_COMM)(all,j,TOTDEM)(all,r,REG)
    ESUBDL(i,j,r) = ESUBD(i);
Read (ifheaderexists)
    ESUBDL from file GTAPDATA header "ESDL";
Variable (all,i,TRAD_COMM)(all,j,TOTDEM)(all,r,REG)
    p_ESUBDL(i,j,r) # Change in long-run el. of sub. among imports #;
Update (all,i,TRAD_COMM)(all,j,TOTDEM)(all,r,REG)
    ESUBDL(i,j,r) = p_ESUBDL(i,j,r);

Coefficient (all,i,TRAD_COMM)(all,j,TOTDEM)(all,r,REG)
    LAMBDAD(i,j,r)
    # Habit persistence coefficient for domestic/imported #;
Formula (initial)(all,i,TRAD_COMM)(all,j,TOTDEM)(all,r,REG)
    LAMBDAD(i,j,r) = 0.0;
Read (ifheaderexists)
    LAMBDAD from file GTAPDATA header "LAMD";
Variable (change) (all,i,TRAD_COMM)(all,j,TOTDEM)(all,r,REG)
    c_LAMBDAD(i,j,r) #Change in long-run el. of sub. among imports #;
Update (change)(all,i,TRAD_COMM)(all,j,TOTDEM)(all,r,REG)
    LAMBDAD(i,j,r) = c_LAMBDAD(i,j,r);

Coefficient (all,i,TRAD_COMM)(all,j,TOTDEM)(all,s,SRC)(all,r,REG)
    VDEMA(i,j,s,r)
    # Demands, agent prices #;

Formula
 (all,i,TRAD_COMM)(all,r,REG) VDEMA(i,"gov","domestic",r) = VDGA(i,r);
 (all,i,TRAD_COMM)(all,r,REG) VDEMA(i,"gov","imported",r) = VIGA(i,r);
 (all,i,TRAD_COMM)(all,r,REG) VDEMA(i,"cons","domestic",r) = VDPA(i,r);
 (all,i,TRAD_COMM)(all,r,REG) VDEMA(i,"cons","imported",r) = VIPA(i,r);
 (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG) VDEMA(i,j,"domestic",r) = VDFA(i,j,r);
 (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG) VDEMA(i,j,"imported",r) = VIFA(i,j,r);

Coefficient (all,i,TRAD_COMM)(all,j,TOTDEM)(all,s,SRC)(all,r,REG)
    VDEMA_B(i,j,s,r)
    # Base demands, agent prices #;

Formula
 (initial)(all,i,TRAD_COMM)(all,j,TOTDEM)(all,s,SRC)(all,r,REG) VDEMA_B(i,j,s,r) = VDEMA(i,j,s,r);

Update (all,i,TRAD_COMM)(all,j,TOTDEM)(all,s,SRC)(all,r,REG)
    VDEMA_B(i,j,s,r) = pdem(i,j,s,r);

Coefficient (all,i,TRAD_COMM)(all,j,TOTDEM)(all,s,SRC)(all,r,REG)
    VDEMA_LR(i,j,s,r)
    # Long-run target demands, agent prices #;
Formula (initial) (all,i,TRAD_COMM)(all,j,TOTDEM)(all,s,SRC)(all,r,REG)
    VDEMA_LR(i,j,s,r) = VDEMA(i,j,s,r);
Read (ifheaderexists)
    VDEMA_LR from file GTAPDATA header "DALR";
Variable (all,i,TRAD_COMM)(all,j,TOTDEM)(all,s,SRC)(all,r,REG)
    qdem_lr(i,j,s,r)
    # Change in LR target demand #;

Update (all,i,TRAD_COMM)(all,j,TOTDEM)(all,s,SRC)(all,r,REG)
    VDEMA_LR(i,j,s,r) = pdem(i,j,s,r) * qdem_lr(i,j,s,r);


!The Long-run demad again corresponds to the standard GTAP model demands!

! Replaces standard GTAp model equations GHHLDAGRIMP, GHHLDDOM, PHHLDDOM,
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  PHHLDAGRIMP, INDIMP, and INDDOM. !

Equation LR_AGGDEMANDS
# regional long-run demands for traded commodities by dom/imp #
(all,i,TRAD_COMM)(all,j,TOTDEM)(all,s,SRC)(all,r,REG)
    qdem_lr(i,j,s,r) = qdem_s(i,j,r) - ESUBDL(i,j,r) * [pdem(i,j,s,r) - pdem_s(i,j,r)];

!The short-run import demand qxs is now dependent on parameter LAMBDA, which defines the "base
 demand" and adjustment speed towards the long-run demand !
Equation AGGDEMANDS
# regional short-run demand for disaggregated imported commodities by source #
(all,i,TRAD_COMM)(all,j,TOTDEM)(all,s,SRC)(all,r,REG)
    VDEMA(i,j,s,r) * [centum+qdem(i,j,s,r) + pdem(i,j,s,r)]
        = LAMBDAD(i,j,r) * VDEMA_B(i,j,s,r) * [centum + pdem(i,j,s,r)]
        + [1-LAMBDAD(i,j,r)] * VDEMA_LR(i,j,s,r) * [centum + pdem(i,j,s,r) + qdem_lr(i,j,s,r)];


! Additional analytics !
Variable
 qgdpworld # Global GDP quantity index #;
 yworld # Global HH income #;
 ypworld # Global private expendture #;

Equation
 E_qgdpworld #Global  GDP quantity index # sum[r,REG,GDP(r)] * qgdpworld = sum[r,REG,GDP(r) * qgdp(r)];
 E_yworld #Global  GDP quantity index # sum[r,REG,INCOME(r)] * yworld = sum[r,REG,INCOME(r) * y(r)];
 E_ypworld #Global  GDP quantity index # sum[r,REG,PRIVEXP(r)] * ypworld = sum[r,REG,PRIVEXP(r) * yp(r)];
```