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Modeling Trade and Income Distribution in Six Developing Countries A dynamic general equilibrium analysis up to the year 2050

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Abstract
This paper presents an empirical exercise, aimed at investigating the implications on poverty and income distribution of a reference scenario (SSP2) of economic development. It does so by coupling a dynamic general equilibrium model of the global economy, specifically designed to capture structural change dynamics in the medium and long run, with detailed micro data on household income in six countries: Albania, Bolivia, Ethiopia, Malawi, Nicaragua and Vietnam. We also consider an alternative scenario of accelerated international trade integration, with a higher degree of trade openness. We found that long run structural change widens income inequality in all six developing countries. Accelerated trade integration amplifies the effect further, but most of it is already generated in the baseline scenario. A decrease in the relative value of land property and an increase in the relative value of capital ownership appear as key determinants. We decompose income differentials in three dimensions. Structural change worsens the income gap between male and female headed households, but the additional impact of trade is minimal. The effect of structural change is not uniform across countries when income of rural households is contrasted with the one of urban households, yet more trade reduces the relative rural income. Relative poverty increases in both the baseline and the larger trade volume case. However, we found that absolute poverty would be eradicated in almost all countries by the year 2050.

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JEL Codes
C68, E17, F17, I32, O11, O15, O41

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Modeling Trade and Income Distribution in Six Developing Countries

A dynamic general equilibrium analysis up to the year 2050

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ABSTRACT

This paper presents an empirical exercise, aimed at investigating the implications on poverty and income distribution of a reference scenario (SSP2) of economic development. It does so by coupling a dynamic general equilibrium model of the global economy, specifically designed to capture structural change dynamics in the medium and long run, with detailed micro data on household income in six countries: Albania, Bolivia, Ethiopia, Malawi, Nicaragua and Vietnam. We also consider an alternative scenario of accelerated international trade integration, with a higher degree of trade openness. We found that long run structural change widens income inequality in all six developing countries. Accelerated trade integration amplifies the effect further, but most of it is already generated in the baseline scenario. A decrease in the relative value of land property and an increase in the relative value of capital ownership appear as key determinants. We decompose income differentials in three dimensions. Structural change worsens the income gap between male and female headed households, but the additional impact of trade is minimal. The effect of structural change is not uniform across countries when income of rural households is contrasted with the one of urban households, yet more trade reduces the relative rural income. Relative poverty increases in both the baseline and the larger trade volume case. However, we found that absolute poverty would be eradicated in almost all countries by the year 2050.

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1. Introduction and Motivation

Trade has played a major role in reducing poverty in the past. A better global allocation of resources and exploitation of comparative advantages have led to significant productivity and thus income increases, and in many countries lifted large groups of people out of poverty. Yet, trade has not been universally inclusive; vulnerable groups are at risk of being left behind, and income inequality is on the rise in many countries.

While economists broadly agree that trade liberalization is welfare increasing in the aggregate, there is clear evidence that not all regions, sectors or households benefit from globalization (Pavcnik, 2017). In particular,

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only some countries, such as the so-called Asian Tigers, India and China, have managed to transform themselves into medium and high-income countries. Other countries, such as many in Sub-Saharan Africa, exhibit low economic growth, limited trade integration and stagnating shares of poor people, facing food insecurity, limited access to health care, decent housing or education (Dodd and Cattaneo, 2007).

Consequently, private and public actors in developing countries need to take far-reaching decisions, such as: should domestic sectors, including agriculture, be promoted (possibly protected from foreign competition), or should a country concentrate on export-led growth, assuming that increased purchasing power in the country will allow buying food and other necessities from international markets? Our papers will not provide answers directly, but will shed some light on several important aspects of the issue.

In particular, we start from the observation that poverty levels and income distribution depend not only on the degree of economic development, but also on the structural change occurring over time inside the economic system, induced by variations in income and international trade volumes and patterns. Therefore, elaborating consistent trade and poverty alleviating policies requires an adequate understanding of the unfolding dynamic processes.

To this end, this paper presents an empirical exercise, aimed at investigating the implications on poverty and income distribution of a reference scenario (SSP2) of economic development. It does so by coupling a dynamic general equilibrium model of the global economy, specifically designed to capture structural change dynamics in the medium and long run, with detailed micro data on household income in six countries: Albania, Bolivia, Ethiopia, Malawi, Nicaragua and Vietnam.

The paper is structured as follows. In the next section, we summarize some key findings from the literature on trade and poverty. We explain our modelling strategy in the third section, focusing on the overall logic of the methodology employed. We run the model under the “middle of the road” Shared Socio-economic Pathway number 2 (Riahi et al., 2017) until the year 2050, which informs about future national GDP and population structure. We do not address issues of realism of the assumed scenario, but rather explore, through our model, its implications in terms of income distribution in the six developing countries. Results of the SSP2 baseline model run are presented and discussed in section four. Afterwards, in section five, we introduce an alternative scenario of accelerated international trade integration. We consider first some recent tendencies in the degree of openness of the six economies, noticing that lower trade frictions, which are the principal explanatory factor in neoclassical trade theory, cannot account for the dramatic observed rise in international trade volumes. We turn then to an alternative explanation, based on higher quality of exchanged goods. We simulate in our numerical model this kind of effect, and we elaborate further its implications in terms of poverty in section six. A concluding section discusses the key insights of our research, its limitations and what remains to be explored.

2. Related Literature

There exists a vast literature, which has inquired, from different angles, the nexus between economic development, international trade and poverty (or income distribution). The literature is so large that we refrain from providing a comprehensive summary here. However, we can state that the key questions addressed in the field could be framed in terms of a triangle growth-trade-inequality. For instance: is growth conducive to more trade (or vice versa)? Does higher growth imply more inequality (or vice versa)? Is trade integration bringing about more (or less) inequality?

The main message is that the channels influencing the mutual interrelationships are many and complex (Winters, McCullock and McKay, 2004). Theory provides a strong presumption that trade liberalization will be poverty-alleviating in the long run and on average. At the same time, since trade liberalization tends to increase the opportunities for economic activity, it can very easily increase income inequality while at the same time reducing poverty. Even if trade could contribute to inequality within a country, however, the academic literature has concluded that trade is not the main driver. Nonetheless, adverse effects of import competition appear to be highly geographically concentrated and long-lasting, in developing and developed countries (Pavcnik, 2017).

One major issue in this literature is the possible ambiguity of concepts. When we talk about poverty, for example, are we (perhaps implicitly) referring to income per capita? Or, should we better consider the risk of getting unemployed, which is actually related to market instability (Santos-Paulino, 2012)? Should we focus on the individual or on the household? How to appropriately account for informal markets, self-employment and subsistence consumption?

In the same vein, the concept of higher trade integration is not without equivocalness. The conventional approach is framed in terms of lower trade frictions: tariff and non-tariff barriers, transport, communication and cost margins. As technological progress lowers mobility costs, on one hand, and international agreements lower tariffs and other normative barriers, on the other, the gross volume of international trade would grow over time proportionately more than global GDP (Brahmbhatt, 1998). However, Feenstra (1998) argues that falling tariffs and transportation costs: "are only partial explanations, leaving three-fifths of the growth in trade relative to income unexplained". Furthermore, "when countries become more similar in size, they import more product varieties from each other", as suggested by the modern theory of trade, which stresses the role of economies of scale and product differentiation. The bottom line is that not only the volume of trade matters, but also its nature and composition.

A recent strand of literature has linked trade to knowledge spillovers and endogenous growth, suggesting that this mechanism could bring about trade benefits much larger than what suggested by the conventional theory (Hsu, Riezman, and Wang, 2019). This argument is relevant for income distribution, to the extent that heterogeneous workers sort themselves into different activities, in such a way that more trade produces effects similar to skill-based technological progress (Grossman and Helpman, 2018).

3. Modeling Strategy

We employ a recursive dynamic global CGE modelling framework, based on the flexible, open-source and open-access platform CGEBox (Britz and van der Mensbrugghe, 2018). Specifically, we base our exercise on the G-RDEM model for the construction of future scenarios and simulation of structural change (Britz and Roson, 2019), integrated with some elements of the GTAP-E (McDougall and Golub, 2007), GTAP-AGR (Keeney and Hertel, 2005) and GTAP-AEZ (Lee, 2005) models.

The G-RDEM model extends the standard GTAP model (Hertel and Tsigas, 1997), by adding some key drivers of long-run structural change, namely: (1) variations in household consumption patterns, giving raise to non-linear Engel curves; (2) differentiated sectoral productivity growth, (3) debt accumulation generated by trade imbalances; (4) variable saving rates, influenced by population and income dynamics; (5) time-varying and income dependent industrial input-output parameters.[2]

During the baseline construction, real GDP, population, and workforce projections are provided exogenously, in this case from the SSP2 scenario, at each time step *t*. The model is solved for a simultaneous equilibrium in all commodity and factor markets globally at each period *t*. As it is typical of recursive dynamic models, net investments from step *t* update the capital stocks at *t+1*, while saving rates and input-output coefficients are

[2] A concise description of the G-RDEM model is provided in Appendix A.

also modified between periods. During the process, sector-specific productivity shifters adjust, to get the aggregate total factor productivity needed to align the model with the given trajectory of real GDP.

We also add some features of the GTAP-E model, where energy commodities are divided into different sets, to better capture technical substitution. We introduced the improved representation of the farm and food system of the GTAP-AGR model. The latter applies different elasticities of substitution in the agricultural sectors, allowing for substitution among feedstuffs in livestock production, as well as specific groups of food products in the top-level final demand system, thereby improving the modelling of cross-price effects in food demand. We model land use as in the GTAP-AEZ model, which disaggregates land types into specific uses across different agro-ecological zones (AEZs). There are 18 AEZs in total, which result from distinguishing tropical, temperate, and boreal AEZs, according to the length of the growing season. We further extend the GTAP-AEZ formulation in a number of ways. Firstly, we consider conversion from secondary forest to productive agricultural land as irreversible, in the sense that areas can grow but not shrink. Secondly, we allow for land supply from natural vegetation. As land expansion to forestry and agriculture mostly serves to increase crop land, we use the remaining available crop land buffers as an estimate for the maximal area which can be converted from natural vegetation.

The G-RDEM model, as the standard GTAP model, normally considers only one representative consumer in each country or region. Here, we instead exploit information from a set of household surveys (Food and Agriculture Organization, 2017), to get 12 distinct household categories, for the six countries considered. We distinguish among male and female headed households, urban and rural, poor below the poverty level in 2011), middle income (between poverty and the mode of the income distribution), and rich (the rest). To model each household category, we need to define the various sources of income and the specific consumption pattern, in such a way that the data is consistent with aggregated consumption in the GTAP social accounting matrix. This is obtained here through the myGTAP module, available in CGEBox. Each household is assumed to own property rights to primary factors (labour, land, capital, natural resources), which is allocated to the different sectors to maximize revenues. There is no perfect factor mobility. Instead, a Constant Elasticity of Transformation function allocates the household specific endowments of primary resources to the various production activities. Beside factor income (net of taxation and capital depreciation), households also receive public and private transfers and remittances.

Because of differences in quality, classifications and methods, the integration of household data into the accounting framework of the CGE model has proved to be a difficult task.[3] The number of variables collected in the FAO household national surveys differs, due to specificity and time of the various data collection processes. The number of surveyed households is also variable among countries. Furthermore, one has to take into account that a substantial part of household´s income in developing countries comes from informal activities, especially for rural poor households.

Households in our model exercise are characterized by: (1) their per capita endowments, (2) from which sectors they draw factor income, (3) transfers from government, other households and abroad, and (4) their consumption bundle. While income per capita and its composition is informed by the household surveys, the consumption bundle needs to be estimated. To do so, we rely on the Engel curves underlying the empirically estimated AIDADS demand system in G-RDEM. The parameters of the demand system are first adjusted to match the per capita demand vector of the average aggregate households in each country, as reported in the SAM. From the per capita income of the different households, we estimate per capita demand, while ensuring

[3] Data inconsistency between surveys and national accounts is a known issue of the CGE-microsimulation models coupling (van Ruijven et al., 2015).

that the reported national totals are matched. The non-linear curves, which might differ from country to country, on the basis of the benchmark consumption bundle, drive the budget shares of the different households in the dynamic simulation. In order to capture cross-price effects for closer substitutes, we introduce CES sub-nests for cereals, meats and energy carriers. It is also important to note that we estimate saving rates for each household group, such that richer households spend less, in relative terms, on total consumption.

Endowments of each household are updated between different simulation periods as follows. The supply labour stock follows the national change in population, i.e. we do not attempt to change the household weights endogenously, or to model changes in labour participation rates. Capital and land endowments follow the national variations in the capital and land stocks. Natural resource stocks (services) are currently assumed as fixed.

In order to link households to production sectors, we use information about where wages are earned from the household surveys (and on self-employed earnings), which allows identifying earning shares by endowment and sector. We assume sluggish factor mobility, through household-specific Constant Elasticity of Transformation (CET) functions. That means that households will allocate their labour, capital and natural resource endowments, according to relative differences in returns between the various production sectors. Land rents are driven by the GTAP-AEZ (Agro Ecological Zones) module, which allocates land to sub-national units and sectors.

According to van Ruijven et al. (2015), heterogeneity across household types can be modelled for three aspects of households in CGE models: (1) heterogeneity in factor endowments, (2) heterogeneity in wage rates (e.g. multiple labour markets, segmented by sector) and/or different return rates to capital, possibly linked to labour market participation, (3) heterogeneity in preferences and savings. We fully capture in our model aspects 1 and 3. We do not have multiple markets for labour or capital, nor have we endogenously varying participation rates. However, average returns on primary resources by household do differ, because they depend on how the various households allocate their endowments across industries. Furthermore, we differentiate between skilled and unskilled labour.

4. Insights from the Baseline Scenario

Before considering more directly the role of trade on poverty and income distribution, it is necessary to scrutinize the implications of the assumed baseline scenario SSP2, which is the intermediate “middle of the road” one in the set of IPCC Shared Socio-economic Pathways. A data repository is maintained at the International Institute for Applied Systems Analysis (IIASA)[4], containing baseline information, for each country and up to the year 2100 about: population structure, urbanization rates, and GDP (three estimates generated by different models). From this source, we extract data about national or regional GDP and population, which are therefore taken here as given. Our G-RDEM model works as a sort of “multiplier of scenario variables”, in the sense that it generates a sequence of global general equilibrium states, consistent with information from SSP2, but including details at the level of industrial production, trade flows, consumption patterns, etc. Furthermore, because of the model extension with finer disaggregation for household classes, we can explore the consequences of the chosen baseline in terms of income distribution.

Perhaps the most frequently used metric of economic development is income per capita. Figure 1 shows the evolution of this variable (in real terms, actual purchasing power at constant 2011 US$), for the six countries

[4] http://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about#v2

considered. Since the starting point is quite different, the figure may mask the underlying hypotheses of growth. Growth in real income per capita, over the whole 2011-2050 period, is actually posited at 134% for Albania, 309% for Bolivia, 480% for Ethiopia, 378% for Malawi, 377% for Nicaragua, and 413% for Vietnam. Therefore, Ethiopia and Malawi are running fast but, because of the initial handicap, they only marginally catch-up.

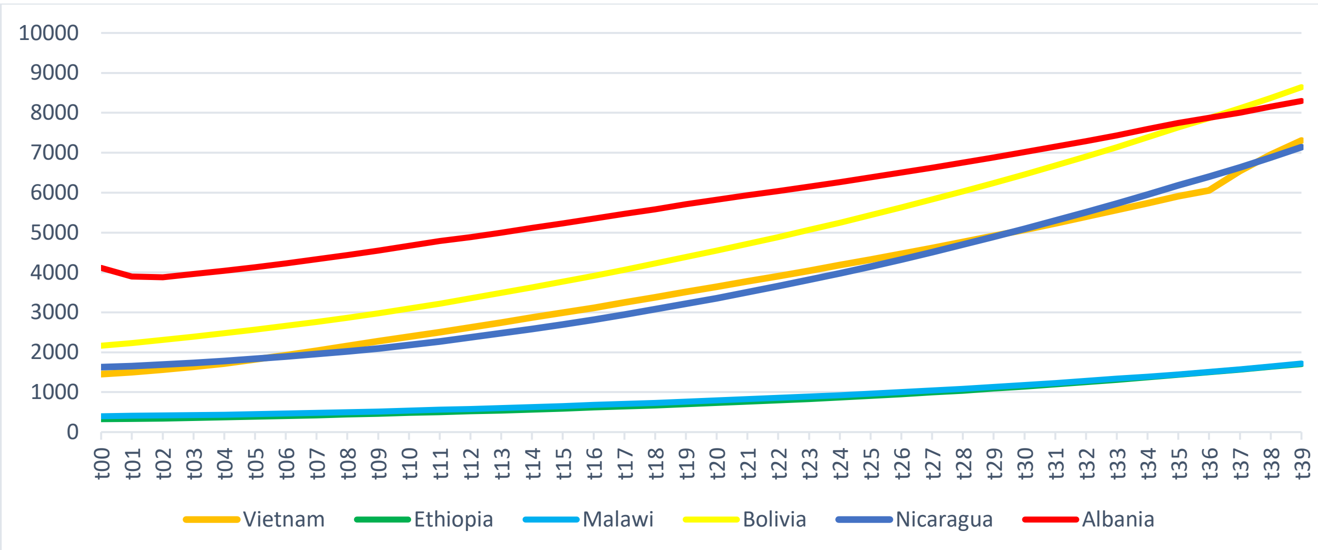

Figure 1. Time profile of per capita real income (constant 2011 US$), from 2011 (t00) to 2050 (t39)

Per capita income or GDP is itself a ratio, therefore dependent on the combined assumptions of growth in GDP and growth in population, which are here totally exogenous. For instance, Figure 2 shows the growth in population.

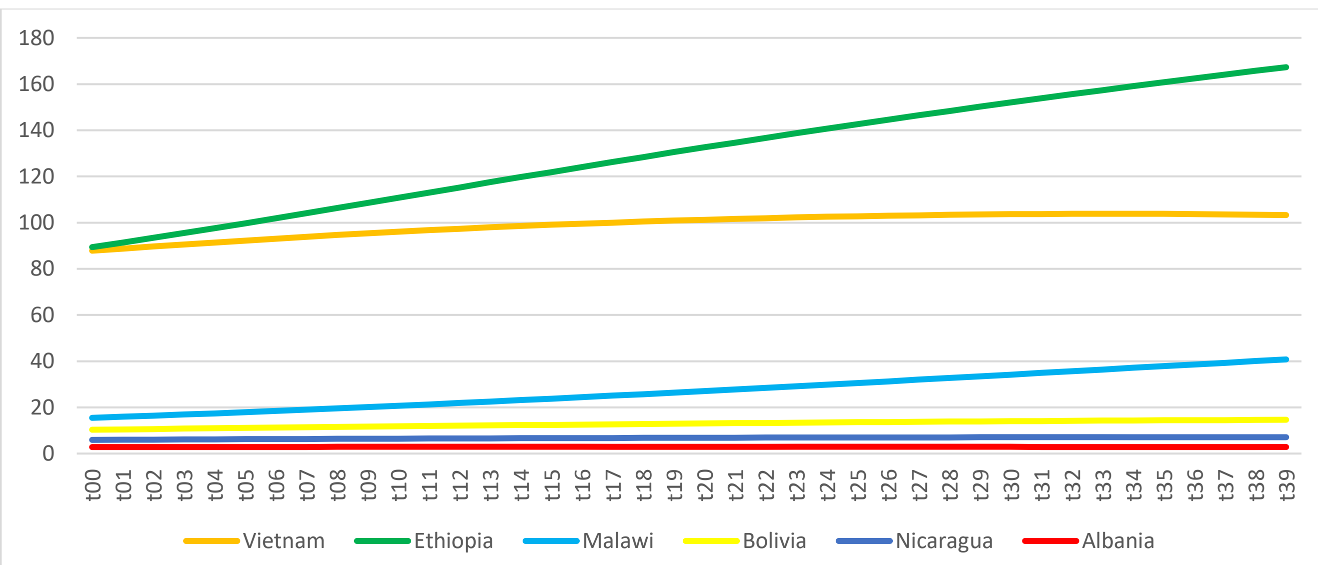

Figure 2. Time profile of population, from 2011 (t00) to 2050 (t39)

We can see that national population is not assumed to grow very much, except for the two African countries. We can therefore infer that the SSP2 scenario is very optimistic about the economic growth in Africa (for an alternative view, see Müller, Stock and Watson, 2019), although the effect at the individual level is curbed by the contemporary increase in population.

What about income at the level of household category? By way of illustration, Figure 3 displays the evolution of nominal income in Bolivia, for the twelve representative households (male/female, urban/rural, poor/mid/rich).

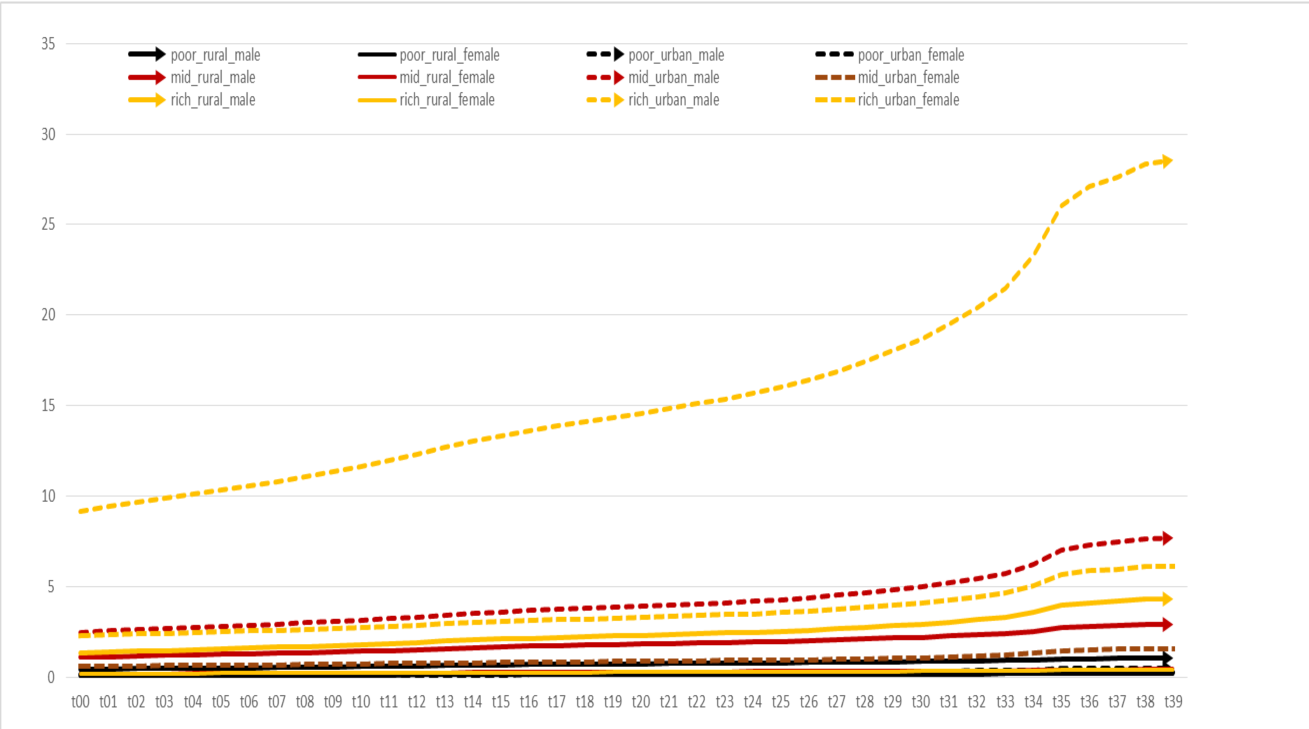

Figure 3. Households' income over time in Bolivia

The key insight here is that the ranking in terms of income does not vary substantially across households, but differentials (therefore inequality) do. Figure 4 further highlights that this is not specific to Bolivia. It shows how the standard deviation in the distribution of income, normalized to one in the base year 2011, varies over time. Malawi stands out as the country experiencing the largest increase in income inequality.

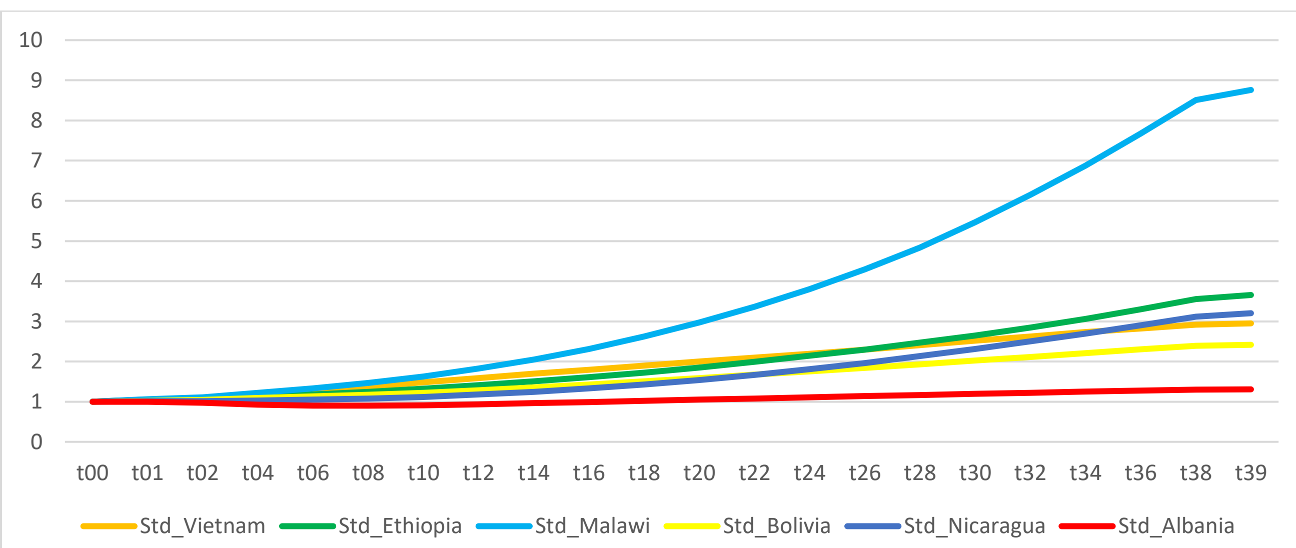

Figure 4. An index of income inequality over time

We also computed a similar kind of index, but considering only poor households versus the rest (Figure 5). The time profile is very similar to the one in Figure 4, with only one major exception: Vietnam. In that country, the increase in *relative* poverty would be substantial, and second only to the one in Malawi.

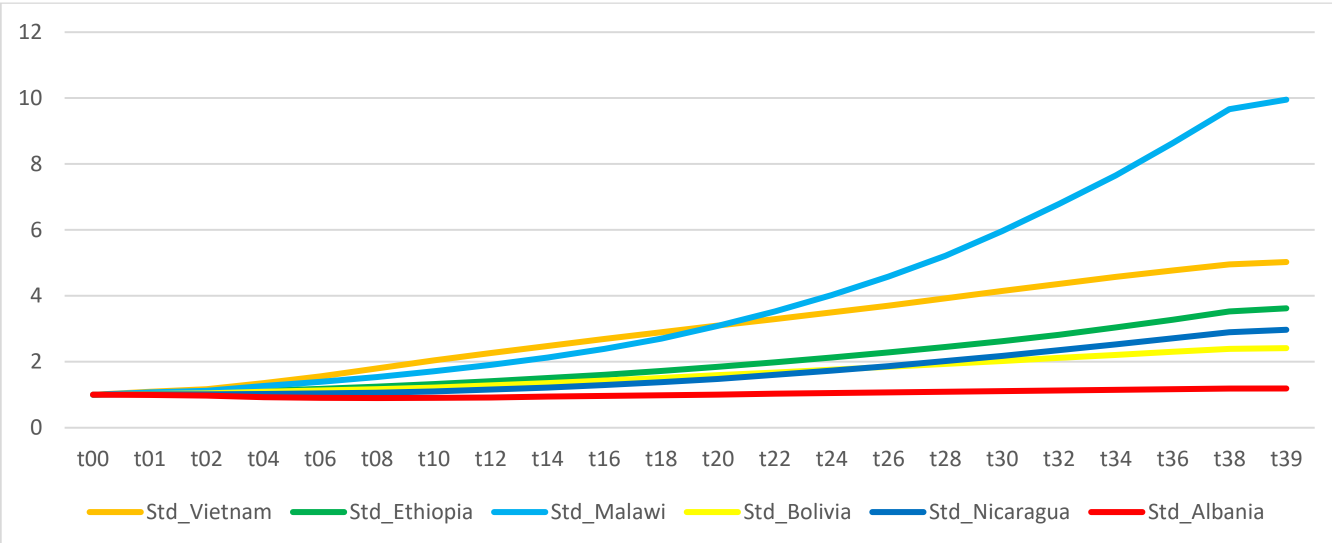

Figure 5. An index of relative poverty over time

Why are we observing higher income inequality? The answer in our model is quite simple. Households get income from the ownership of primary resources: capital, land and labor of different types, natural resources. Those households better off are also those who own larger shares of factors where relative returns grow more. For example, we can imagine that rich households possess large shares of capital and skilled labor. If returns on capital and skilled labor are higher than, say, land and unskilled labor, then they will get relatively richer.

As we shall better see in the following, this is related to the increased volume of trade, which is generated already in the baseline scenario. Indeed, our model is based on the neoclassic theory of trade, driven by differences in relative prices. Figure 6 shows the variation of the ratios between global and national GDP deflators (price indexes), which could be interpreted as indicators of relative competitiveness.

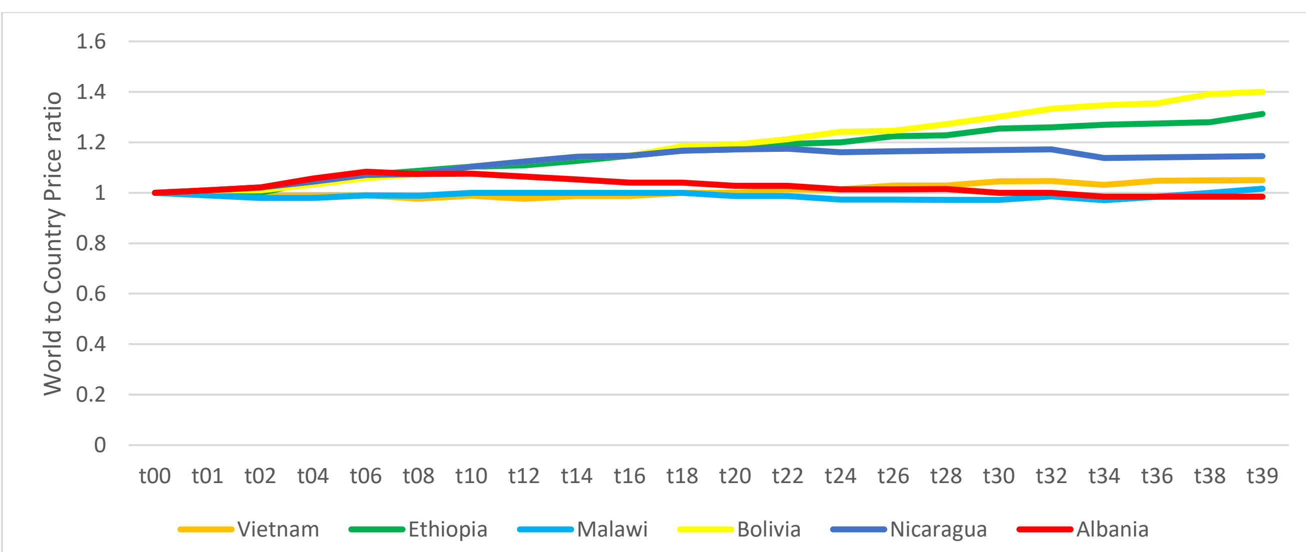

Figure 6. Relative GDP deflators over time

We see that most countries will experience a decrease in the relative price of their products, which boosts exports. The key point here, however, is the enlarging spread in the distribution of price indexes. In a neoclassic model like G-RDEM this means more scope for international trade. All this is confirmed by Figure 6, which shows how the ratio of imports to GDP is getting larger over time. In other words, the volume of trade grows faster than GDP.

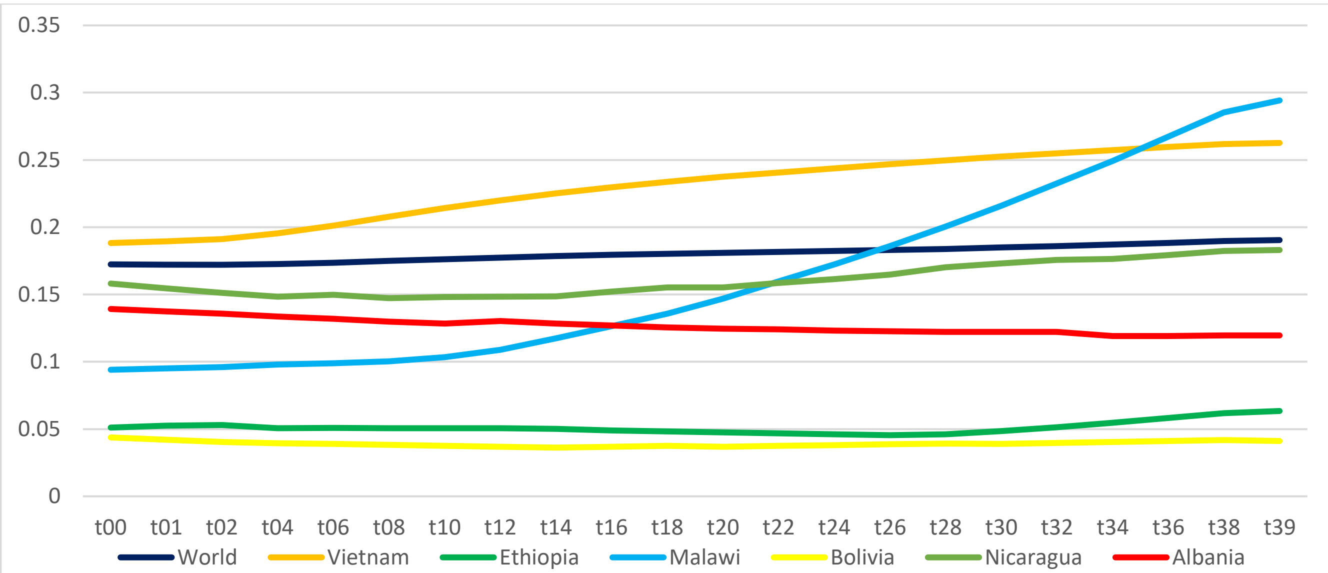

Figure 7. Evolution of the ratio Imports/GDP

It may be worthwhile to take a closer look at trade in agricultural products, both because agricultural goods account for the largest share in the consumption basket of the poor, and because it provides information about the degree of agricultural self-sufficiency in the six developing countries we are considering here. Figure 8 displays the shares of imported grains and crops over total domestic demand for the same commodities.

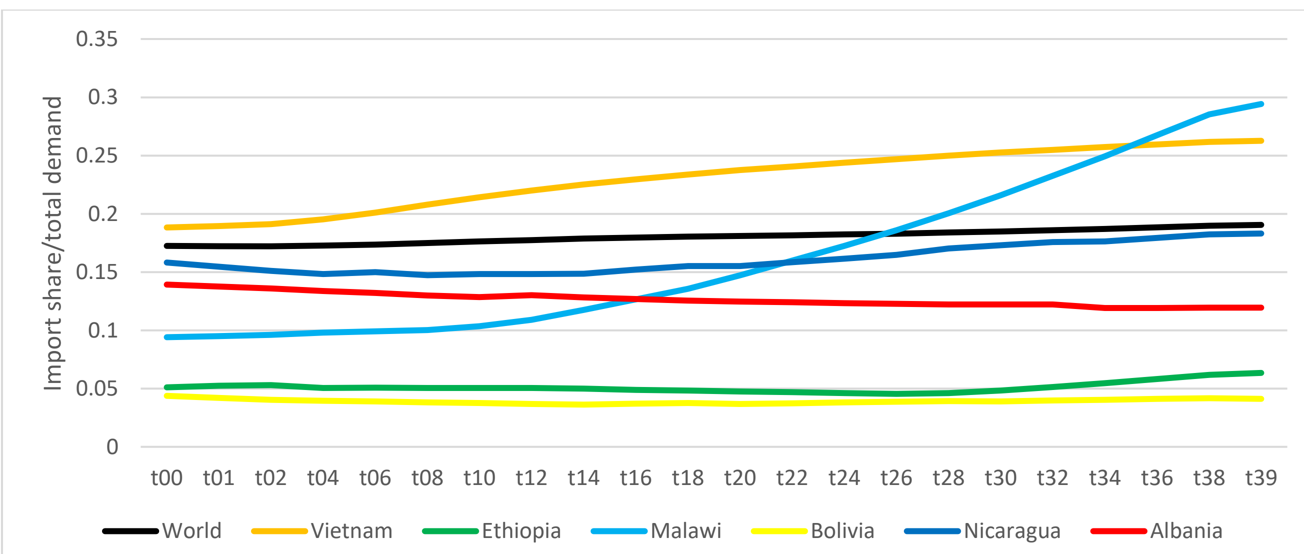

Figure 8. Shares of imported grains and crops over time

Over time, Malawi becomes more dependent on imports of grains and crops from the rest of the world. Something similar occurs in Vietnam (which is already quite import dependent in 2011) and, to a lesser extent, in Nicaragua. Bolivia and Ethiopia do not import much, and they will keep low volumes of imports in agricultural products in 2050.

5. An Alternative Scenario of Increased Trade Integration

The global economy has experienced several decades of increased integration, and this is a long lasting trend, which could only partially explained in terms of reduced trade frictions (Wei, 1996; Feenstra, 1998; Brahmbhatt, 1998). Gravitational models of trade have been proved successful in explaining the amount of trade between countries, and they are today the empirical workhorses in applied international economics. Interestingly, Mussa (2000) notices that "if trade between two countries tends to rise proportionately with respect to each of their economic sizes and diminish with the distance between them, then the suggestion is that doubling the size of both economies should raise their bilateral trade by a factor of four rather than by a factor of two.". This observation is quite relevant for our modeling exercise, since here the baseline scenario is driven by exogenous assumptions about GDP growth, therefore about the future size of the national economies.

In order to check whether the globalization trend is affecting (and to what extent) the six developing countries under consideration, we carried out a preliminary analysis, based on recent historical data. First, for the six countries and for three sectors (Agriculture, Extraction, Manufacturing), we constructed a panel data set 1995-2013 of import and export shares, combining different data sources. More precisely, we estimated the shares of imports on total domestic consumption and the shares of exports on total domestic production. Subsequently, we performed a nonlinear panel regression with random effects, to identify an historical trend component.[5] Figures 9 and 10 display the simulated and forecasted evolution of the *average* (over countries) import and export shares. The vertical line divides the periods between historical past and forecasted future.

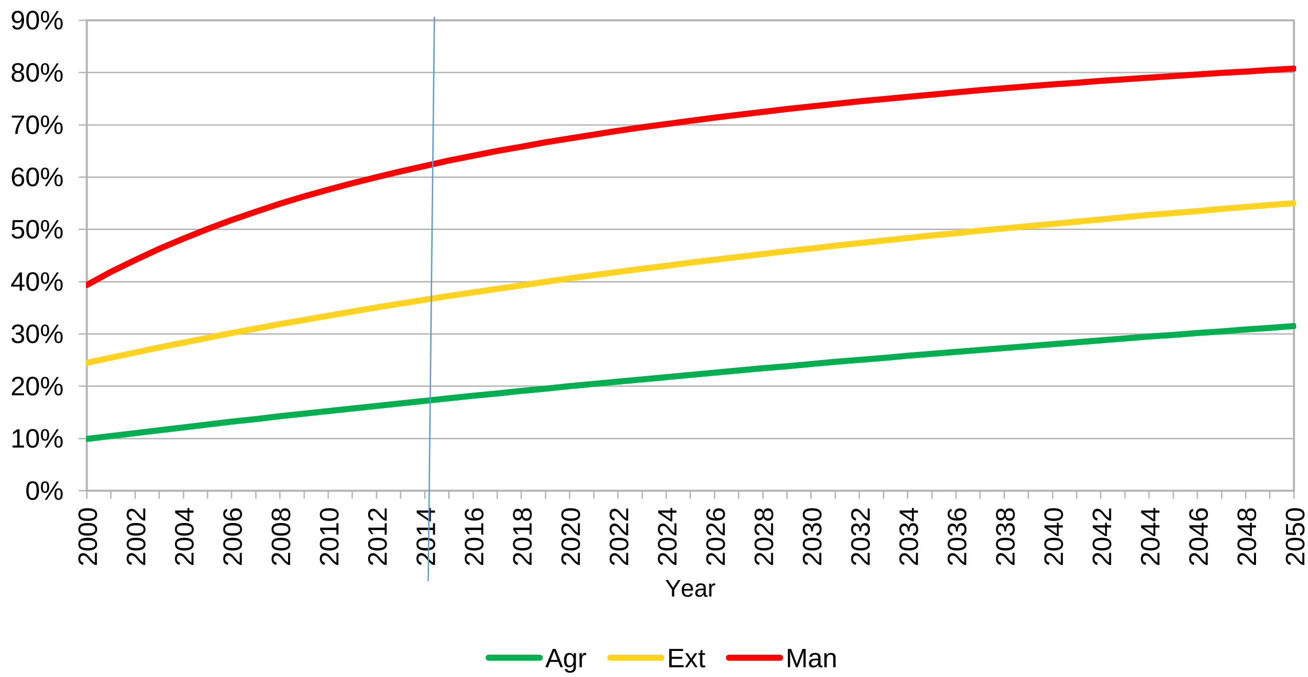

Figure 9. Simulated average import shares

[5] Details of the exercise are provided in Appendix B.

Our econometric results highlight the existence of a clear trend towards increased trade integration for the six countries, which however affects the sectors in a rather different way. Most of the phenomenon involves the manufacturing sector, whereas the agricultural one is comparatively less affected. Because of the paucity of data, we cannot get more detail in terms of sectors. Also, and despite the utilization of random error effects (which partly capture country and time specific idiosyncratic shocks) we cannot single out the potential factors affecting the trend, such as reduced frictions, changing preferences, and variety or quality effects.

Because of the limited time span considered, the high level of aggregation and the low quality of the data employed in our econometric experiment, this is only intended to highlight a broad tendency in the countries under investigation and, for this reason, we do not force our dynamic CGE model to produce results fully consistent with the econometric projections. Rather, we are interested to assess under what conditions, in other words after what parameter variations, the model generates an evolution in import and export shares akin to the one observed in Figures 8 and 9.

To this end, we first carried out a conventional simulation of trade liberalization, by halving all import tariffs in all industries around the world in the period 2011-2050. The effect on trade shares is minimal. This is likely due to the low initial level of tariffs, which furthermore are even lower for manufactured goods.

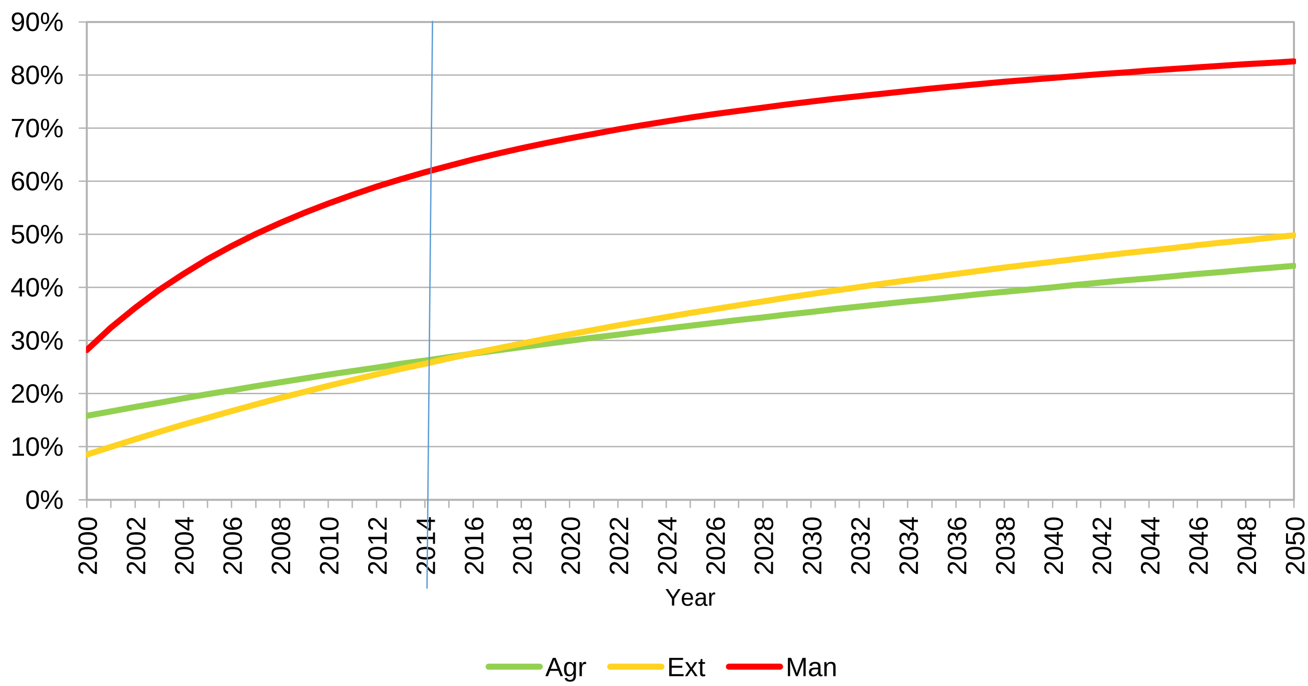

Figure 10. Simulated average export shares

We looked then for some alternative factors, possibly driving the trend of increased globalization and trade openness. Modern international trade theories suggest that more exchanges with the rest of the world make more goods, at higher quality, available to consumers and firms. This could be interpreted as an increase in the productivity of the bundle of traded goods and services, in the sense that more utility or output is obtained from a physically equivalent aggregate of exchanged items.

To simulate this effect into our model, we consider the CES demand layer, steering the choice in demand between imports and domestic products, which has the following structure:

$$\frac{\lambda M}{D} = \alpha \left(\frac{\lambda P_D}{P_M}\right)^{\sigma} \qquad (1)$$

where M are imports, D domestic products in the same industry, σ is the elasticity of substitution, P are price indexes, and the remaining symbols are parameters. The parameter λ, which is initially set to one, expresses the relative productivity/quality of imports over domestic products, such that λM expresses imports in efficiency units. When the model is calibrated at the initial year, prices are normalized to one and therefore a value is assigned to the structural parameter α.

When λ increases, two opposing effects are at work. First, there is a direct productivity effect, by which you need to import lower quantities to get the same utility level. Second, there is a substitution effect, because imports get more convenient, which is equivalent to a reduction in the price index P_M. It is straightforward to show that the substitution effect prevails over the direct productivity one if the elasticity of substitution is larger than one (as it is the case in our model).

Consequently, one way to generate larger import shares (and export shares, since imports by one country correspond to exports by other countries), is to set higher values for parameters λ in the model. Figure 11 presents the total export and import shares for the whole set of six countries in the tree cases: baseline, trade liberalization through lower tariffs (Low-Tariff) and higher productivity /quality (Open-Trade).

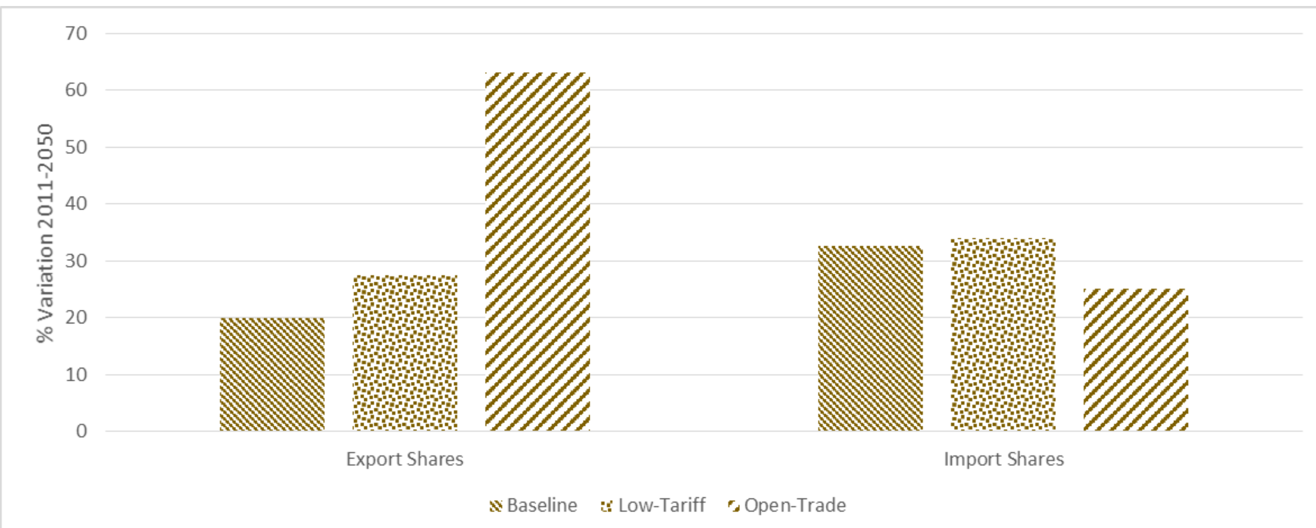

Figure 11. Trade shares in three different scenarios

We can see that lower tariffs do not vary the shares much, whereas the higher productivity of internationally traded goods boosts exports, but at the same time shrinks import shares. This seeming contradiction can be explained by the fact that the model generates, under the Open-Trade scenario, a real devaluation of the currencies (on average) in the six countries. Indeed, whereas the balance of trade for the six countries turns out to be negative at the year 2050 in the baseline (-469M US$) and in Low-Tariff (-397 US$), it becomes a surplus when trade productivity is increased (+258 US$). This devaluation makes imported goods less convenient, counteracting the substitution effect associated with the higher relative productivity of imports.

Nonetheless, we can conclude that, net of the endogenous devaluation mechanism, the scenario based on higher values for the productivity parameters λ succeeds in simulating an increase in the degree of trade openness. For this reason, we adopt it here as a contrasting case with respect to the baseline, mainly to investigate the implications of such accelerated globalization scenario on income distribution and poverty.

We start by considering the variation in relative income, with respect to the initial year, separately for female- vs. male-headed households, rural vs. urban households, poor vs. non-poor households. Therefore, a negative variation should be interpreted as a worsening of income inequality, in the corresponding dimension.

Figure 12 illustrates the evolution of inequality between male and female headed households in the six countries. Much of the income gap is generated already in the baseline, most notably in Albania and, to a lesser extent, in Malawi and Bolivia, whereas Ethiopia goes to the opposite direction. More trade does not add very much to the picture, worsening inequality in Malawi, but improving it somewhat in Bolivia, Nicaragua and Ethiopia.

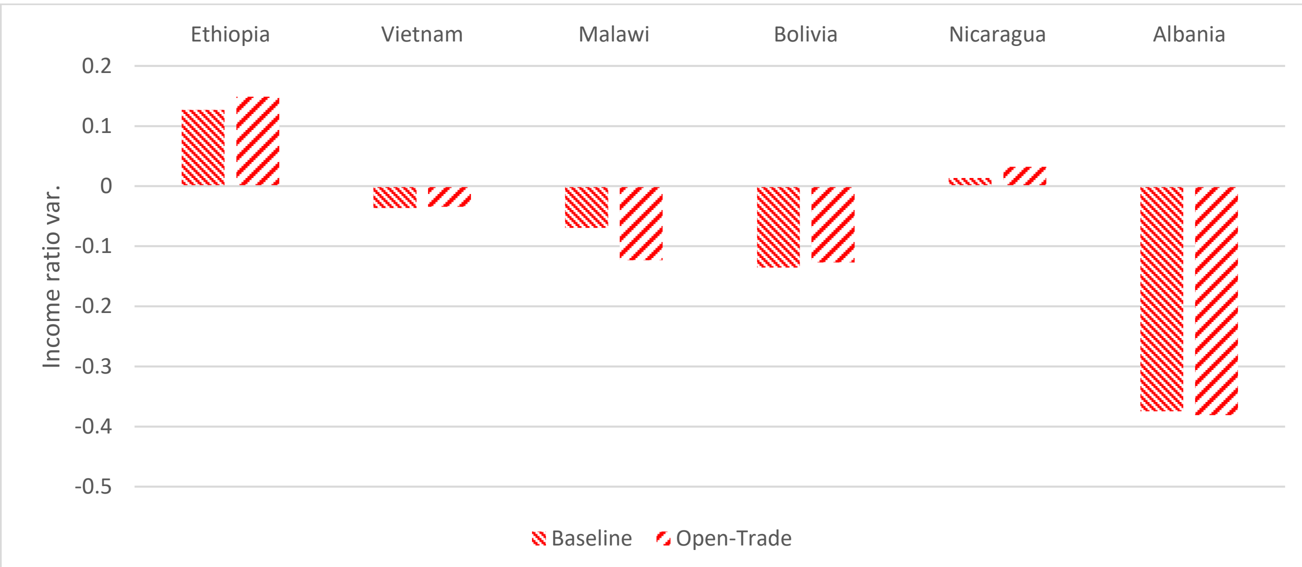

Figure 12. Variations 2011-2050 in relative income female/male

Figure 13 presents a similar kind of analysis, but this time considering the relative income of rural and urban households. We can see here a quite different picture. First, inequality does not vary to the same direction in all countries in the baseline. Rural/urban income inequality is narrowed (in the sense that rural income increments more than the urban one) in Malawi, but widened in all other countries. Accelerated trade integration does make a difference here, unambiguously worsening income inequality with respect to the baseline, most notably in Malawi, Bolivia, Nicaragua and Albania.

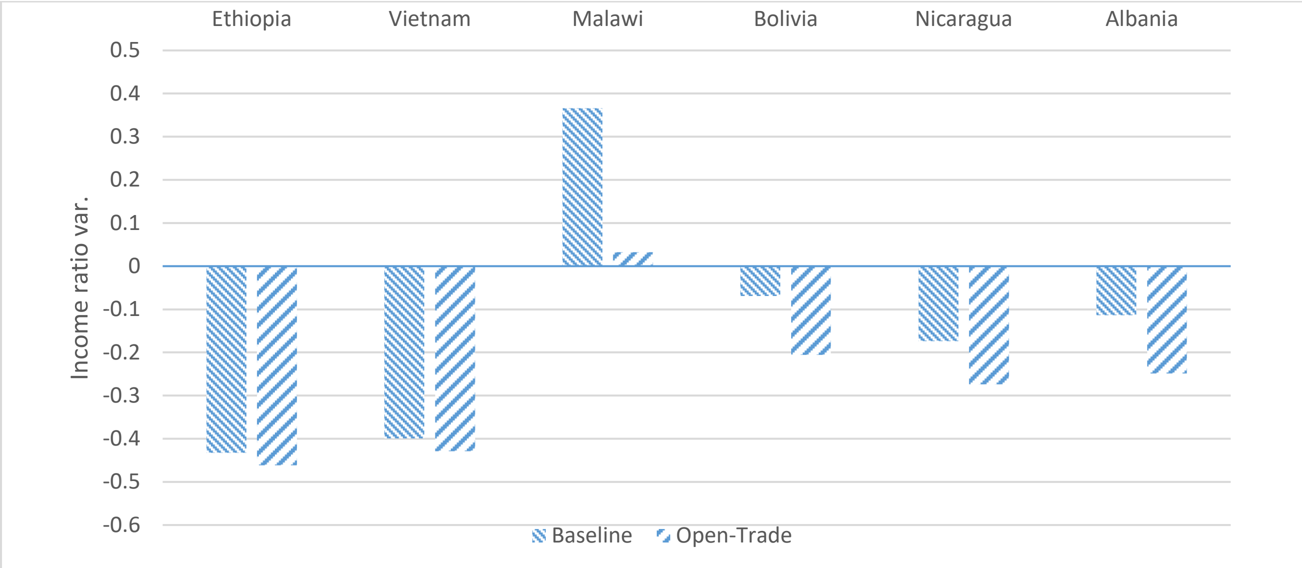

Figure 13. Variations 2011-2050 in relative income rural/urban

Finally, Figure 14 considers income differentials in terms of relative poverty. The growth paths embedded in the baseline are generally characterized by a worsening of relative poverty, which is especially evident in Ethiopia, Vietnam, Nicaragua and Albania. More international trade further worsens relative poverty, especially in Malawi, Bolivia and Albania.

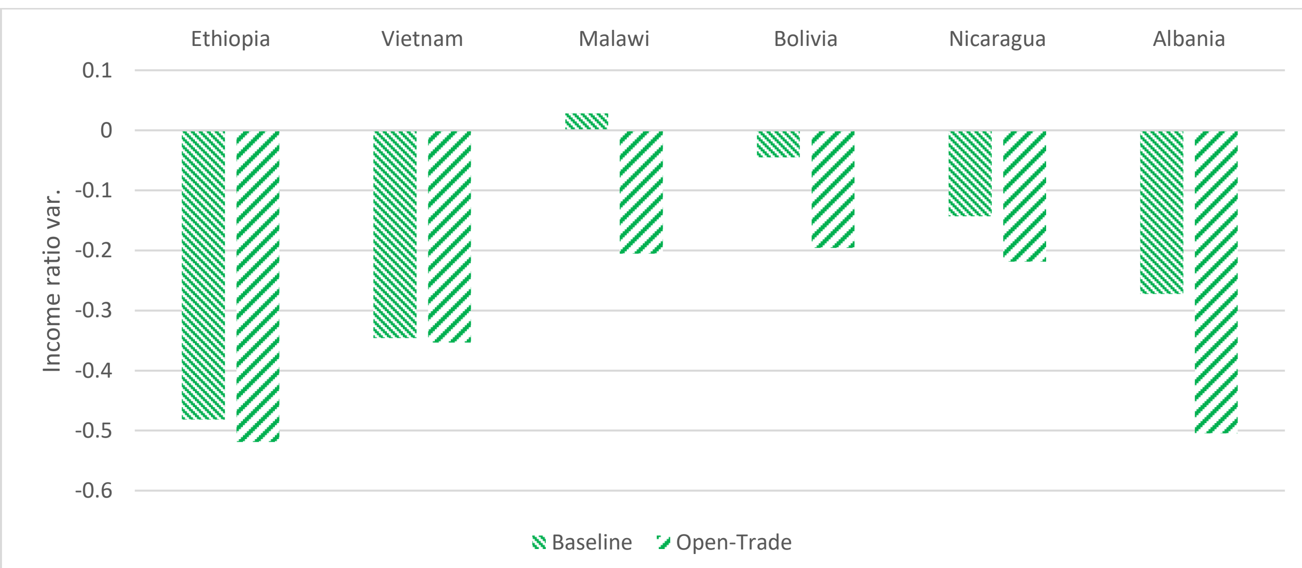

Figure 14. Variations 2011-2050 in relative income poor/non-poor

6. Analyzing the results in terms of absolute and relative poverty

We consider now what the main determinants of changes in relative poverty are, expressed as percentage variations in the ratio (R) of incomes of poor (I_P) and non-poor (I_n) household groups. We focus here on the factor income only, which is income derived from the ownership of primary factors, neglecting other elements, like taxes or transfers.[6] Using lowercase letters to indicate percentage variations (equivalently, changes in logarithms), then:

$$r = i_P - i_N \tag{2}$$

We can further decompose the change in income by source (land *L*, capital *K*, unskilled labor *U*, skilled labor *S*, natural resources *R*), as:

$$i_P = S_P^L i_P^L + S_P^K i_P^K + S_P^U i_P^U + S_P^S i_P^S + S_P^R i_P^R \tag{3}$$

$$i_N = S_N^L i_N^L + S_N^K i_N^K + S_N^U i_N^U + S_N^S i_N^S + S_N^R i_N^R \tag{4}$$

Where *S* are the shares of each source in total factor income of the household category.

Plugging (3) and (4) into (2), and grouping:

$$r = i_P - i_N =$$

$$= (S_P^L i_P^L - S_N^L i_N^L) + (S_P^K i_P^K - S_N^K i_N^K) + (S_P^U i_P^U - S_N^U i_N^U) + (S_P^S i_P^S - S_N^S i_N^S) + (S_P^R i_P^R - S_N^R i_N^R) \tag{5}$$

Therefore, the components in parentheses express the contribution of the various sources of income to the overall variation in relative poverty.

To better appreciate the decomposition above, consider that the percentage variations in income by source are *approximately* the same for the two groups. This is because income is the product of factor quantity and price. In our model, ownership shares are given, so that group specific factor endowments move proportionally. On the other hand, prices are actually price indices, because they depend on how households allocate their resources among the various sectors. Without a major reallocation of resources, however, the two price indices will be characterized by variations of comparable magnitude.

This implies that the contribution of a specific source to relative poverty is driven by two elements: (a) the (similar) variation in source income, (b) the difference in the shares *S*. For example, if land income increases significantly and/or poor households get most of their income from land ownership, then land would contribute to narrow the relative poverty differential.

In Table 1 below, we summarize the main findings of the relative poverty impact decomposition, for all six countries, using the methodology described above. More detailed regional results are presented in Appendix C. We consider two variations in relative income of the poor: the change in the baseline 2011-2050, and the change in 2050 between the two scenarios (baseline and open-trade). Therefore, the first variation refers to the assumptions employed for long term growth, whereas the second one gauges the incremental effect of accelerated trade integration. Alongside both variations, we identify the most important factor in terms of impact on the relative income of poor households, which is the one having the largest change in absolute value.

[6] These other elements are considered in Figure 14.

	Var. 2011-2050 BL	Most Imp. Factor	Var. 2050 OT-BL	Most Imp. Factor
Albania	-10%	Capital (-7%)	-45%	Land (-25%)
Bolivia	-15%	Capital (-14%)	-8%	Land (-11%)
Ethiopia	-32%	Capital (-36%)	+9%	Capital (+7%)
Malawi	9%	Land (+25%)	-13%	Land (-21%)
Nicaragua	-12%	Capital (-20%)	-3%	Land (-6%)
Vietnam	-53%	Capital (-55%)	+18%	Capital (+23%)

Table 1. Analysis of changes in the relative income of poor households

A quick inspection of Table 1 reveals some interesting points. First, our growth baseline scenario generally worsen relative poverty (except in Malawi). This effect is generally driven by increases in capital income, which is an important source for non-poor households. Second, higher international trade also generally worsen relative poverty (except in Vietnam and Ethiopia). This time the key driver is land, because higher trade openness tends to reduce the value of land, which is a very important asset for poor households.

We now turn to analyze the findings in terms of absolute poverty, which in the FAO household surveys is defined as a daily average expenditure below the threshold level of 1.9 US$, in the reference initial year. Incidence of absolute poverty is especially relevant in the two African countries (Ethiopia 82.5%, Malawi 70.8%), but also in Vietnam (54.1%).

To estimate absolute poverty levels for the year 2050 in the baseline scenario, we got from the model the regional variations in income by source, already employed for the assessment of relative poverty. These variations have been divided by the corresponding GDP deflator, to convert income 2050 to equivalent purchasing power 2011. Using household data, which inform about the income structure of each unit, we have therefore been able to roughly estimate what would be the household income at the final year 2050, expressed in terms of 2011 US$, which makes it comparable with the conventional poverty line.

This kind of elaboration could be considered as an implementation of a simple, accounting or "non-behavioural" microsimulation framework (Estrades, 2013, van Ruijven et al., 2015).

Table 2 presents the percentage of households below the absolute poverty threshold in the two years 2011 and 2050.

	% HH poverty 2011	% HH poverty 2050
Albania	0.86	7.86
Bolivia	11.89	0.00
Ethiopia	82.49	1.64
Malawi	70.77	10.01
Nicaragua	20.33	0.00
Vietnam	54.07	0.00

Table 2. Share of households below the absolute poverty threshold

The key insight from Table 2 is that absolute poverty would be eradicated in all countries, with the exception of Malawi.[7] The main reason behind the persistence of poverty in this country is the high population growth.[8]

[7] We do not regard the result of Albania as very reliable. There is no reported information in the FAO survey for Albanian poor households (only 12 units) in terms of capital and unskilled labor income (see Table C1). Factor income is seemingly obtained in equal proportion from land and skilled labor, which explains the figures in Table 2.

Combining these findings with those summarized in Table 1, we can conclude that our scenario implies a substantial improvement of average living conditions, associated however with more inequality in the six countries.

7. Concluding Remarks

The analysis presented in this paper is not about forecasting. Rather, we have adopted one hypothetical scenario, which is often taken as a reference in climate and environmental modeling, without discussing its likelihood. Furthermore, we have shocked parameters in our model, to build an alternative setting characterized by larger trade volumes, without really worrying about whether or not some past trends about trade intensity can extend to the distant future. This is because our primary aim is investigating the implications of given assumptions of growth, in terms of income distribution, for a set of developing countries.

We have pursued this objective through a complex but innovative modeling methodology. Since the SSP2 scenario only informs about GDP and population growth, we have employed a recursive dynamic CGE model (G-RDEM) to get a sequence of general equilibria for the global economy, consistent with the SSP2 hypotheses but with much more sectoral detail. Furthermore, the G-RDEM model simulates a series of adjustment processes occurring during various stages of economic development, such as changes in demand patterns, or non-uniform gains in sectoral factor productivity.

The structural change simulated in the model has direct consequences on the distribution of income. For instance, as the share of services in intermediate and final consumption gets larger, and at the same time productivity in the production of services improves at a slower rate than in other sectors, the relative price of services is bound to increase (the "Solow disease"). Consequently, even the price of those primary factors for which the services are intensive (e.g. skilled labor) will follow. Income distribution would then also vary, because of the diverse ownership shares of primary factors ascribed to the various population groups.

There exists a vast literature dealing, on one hand, with the link between inequality and growth and, on the other, between growth and structural change. Surprisingly enough, very few research works have directly tackled the relationship between structural change and income distribution, or poverty, like we have done in this paper. One exception is Cook and Uchida (2008) who came to some conclusions confirming the key findings of our modeling exercise, despite the fact that the two studies are based on completely different methodologies and approaches. They noted that industries that have the highest impact on growth (like high tech) have the greatest potential for worsening income distribution in developing countries. However, income inequality effects could be offset if the growth effects are large enough and, therefore, contribute to reducing poverty by raising average incomes.

A distinguishing feature of our exercise is the disaggregation of final consumption demand in 12 distinct household classes, thereby departing from the standard CGE setting with a single representative consumer. Multiple households CGE models for the assessment of poverty and income distribution do exist, since the seminal studies by Cogneau and Robilliard (2000), and Cockburn (2006), but the prevalent approach in the literature is the one in which a macro CGE model and a microsimulation household model are kept separate and soft-linked (Ahmed and Cathal, 2007).

Furthermore, almost all studies of this type have a comparative static nature. This is because the typical research question deals with the impact on the distribution of income of some fiscal reform, or some change in

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[8] Population growth is high but comparatively smaller in Ethiopia, whereas the opposite occurs for regional income.

international prices (e.g., Dartanto and Usman, 2011). There are only a few dynamic CGE models with multiple households (e.g., Annabi et al., 2012, for a review see van Ruijven, 2015). However, contrary to our G-RDEM model, the typical dynamic CGE model does not account for long run structural adjustment processes.

When reconciling data from the social accounting matrix used to calibrate our CGE model, and data from household surveys in the six countries, we decided to give preponderance to the SAM (to keep all accounting balances), whereas information from the surveys was only employed to infer a set of disaggregation weights. More generally, we were unable to model inter-households dynamics, such as rural households migrating to the city, thereby moving from one group to another. We acknowledge that this is a serious limitation in our model, which could possibly be overcome in the future, when more data will hopefully allow introducing specific behavioral assumptions.

Keeping these caveats in mind, we believe that the insights obtained by our modeling exercise are sufficiently robust. We have found that long run structural change widens income inequality in all six developing countries. Accelerated trade integration amplifies the effect further, but most of it is already generated in the baseline scenario. A decrease in the relative value of land property and an increase in the relative value of capital ownership appears as key determinants.

We have decomposed income differentials in three dimensions. Structural change worsens the income gap between male and female headed households, especially in Albania, but the additional impact of trade is minimal. The effect of structural change is not uniform across countries when income of rural households is contrasted with the one of urban households, yet more trade reduces the relative rural income. Relative poverty increases in both the baseline and the larger trade volume case. However, we found that absolute poverty would be eradicated in almost all countries by the year 2050.

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Appendix A: A Concise Description of the G-RDEM Model

G-RDEM is a computable general equilibrium model, designed for the construction of internally consistent and sufficiently detailed scenarios of long-run economic development (Britz and Roson, 2019). The model is a recursive dynamic extension of the GTAP standard comparative static model, with the inclusion of five distinguishing features, meant to capture some key adjustment processes in the long run.

The structure of the GTAP model is fully described in Hertel and Tsigas (1997), although some minor changes have been introduced recently (Itakura and Hertel, 2001; Corong et al., 2017). Most basic assumptions in the model are canonical for a general equilibrium setting: industries are modeled through representative, cost-minimizing firms with constant returns to scale and zero profits; households maximize utility under a budget constraint; revenues are obtained by selling services of primary factors; all macroeconomic identities hold, etc.

Some other assumptions are less common, in particular:

- Utility of the representative household is implicitly defined as a Constant Differences in Elasticity (CDE) function (Hanoch, 1975). This function allows for (rather limited) differences in income elasticities among consumed goods and services.
- Aggregate savings are a constant share of national income. Savings are virtually collected by a global bank and redistributed as physical investments, without the need to match national savings to investments, therefore to have the trade balance in equilibrium.
- Trade and transport margins in international commerce are handled similarly, by means of virtual global transport and trade agents.

Although a dynamic variant of the GTAP model does exist (Ianchovichina and Walmsley, 2012), the simplest way of making the model dynamic is by framing it as a chain of temporal general equilibria. This can be simply done by making the (exogenous) capital stock at time *t* dependent on (endogenous) investments at time *t-1*. When there is no intertemporal optimization, this approach is often termed “recursive dynamics”. In general, that extension alone will not generate a realistic path of economic growth.[9] This is why the usual methodology for the calibration of this kind of models entails the generation of a “baseline” path, obtained by imposing GDP levels at each period (obtained, e.g., by a macroeconometric model or by a given scenario), while making endogenous some factor productivity parameter. Counterfactual simulations are then obtained by setting the resulting productivity parameter back to exogenous, while over-imposing shocks, possibly time-dependent, to other parameters. This means that the model dynamics is partly endogenous (capital accumulation) and partly exogenous (productivity growth).

G-RDEM introduces five additional features into the recursive system:

[9] There are several reasons for this. One reason, for example, is the assumption of exactly one year lag for the transformation of investments in fresh new capital, which may not hold in the real world.

1. The GTAP CDE utility function is replaced by an AIDADS demand system.[10] The AIDADS is An Implicit, Directly Additive Demand System (Rimmer and Powell, 1992). It can be understood as a generalization of a Linear Expenditure System, where marginal budget shares are not fixed, but are a combination of two vectors, depicting the budget structure at very low and very high utility (income) levels. The reason for replacing CDE with AIDADS is that the latter can account for more effects driven by differences in income elasticity, which is important when variations in per-capita income are large, as it is typically the case in the long run.

2. Total factor productivity is allowed not to vary uniformly among industries and sectors. Indeed, differential productivity growth is one key factor of structural change in the economic systems, and probably the most important one (Swiecki, 2017). In G-RDEM, a function of the GDP growth rate is used, expressing the variation of productivity in Agriculture and Manufacturing relative to the one in the Services. The latter is endogenously computed during the generation of the baseline dynamic path, to get consistency with the imposed trajectory of growth.

3. The national, aggregate saving rate (marginal propensity to save out of the national income) can change over time, mainly as a consequence of variations in the demographic structure. The saving rate is expressed as a function of: (a) Population composition by age group; (b) per capita GDP growth and its growth. Parameters for this relationship have been estimated through a cross-section econometric regression.

4. Interest payments on cumulated past foreign debt are considered in the model. To this end, an equation is introduced, which computes the debt stock.[11] The given interest payments on the stock of foreign debt enter the equation defining the regional income, in addition to the factor and tax income. They are positive for a country which was in the past a lender and negative for past debtors.

5. Parameters of the production function, applied to the representative firm in each regional industry, are calibrated on the observed cost structures of the base year SAM, but in G-RDEM they are allowed to vary. This is because, as the economy grows, the average industrial cost structure may vary even if the production technologies for individual goods stay the same. The relevance of the composition effect is a purely empirical question, which is addressed in the model by checking for the existence of a relationship between cost shares and an index of per-capita income[12]. It is found that, out of the 65 input-output coefficients with a cost share of at least 1%, more than 40 turn out to have a highly significant relation with per capita income. The estimates have therefore been introduced in G-RDEM as functions, updating input-output coefficients (parameters of the industrial production functions), from one time period to the next.

[10] The parameters of the demand system has been estimated in a cross-sectional analysis by , based on global data by the International Comparison Network (ICP).

[11] This is usually assumed to be zero in the starting year.

[12] Economies are not closed in our system. Therefore, the index was built though trade weighted aggregation of per-capita incomes.

Appendix B: A Panel Estimation of Trade Shares Evolution

Estimates of gross industrial production are not regularly produced by national accounts agencies. We therefore built our own estimates, starting with sectoral value added data obtained from the UNData search engine (https://data.un.org/). Value added is available for seven industries in the period 1995-2013 and for the seven developing countries under consideration. However, data on international trade is accessible for only three of them: Agriculture, hunting, forestry, fishing (ISIC A-B, termed Agriculture in the following); Mining, Manufacturing, Utilities (ISIC C-E, termed Extraction in the following); Manufacturing (ISIC D).

We employed data from the GTAP9A data base (http://gtap.org), to get two different pieces of information. First, time series of export and import flows, by sector and country. Second, from the global Social Accounting Matrix of the year 2004 (central year in our time window), we obtained the ratio between gross output and value added. We made the (strong) assumption that this ratio stays approximately constant along the period 1995-2013, so that we could convert value added to production volumes.

	Albania	Bolivia	Ethiopia	Malawi	Nicaragua	Vietnam
Agriculture	2.17	2.65	1.39	2.06	2.20	2.32
Extraction	2.13	2.74	3.33	3.12	5.63	2.29
Manufacturing	3.04	3.98	10.22	3.64	3.00	5.69

Table B1. Output/VA ratios

Table B1 shows the ratios used for the conversion. The lower the value, the lower the employment of intermediate factors in the production processes. You can notice that Ethiopia stands out as an outlier, which casts some doubts about the quality of data for this country.

The difference between gross output and export gives domestic absorption of national products. The ratio between imports and the sum of imports and absorption (total internal demand) provides the share of demand, which is satisfied through imports. Conversely, the ratio of export over gross production right away informs about the share of production, which is directed abroad. In a scenario of increased international trade integration, we expect that both import and export shares increase over time.

To identify a trend component in the evolution of import and export shares, we ran a panel regression with random effects, using the plm package of the R software. Since shares *s* are constrained to stay within the [0,1] interval, the regression is performed in terms of the transformed variables *s/(1-s)*, whose domain is [0, infinity]. More precisely, the estimated model is:

$$\frac{s_{c,t}}{1-s_{c,t}} = \alpha + \beta(t-1995) + u_c + v_t + e_{c,t}$$

Where *s* are import or export shares of country *c* in year *t*, and *u, v, e* are random variables. Table B2 below presents the estimated values for the α and β coefficients.

Shares	α	β
Agriculture, imports	.07530	.00655
Extraction, imports	.2335	.0185
Manufacturing, imports	.2943	.0711
Agriculture, exports	.1277	.0122
Extraction, exports	.00295	.01755
Manufacturing, exports	-.0424	.087

Table B2. Estimated coefficients

Appendix C: Regional Relative Poverty Impact Analysis

	Poor	Non-Poor	Diff.
Factor Income - Land	12.5%	3.3%	9.2%
Factor Income - Capital	0.0%	27.1%	-27.1%
Factor Income - UnSk Labor	0.0%	5.6%	-5.6%
Factor Income - Skill Labor	12.5%	23.5%	-11.0%
Factor Income - Nat.Res.	0.0%	1.3%	-1.3%
Direct taxes	-0.1%	-7.1%	7.0%
Remittances received	6.1%	1.3%	4.8%
Remittances sent	-0.1%	-0.3%	0.2%
Govern transfers	56.4%	33.9%	22.5%
Private transfers	12.7%	11.5%	1.2%
Total	100.0%	100.0%	0.0%

Table C1. Income structure poor/non-poor in Albania

	Poor	Non-Poor	Diff.
Factor Income - Land	22.9%	3.4%	19.5%
Factor Income - Capital	34.3%	33.2%	1.1%
Factor Income - UnSk Labor	4.9%	13.2%	-8.3%
Factor Income - Skill Labor	50.7%	37.9%	12.8%
Factor Income - Nat.Res.	3.3%	3.9%	-0.6%
Direct taxes	-0.4%	-1.3%	0.9%
Remittances received	0.9%	2.3%	-1.4%
Remittances sent	-1.4%	-1.2%	-0.2%
Govern transfers	0.0%	7.3%	-7.3%
Private transfers	-15.3%	1.4%	-16.7%
Total	100.0%	100.0%	0.0%

Table C2. Income structure poor/non-poor in Bolivia

	Poor	Non-Poor	Diff.
Factor Income - Land	7.4%	4.5%	2.9%
Factor Income - Capital	40.4%	52.9%	-12.5%
Factor Income - UnSk Labor	11.2%	18.5%	-7.3%
Factor Income - Skill Labor	56.0%	45.2%	10.8%
Factor Income - Nat.Res.	0.8%	0.9%	-0.1%
Direct taxes	-1.6%	-0.5%	-1.1%
Remittances received	0.1%	0.2%	-0.1%
Remittances sent	-0.3%	-0.3%	0.0%
Govern transfers	2.1%	0.5%	1.6%
Private transfers	-16.2%	-22.4%	6.2%
Total	100.0%	100.0%	0.0%

Table C3. Income structure poor/non-poor in Ethiopia

	Poor	Non-Poor	Diff.
Factor Income - Land	8.6%	3.9%	4.7%
Factor Income - Capital	27.6%	34.5%	-6.9%
Factor Income - UnSk Labor	7.4%	12.7%	-5.3%
Factor Income - Skill Labor	47.3%	47.6%	-0.3%
Factor Income - Nat.Res.	1.8%	3.6%	-1.8%
Direct taxes	-8.7%	-4.0%	-4.7%
Remittances received	1.7%	1.7%	0.0%
Remittances sent	-0.5%	-0.5%	0.0%
Govern transfers	3.9%	1.8%	2.1%
Private transfers	10.9%	-1.2%	12.1%
Total	100.0%	100.0%	0.0%

Table C4. Income structure poor/non-poor in Malawi

	Poor	Non-Poor	Diff.
Factor Income - Land	14.9%	4.8%	10.1%
Factor Income - Capital	24.3%	31.9%	-7.6%
Factor Income - UnSk Labor	5.4%	16.1%	-10.7%
Factor Income - Skill Labor	46.0%	35.6%	10.4%
Factor Income - Nat.Res.	0.0%	0.6%	-0.6%
Direct taxes	-0.1%	0.0%	-0.1%
Remittances received	0.0%	0.1%	-0.1%
Remittances sent	-1.0%	-0.9%	-0.1%
Govern transfers	4.8%	9.4%	-4.6%
Private transfers	5.8%	2.3%	3.5%
Total	100.0%	100.0%	0.0%

Table C5. Income structure poor/non-poor in Nicaragua

	Poor	Non-Poor	Diff.
Factor Income - Land	14.3%	4.9%	9.5%
Factor Income - Capital	12.6%	28.7%	-16.0%
Factor Income - UnSk Labor	2.8%	7.8%	-5.0%
Factor Income - Skill Labor	30.6%	39.8%	-9.2%
Factor Income - Nat.Res.	2.1%	5.0%	-2.9%
Direct taxes	-3.7%	-4.0%	0.3%
Remittances received	9.4%	5.0%	4.4%
Remittances sent	0.0%	-0.1%	0.0%
Govern transfers	17.0%	18.6%	-1.6%
Private transfers	14.9%	-5.7%	20.7%
Total	100.0%	100.0%	0.0%

Table C6. Income structure poor/non-poor in Vietnam

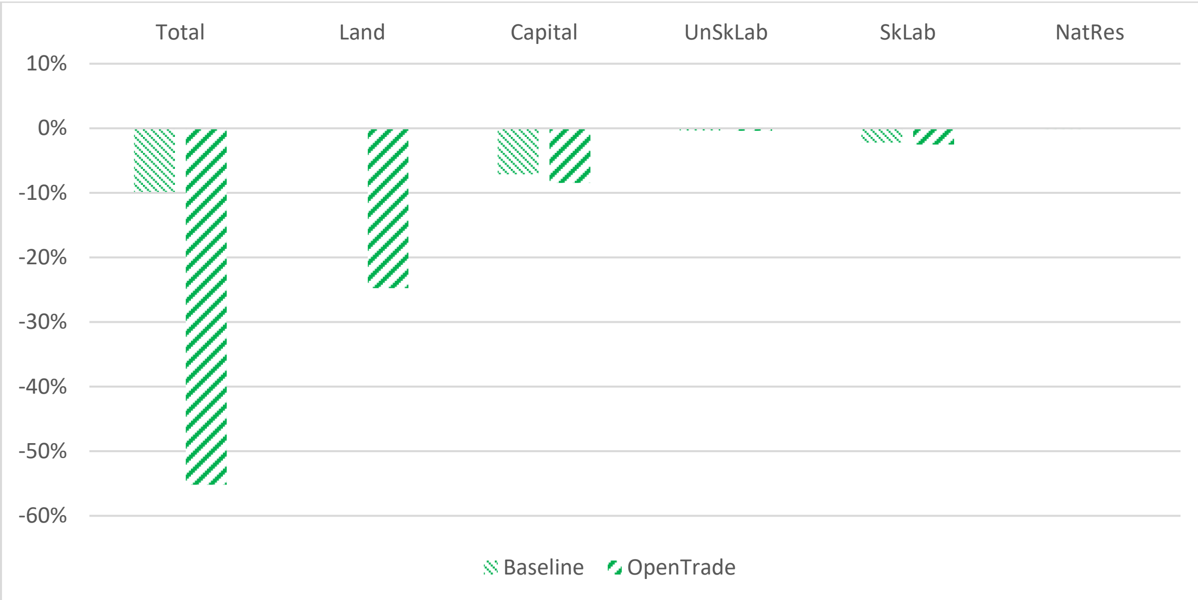

Figure C1. Variations 2011-2050 in relative factor income poor/non-poor, by source, Albania.

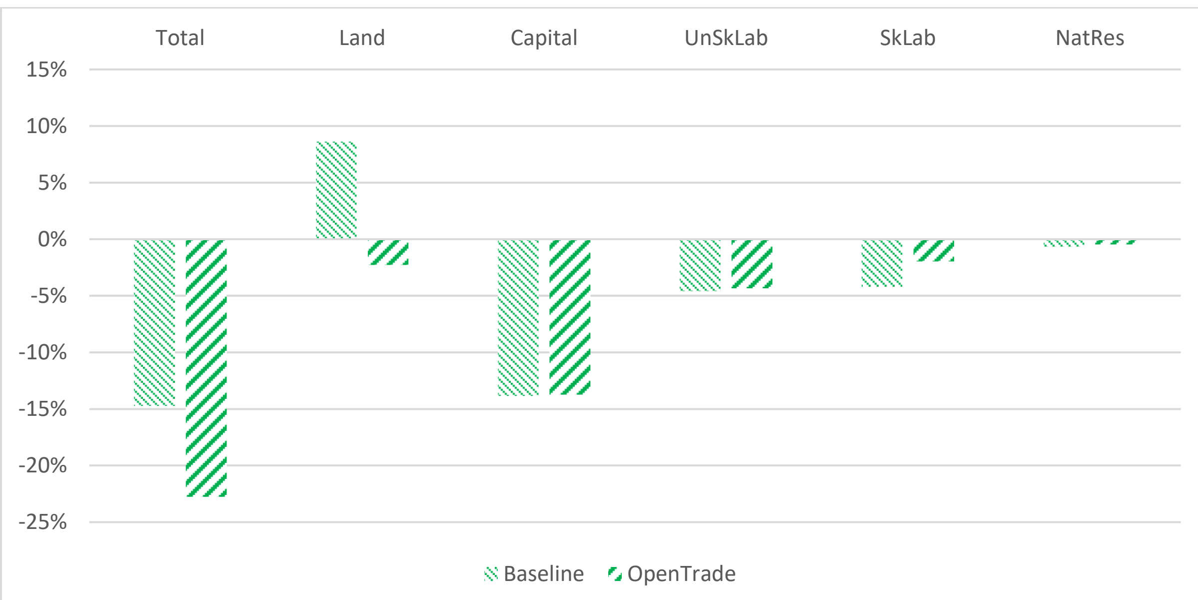

Figure C2. Variations 2011-2050 in relative factor income poor/non-poor, by source, Bolivia.

Figure C3. Variations 2011-2050 in relative factor income poor/non-poor, by source, Ethiopia.

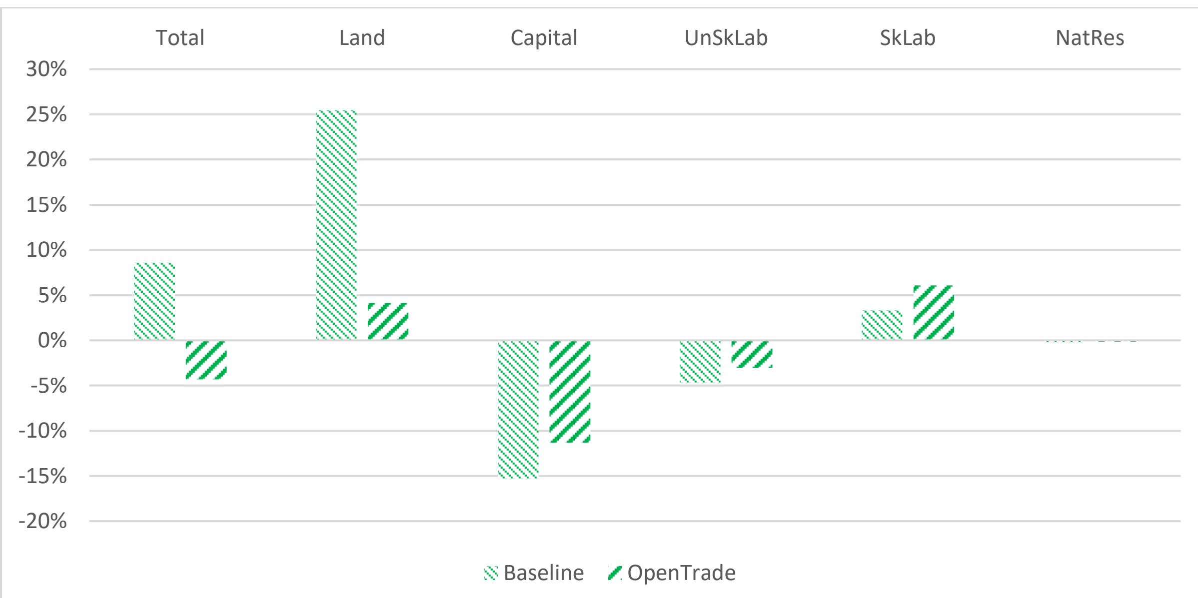

Figure C4. Variations 2011-2050 in relative factor income poor/non-poor, by source, Malawi.

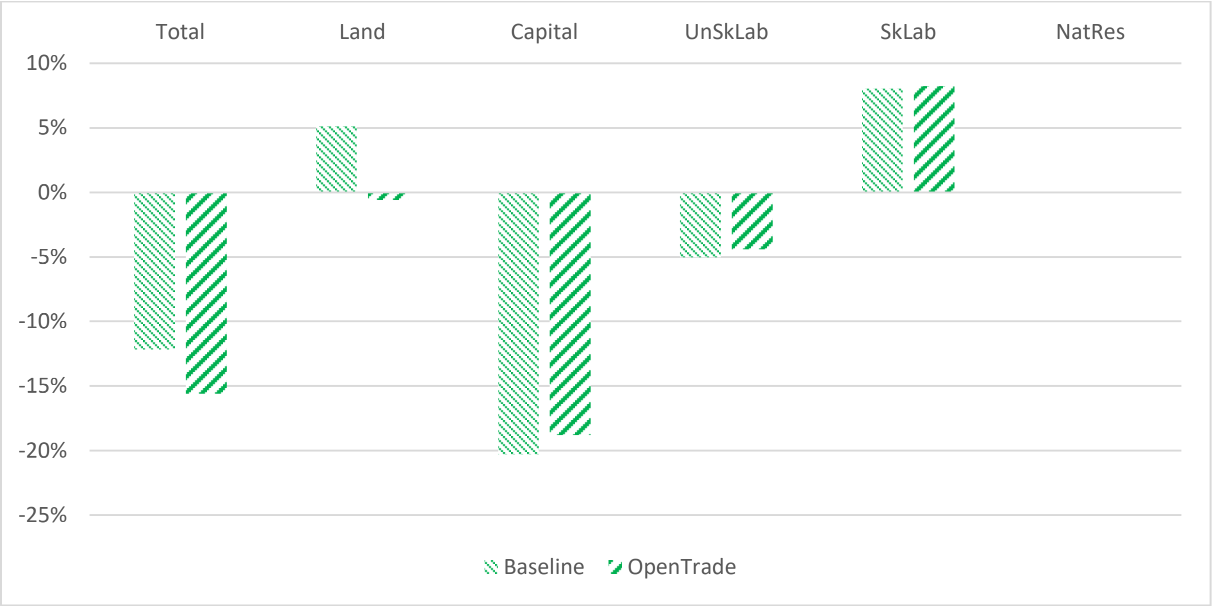

Figure C5. Variations 2011-2050 in relative factor income poor/non-poor, by source, Nicaragua.

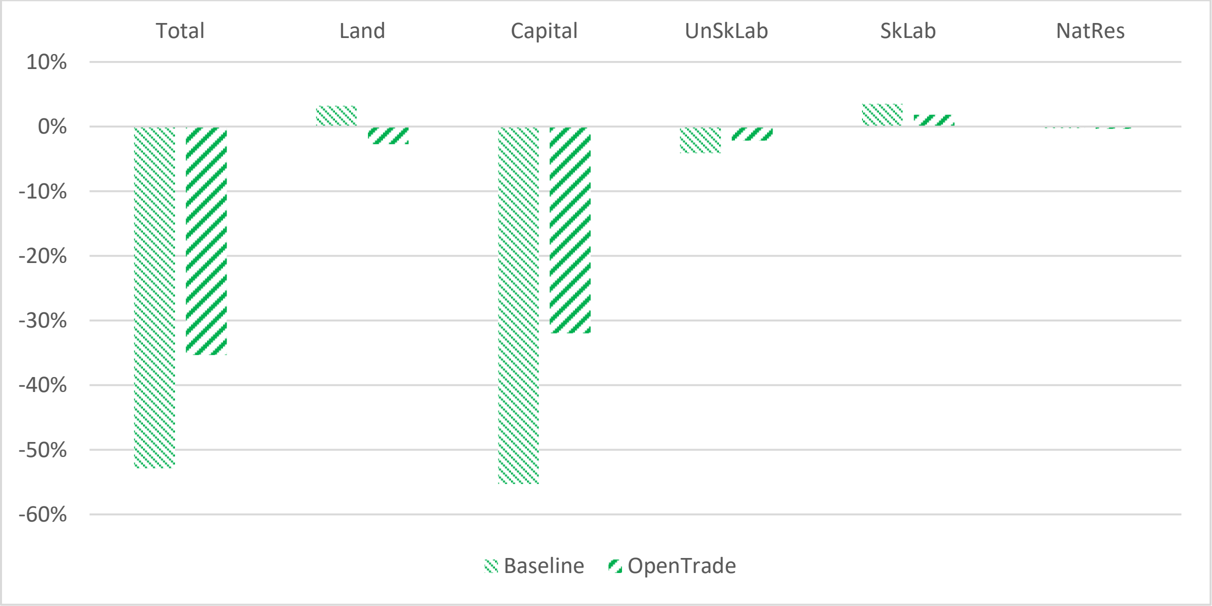

Figure C6. Variations 2011-2050 in relative factor income poor/non-poor, by source, Vietnam.