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From Poverty to Prosperity and Well-Being:

The UNDP World CGE Model for Policy Scenario Analysis

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Abstract

Economic policies and external shocks shape development outcomes in profoundly uneven ways. Yet many macroeconomic models still rely on representative households, masking the distributional effects that matter most for policy. This paper introduces the UNDP World CGE Model, a people-centered global framework covering 125 countries and designed to assess how policy choices and shocks affect economies, households, and vulnerable groups.

The model moves beyond aggregate indicators to show who gains, who loses, and through which channels. It captures impacts across household income groups, gendered labour categories, sectors, trade flows, public finance, investment, consumption, and unemployment. It can also support poverty analysis by estimating changes in poverty rates and headcounts under alternative policy scenarios, helping assess whether interventions move people above or below defined poverty thresholds.

Positioned as an analytical tool for UNDP's Strategic Plan 2026–2029, the model links economy-wide policy analysis to human development outcomes. It provides a practical framework for examining pathways from poverty to prosperity and well-being, with applications across prosperity for all, gender equality, crisis resilience, sustainable finance, and structural transformation. By translating complex macroeconomic dynamics into distributional and policy-relevant insights, the UNDP World CGE Model helps countries and partners better understand the trade-offs, risks, and opportunities embedded in different development pathways.

1. Introduction

When an economy is shocked — by a trade disruption, a fiscal adjustment, a commodity price swing, or a climate-related stress — GDP may contract, unemployment may rise, and per capita consumption may fall. However, the aggregate numbers tell only part of the story, indicating what happens to the economy but not to the people (Stiglitz, Sen and Fitoussi, 2009; UNDP, 2019).

A trade shock that reduces aggregate income may be barely perceptible for a household at the top of the income distribution with diversified income sources and savings to draw on — and catastrophic for a household at the bottom whose income depends entirely on unskilled wages or remittances, and whose consumption basket is dominated by food and energy. Standard macroeconomic models, built around representative households, are structurally unable to reveal who gains and who loses within those aggregates (Kirman, 1992; Ravallion, 2001; Stiglitz, 2012; Piketty, 2014).

This paper presents the UNDP World CGE Model, a people-centred policy simulation framework designed to answer precisely those questions. At its core is a distributional layer that transforms standard macroeconomic analysis: every simulation produces results not just for the economy as a whole, but for households across the income distribution, revealing who bears the burden and who captures the gains. The model also supports the estimation of poverty rates and headcounts, helping fill a gap that most global modelling frameworks leave unaddressed. It is a direct analytical instrument for UNDP's Strategic Plan 2026–2029, whose commitments to prosperity for all, gender equality, and crisis resilience require tools that can see beyond aggregates and into people's lives.

The model is built on the GTAP 12 database (Aguiar et al., 2025) and extends distributional approaches from the PEP-w-1 (Lemelin et al., 2013) and MIRAGRODEP (Bouët et al., 2022) frameworks by replacing the standard representative household with five quintile-specific households, each with tailored consumption and income patterns. Its labour market structure, which tracks skilled and unskilled workers disaggregated by sex as distinct factors of production, directly supports UNDP's Jobs for Prosperity Facility agenda by enabling analysis of the quality and distribution of employment, not just its volume.

The result is a flexible analytical instrument designed to support governments and development partners in understanding the human consequences of policy choices — across trade, fiscal policy, climate and commodity shocks, labor market reform, structural transformation and development finance — always translating macroeconomic change into evidence about people. It is deliberately presented as a living tool, designed to evolve as data improves, policy questions shift and new applications emerge, and as a platform for collaboration between UNDP country offices, national governments, research partners and the broader network of development practitioners.

The paper proceeds as follows. Section 2 makes the case for people-centred analysis, drawing on evidence on multidimensional poverty, inequality, and the limits of aggregate frameworks. Section 3 presents the UNDP CGE model, situating it within the broader modelling literature and outlining its key structural features and innovations. Section 4 describes the policy questions the model can address and how these relate to UNDP's Strategic Plan 2026–2029. Section 5 discusses how the model can be adapted to national contexts. Sections 6 and 7 discuss planned extensions, limitations and conclude, respectively.

2. Why integrated, people-centred modelling analysis matters now

2.1 A development context defined by interacting crises

The global development context has become more complex, interconnected, and uncertain. Countries are not facing isolated shocks that can be understood or addressed one at a time. Climate stress, conflict, debt distress, commodity price volatility, geopolitics, trade fragmentation, food and energy insecurity, fiscal constraints, demographic pressures, and rapid technological change increasingly interact with one another.

These pressures create a policy environment in which shocks compound across systems and transmit quickly from global markets to national economies, from national economies to sectors, and from sectors to households. A climate shock can reduce agricultural output, raise food prices, increase import needs, affect household consumption, weaken fiscal space, and expand social protection needs. A commodity price shock can affect inflation, wages, trade balances, public revenue, and poverty at the same time. A fiscal adjustment can stabilize public accounts while also changing household disposable income, public services, investment, and vulnerability.

This is the essence of the current polycrisis: the problem is not only that multiple shocks are occurring, but that they interact. Policy responses therefore need to account for these interactions rather than treating each shock as a separate sectoral problem.

2.2 Why aggregates are insufficient

Aggregate indicators remain essential for understanding economic performance, but they are insufficient for assessing whether development is becoming more inclusive, resilient, and people-centred. GDP, investment, trade, unemployment, inflation, and average consumption can indicate the direction of macroeconomic change, but they do not show who is affected, through which channels, or with what consequences for welfare and wellbeing.

This distinction matters because the same aggregate shock can affect households very differently. A rise in food or energy prices may appear in national accounts as a change in the consumer price index, but for poorer households it can mean an immediate loss of purchasing power. A trade disruption may appear as a change in exports or imports, but for workers in affected sectors it can mean lost wages, unemployment, or movement into lower-productivity activities. A fiscal adjustment may improve macroeconomic balances, but it can also reduce transfers, services, or public spending on which vulnerable households depend.

In each case, the aggregate result tells only part of the story. It describes what is happening to the economy, but not necessarily what is happening to people.

2.3 Poverty, vulnerability, and prosperity are multidimensional

For UNDP, this people-centred lens is central. The pathway from poverty to prosperity is not simply a matter of increasing national income. It depends on whether economic transformation expands people's capabilities and agency, raises productivity, creates better livelihoods, reduces vulnerability, and strengthens resilience to shocks. Prosperity is therefore not only about growth; it is about whether growth improves people's choices, security, and well-being.

This is reinforced by the multidimensional nature of poverty. Poverty is not one thing; it is many deprivations experienced at the same time. The 2025 Global Multidimensional Poverty Index shows that 1.1 billion people across 109 countries live in acute multidimensional poverty, facing overlapping deprivations in health, education, and living standards. People may live above an income poverty line while still lacking access to nutrition, schooling, clean water, electricity, sanitation, or other essentials that shape life chances and productive potential.

These deprivations are mutually reinforcing. Poor health constrains learning, limited education reduces labour market opportunities, and inadequate living standards weaken resilience. In a world of compounding crises, these overlaps become even more consequential. Households already facing multiple deprivations are less able to cope when prices rise, jobs are lost, remittances fall, public services are reduced, or climate hazards destroy assets and livelihoods. For these households, shocks do not merely reduce income in the short term. They can trigger negative coping strategies, reduce investment in children's education and nutrition, weaken productive capacity, and deepen vulnerability over time.

2.4 From growth to prosperity: the role of structure and distribution

Growth remains essential, but it is not automatically poverty-reducing. Its impact depends on the structure of the economy, the sectors in which growth occurs, the distribution of productive assets, the nature of labour markets, and the ability of poor and vulnerable households to participate in and benefit from economic change.

Growth driven by agriculture or labour-intensive services may have stronger poverty-reducing effects where poorer households are concentrated in those activities. By contrast, growth concentrated in capital- or skill-intensive sectors can disproportionately benefit capital owners and higher-skilled workers, widening inequalities unless accompanied by policies that expand access to assets, skills, finance, markets, and social protection.

This is why poverty reduction must also be understood as a structural transformation challenge. Households do not move from poverty to prosperity only because an economy expands. They move when they gain access to productive assets, better jobs, more stable incomes, affordable services, markets, finance, social protection, and the capabilities needed to participate in higher-productivity activities.

Conversely, where assets are concentrated and opportunities are uneven, growth can reproduce existing inequalities rather than reduce them. Households without land may not benefit from agricultural growth; households without education may be excluded from skill-intensive employment; households without finance may be unable to invest in productive activity; and workers in informal or low-wage employment may remain poor despite being employed.

The pathway from poverty to prosperity therefore depends not only on how much an economy grows, but on how growth is generated, who participates in it, who benefits from it, and whether policy helps people move into more productive and resilient livelihoods.

2.5 Why integrated policy needs integrated models

The policy implication is clear: integrated development challenges require integrated policy responses, and integrated policy responses require integrated analytical tools. However, many existing modelling approaches are not designed for this complex, interconnected development changes.

This is the gap the UNDP World CGE Model is designed to address. It provides an integrated economy-wide framework that connects macroeconomic change to household-level and human development outcomes. By linking production, trade, prices, public finance, investment, labour markets, remittances, aid flows, and household distribution within a single modelling structure, it allows policy scenarios to be assessed across multiple channels at once.

Its household quintile structure makes it possible to examine how shocks and policies affect different income groups, while its labour market disaggregation by skill and sex enables analysis of differentiated effects on women and men, skilled and unskilled workers, and sectoral employment outcomes. It can help assess not only whether a policy raises GDP, but whether it raises household consumption among poorer groups; improves employment and real wages; protects vulnerable households from price shocks; expands fiscal space for social spending; supports productive transformation; and reduces poverty rates and headcounts.

For UNDP, this is not only a technical modelling issue. It is about strengthening the evidence base for integrated policy support. The model can help connect work on multidimensional poverty, jobs and livelihoods, gender equality, social protection, sustainable finance, resilience, and structural transformation. It provides a way to examine how these agendas interact rather than treating them as separate policy domains.

At a time of polycrisis, countries need tools that help them move beyond crisis management toward strategic choices for transformation. The UNDP World CGE Model is intended to support that shift. Its purpose is not simply to simulate the economy, but to help governments and development partners understand which pathways are most likely to protect people today while expanding the foundations for prosperity and well-being tomorrow.

3. The UNDP world CGE model

3.1 Overview of models and UNDP's CGE model added value

Over the past five decades, a broad range of Computable General Equilibrium (CGE) models has been developed to assess the economy-wide effects of policy changes and external shocks. These models differ in their treatment of global linkages, sectoral coverage, dynamic structure, and capacity to capture distributional outcomes. This section provides an overview of the main modelling traditions that inform the UNDP CGE model.

Despite considerable variation in scope and application, the major CGE frameworks share a set of core methodological principles on which the UNDP CGE model also draws. Understanding these common elements helps situate the UNDP CGE model within the broader modelling tradition and clarifies the nature of its contribution.

Global social accounting structure. Like GTAP (Corong et al., 2017), MIRAGE (Modelling International Relationships in Applied General Equilibrium; Fontagné et al., 2013), and MIRAGRODEP (a variant of MIRAGE with a focus on agriculture and development; Bouët et al., 2022), the UNDP CGE model is calibrated to a globally consistent social accounting matrix derived from the GTAP 12 database (Aguiar et al., 2025). This updated database expands country coverage and, crucially, enables the explicit representation of cross-border income flows — including remittances, investment income, and foreign aid — as integral components of the circular flow of income across agents, which are particularly relevant in development contexts (see details in Section 3.3).

Standard production and trade architecture. Across models, production is represented using nested functional forms[1] that describe how firms combine labour, capital, land, and other inputs, while trade distinguishes goods by origin to reflect imperfect substitutability between domestic and imported varieties. The UNDP CGE model follows these conventions, ensuring comparability with established frameworks, while introducing economy-wide and sector-specific productivity parameters that shift the efficiency of production. These enable the simulation of structural transformations — such as technological change or climate-related shocks — within the production system.

Factor and market equilibrium. In common with GTAP, PEP, STAGE, and MIRAGRODEP, the UNDP CGE model determines wages, capital returns, and commodity prices through the interaction of supply and demand across sectors and regions. Factor returns adjust to clear markets, and commodity prices reflect production costs, taxes, and trade margins. This standard equilibrium mechanism ensures that the model captures economy-wide feedback effects rather than treating markets in isolation.

Sectoral and factor market detail. Like GTAP and the PEP model family, the UNDP CGE model disaggregates production across multiple sectors and represents factor markets by type, including labor (by skill and sex), capital, land, and natural resources. A key extension is that labor supply is specified at the household-quintile level, where each quintile is assigned a specific productivity factor, so that aggregate labor supply reflects heterogeneous household characteristics rather than being imposed exogenously. This strengthens the link between micro-level characteristics and macroeconomic outcomes.

Linkage to macroeconomic aggregates. Consistent with the standard CGE tradition, the model generates outputs on GDP, trade flows, sectoral production, government revenues, and external balances. Fiscal structure is also more explicitly represented: household income taxes are levied on labor and capital income (excluding transfers), allowing fiscal policy to directly shape disposable income and distributional outcomes within the general equilibrium framework.

Development and poverty focus. In its orientation toward developing country contexts, the UNDP CGE model shares the motivating purpose of the PEP (Decaluwé et al., 2013; Lemelin et al., 2013; Cockburn et al., 2014) and STAGE model families (McDonald, 2007) to make CGE analysis relevant not only to aggregate economic performance but also to the living standards of households, particularly those in the lower income distribution. The UNDP CGE model uses a Stone–Geary utility function to represent household consumption decisions, from which a Linear Expenditure System (LES) is derived for each household group. This specification allows for differentiated expenditure patterns across income groups and incorporates minimum consumption requirements calibrated as a fixed share of total consumption — set higher for poorer countries and lower for richer ones, but uniform across quintiles within each country — ensuring that a baseline level of consumption is met before additional income is allocated across other goods.

While the UNDP CGE model inherits these shared foundations, its defining contribution lies in the integration of distributional analysis as a structural feature of the model itself rather than an optional add-on. Crucially, this integration operates simultaneously through income generation, labour supply, and consumption behaviour, allowing macroeconomic shocks to transmit across households through multiple channels within a unified general equilibrium framework. The main dimensions of this contribution are as follows:

Household heterogeneity within a global framework. The model disaggregates households by income quintile (Q1–Q5) directly within a multi-country CGE structure. In most global models — including GTAP, MIRAGE, and ENVISAGE — a single representative household per country aggregates all income and expenditure,

[1] A nested function represents production as a sequence of steps, where inputs are combined in layers rather than all at once. This allows the model to capture how easily firms can substitute between different inputs.

limiting the ability to assess distributional impacts. While the PEP and STAGE model families incorporate multiple household groups — most commonly in single-country settings, and in some cases complemented by linked microsimulation modules — the UNDP model embeds household heterogeneity directly within a multi-country general equilibrium framework, so that distributional outcomes are generated endogenously as part of the model solution.

Multi-source income transmission and household-level labour supply. Each quintile is characterised by a distinct income structure — described in detail in Section 3.3 — and a household-level labour supply function, linking micro-level characteristics directly to aggregate labour market outcomes.

Differentiated labour market structure. The labour market architecture incorporates a wage-curve specification for unemployment, in which real wages and unemployment are inversely related. While this approach is common in development-oriented CGE models such as PEP and STAGE, standard global models like GTAP and MIRAGE typically assume full employment. The UNDP CGE model extends this framework by introducing differentiated labour market mechanisms across country contexts. In higher-income countries, unemployment affects all labour categories, while in lower-income countries unemployed skilled workers transition into unskilled employment, capturing underemployment and downward occupational mobility.

Poverty sensitivity and consumption behaviour. Unlike standard global models that use Cobb–Douglas utility functions — which cannot capture subsistence needs — the model's Stone–Geary specification ensures that distributional welfare results reflect the different initial consumption patterns across income groups. Critically, the model also estimates poverty rates and headcounts directly — showing whether a policy reduces the number of people living below any given poverty threshold. This is done by taking the USD per capita per day values generated endogenously for each income quintile as inputs into an ex-post distributional analysis that reconstructs the full income distribution using methods such as a Lorenz curve[2] approach, and derives poverty rates and headcounts for any given threshold. The poverty line is fully adjustable — USD 3 per day for extreme poverty, USD 4.20 for the lower-middle-income line, and USD 8.30 for the upper-middle-income line — allowing the analysis to be calibrated to the country context at hand. A fully worked numerical example using real quintile data for Angola, illustrating each step of the estimation from quintile averages to poverty headcount, is provided in Appendix D.

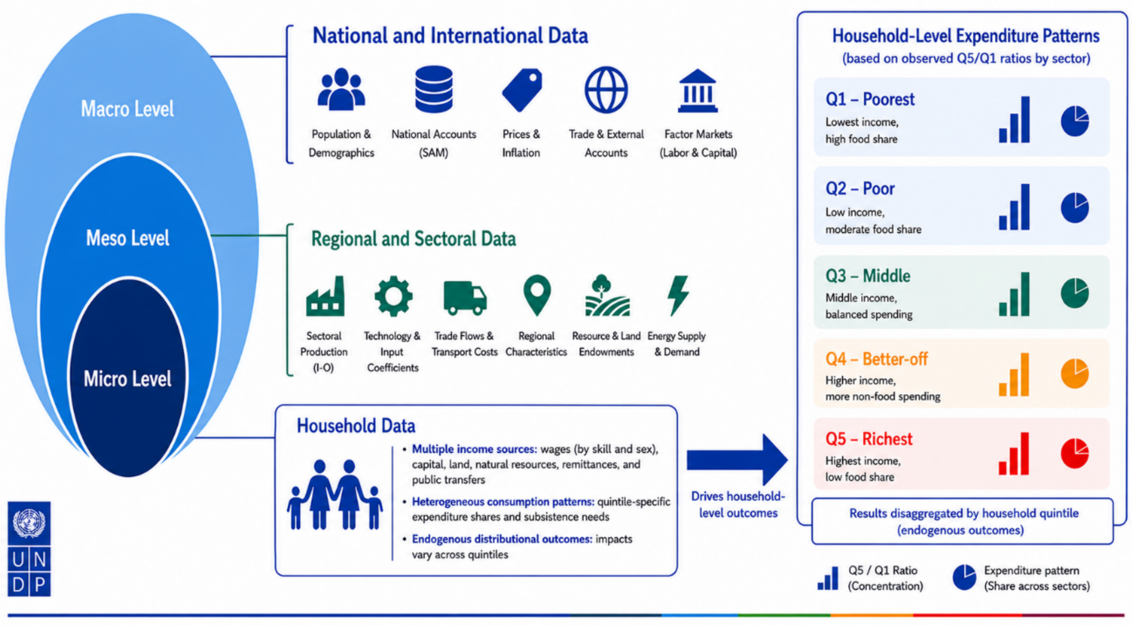
Sex-disaggregated and factor-specific impacts. By distinguishing labour by both skill level and sex, and by explicitly modelling capital, land, natural resources, remittances and public transfers, the model captures how structural inequalities shape the distributional impacts of economic change. This enables the analysis of sex-differentiated and factor-specific outcomes, which are typically not represented in standard global CGE models.

Enhanced global flows relevant to developing countries. The adoption of the GTAP 12 database strengthens the representation of cross-border flows — including remittances, investment income, and foreign aid — that are particularly important for low- and middle-income countries.

Figure 1 summarizes the scope of the UNDP CGE model, highlighting the added value of integrating household heterogeneity in both income generation and expenditure within a unified global framework.

[2] The Lorenz curve describes the cumulative share of total income held by the bottom p percent of the population. Both Beta and General Quadratic Lorenz curve are fitted to the model's five quintile income points, from which the poverty rate and headcount are derived for any given threshold. See Appendix D for a step-by-step illustration. Alternative methods — including uniform interpolation and log-normal parametric fitting — can also be used to estimate poverty headcounts from quintile averages, but are less precise: uniform interpolation assumes income is evenly distributed within each quintile, which understates inequality at the tails, while the log-normal fit imposes a distributional shape that may not reflect the actual income distribution in many developing countries. The General Quadratic Lorenz curve is preferred as it fits the full distribution flexibly without imposing restrictive assumptions.

Figure 1. The UNDP CGE model: an integrated modelling framework with distributional layers



Source: Elaborated by the authors.

3.2 The foundation: GTAP 12

Building on the modelling traditions described above, the UNDP CGE model is calibrated to the latest version of the GTAP database, GTAP 12. Released in 2025, GTAP 12 provides a globally consistent benchmark of the world economy for the 2023 reference year, in which production, income, and expenditure are fully reconciled across agents and regions. By capturing the circular flow of income between firms, households, governments, and the rest of the world, it offers a harmonized macroeconomic framework underlying most global CGE models (Aguiar et al., 2019; Aguiar et al., 2025). The dataset distinguishes 163 countries and aggregate regions across 65 sectors, covering nearly 99 percent of global GDP and more than 97 percent of the world population (Aguiar et al., 2025).

The GTAP 12 database combines two core data pillars. The first is a set of domestic input-output tables contributed by the GTAP Network, which describe production structures — including intersectoral linkages, the use of primary factors, and the allocation of output across domestic and foreign demand. The second consists of harmonized international datasets covering macroeconomic aggregates (World Bank and IMF), trade flows (UN Comtrade), trade policy instruments (ITC, OECD, WTO), and energy balances (IEA and UN).

A key enhancement in GTAP 12 is the explicit inclusion of balance-of-payments components — notably remittances, foreign investment income, and foreign aid. The database also distinguishes labor by skill level and sex, a structure the UNDP CGE model builds upon to construct sectoral wage-bill shares across four sex-skill categories and allocate them across household quintiles (see section 3.3.3).

3.3 Adding the distributional layer

The disaggregation of households into five income quintiles directly within the global framework is one of the model's most significant contributions. External distributional data is used for this disaggregation, as described below.

3.3.1 Disaggregated income sources

Labor income in GTAP 12 is recorded as an aggregate national wage bill. Since the World Bank's Statistics Online (SOL) platform — covering 26 countries — does not provide separate labor income breakdowns, the distribution of total household welfare[3] by quintile, derived from harmonized household survey microdata from SOL, is used as the best available proxy. Within each survey, individuals are classified by sex and skill level — skilled workers having completed secondary, post-secondary or tertiary education; all others classified as unskilled — producing four sex-skill categories (female skilled, female unskilled, male skilled, male unskilled). Quintile-level wage-bill shares are constructed across these four categories and applied to GTAP 12 aggregate totals. For

[3] Measured as income or consumption, depending on the survey.

countries without SOL coverage, distributions are imputed using donor-country averages defined by regional classification and HDI groups.

Capital income, equivalent to returns to non-labor productive assets — is disaggregated using harmonized household survey microdata from the Luxembourg Income Study (LIS), covering interest, dividend and rental income for 20 countries spanning all regions. For countries without LIS coverage, imputation follows the same stepwise donor assignment as for labor income, based on HDI category and regional classification.

Land income, the aggregate national total of returns to land used in agricultural production as recorded in GTAP 12, is disaggregated across quintiles using on-farm income shares from the FAO's Rural Livelihoods Information System (RULIS), which provides harmonized household survey data for 39 countries across Africa, Asia and Latin America. On-farm income — earnings from crop production, livestock, fisheries and forestry — is used as a proxy for land income on the grounds that agricultural households' returns to land are primarily captured through farming activities. Where country-specific RULIS data are available, quintile shares are taken directly; where not, the same hierarchical donor imputation approach described for labor income is used.

Natural resource income, the aggregate national total of returns to natural resources, is disaggregated across quintiles using the same quintile shares derived for capital income. This reflects the well-documented tendency for natural resource wealth to concentrate among upper income groups, with rents accruing through financial instruments, corporate ownership or concentrated asset holdings rather than being broadly distributed — a pattern that closely mirrors the ownership structure of capital (Piketty, 2014; Ross, 2012; Caselli and Michaels, 2013).

Remittances are disaggregated across household quintiles using the Global Findex Database (2024), a nationally representative individual-level survey covering more than 140 economies. The survey includes a binary variable recording whether each respondent (aged 15 and above) received international remittances in the past year. The share of adults reporting receipt within each income quintile is used as a proxy to allocate the total remittance aggregate from GTAP 12 across quintiles. This approach assumes that the likelihood of receiving a remittance is a valid proxy for the share of total remittance income accruing to each group — an assumption that may not hold where average transfer amounts differ systematically across quintiles, and results should be interpreted accordingly. For high-income economies not covered by Findex, the distribution of private transfers from LIS serves as a proxy-reflecting the assumption that, in advanced economies, international remittances follow a distributional pattern similar to broader private transfer income. For countries without either source, the same hierarchical donor imputation approach applied to other income sources is used, based on HDI category and regional classification.

Public transfers represent one of the most important additions to the UNDP CGE model. Unlike the other income sources, which are present in GTAP 12 as national aggregates and disaggregated across quintiles using external distributional data, public transfers — defined as social assistance payments made by governments to households[4] — are introduced as an entirely new income flow not available in GTAP 12. This addition is particularly important for distributional analysis: social assistance is by design targeted at lower income groups, meaning its presence or absence in a model fundamentally shapes how fiscal policy shocks, subsidy removals and transfer reforms transmit across the income distribution. Ignoring it, as standard models do, systematically understates the income buffering capacity of the poorest quintiles and overstates their exposure to adverse shocks.

The disaggregation of public transfers is constructed as follows. Two indicators from the World Bank's Atlas of Social Protection Indicators of Resilience and Equity (ASPIRE) database are used: coverage rates (the percentage of population in each income quintile receiving social assistance) and average per-capita transfer amounts (in 2017 PPP USD). These are combined with population data by quintile from the World Bank to derive aggregate transfer amounts per quintile, and later converted to 2023 market USD (GTAP 12's base year). For countries not covered by ASPIRE, the same hierarchical imputation strategy by HDI and regional groups is applied.

3.3.2 Disaggregated consumption data

The second contribution to understanding distributional effects concerns how households spend their income. In the original GTAP 12 database, household consumption is available by commodity at the national level without disaggregation by

[4] As per the World Bank's ASPIRE database, social assistance encompasses a broad range of government transfer programmes directed at poor and vulnerable households, including unconditional and conditional cash transfers, social pensions (non-contributory), food and in-kind transfers, school feeding programmes, public works and direct job creation schemes, fee waivers and subsidies (covering health, education, food, housing and utilities), and other targeted transfers.

income group. The UNDP CGE model introduces quintile-specific consumption baskets across all five income quintiles for each of 125 countries and regional aggregates — ensuring that the model captures not only that poor and rich households consume differently, but that macroeconomic shocks and price changes transmit differently across the income distribution.

Consumption data by household quintile and commodity are constructed based on the World Bank's Global Consumption Database (GCD), which provides consumption distributions across 110 product and service categories for 92 countries, disaggregated by four consumption segments: lowest (covering the bottom 0–50 percent of the global income distribution), low (50–75 percent), middle (75–90 percent) and higher (90–100 percent). Individual products and services are mapped to the model's 27-commodity classification through a manual concordance process, with unmatched categories merged with the most proximate industries.[5]

A central methodological challenge is that the GCD's four consumption segments do not align neatly with the model's five income quintiles. To bridge this, a Lorenz curve approach is applied, calibrated using each country's Gini coefficient sourced from the World Inequality Database (2024). This ensures that the within-segment distribution of spending reflects each country's actual inequality profile rather than a uniform assumption, and that quintile-specific spending shares are derived consistently with observed distributional patterns. For countries not covered by the GCD, the same hierarchical imputation strategy applied to income sources is used.

3.3.3 Disaggregated labor market data

The sex and skill disaggregation of labour represents one of the most important structural innovations of the UNDP CGE model. While GTAP 12 contains information on skilled and unskilled labour disaggregated by sex — female skilled, female unskilled, male skilled, and male unskilled — as distinct factors of production, it does not provide a sectoral breakdown of how these labour factors are deployed across industries. The UNDP model introduces this sectoral disaggregation across all 27 sectors/commodities and 125 countries/regions, enabling analysis of not just how many jobs are created or lost, but what kind, for whom, and in which sectors — a dimension that is absent from standard global CGE models.

This disaggregation draws on two ILO data sources: employment data disaggregated by country, sector, sex and occupation, and average earnings data disaggregated by country, sex and occupation. Occupational categories are mapped to skill levels following the International Standard Classification of Occupations (ISCO): managers, professionals, technicians and associate professionals are classified as skilled; clerical, service, agricultural, craft, machine operators and elementary occupations are classified as unskilled. By multiplying employment shares by relative earnings produces a wage-bill share for each sex/skill category in different sectors, reflecting both how many workers of each type are employed and how much they earn relative to others. Given the absence of sector-level earnings data in ILO, this approach assumes that earnings vary by sex and skill level but are uniform across sectors within a given country. The resulting shares are then applied to GTAP 12 aggregates to allocate wage-bills across sex and skill categories for all 27 sectors and 125 countries. For countries without sufficient ILO coverage, the same hierarchical imputation strategy applied to income sources is used, based on regional classification and HDI group.

The sex- and skill-disaggregated labor market data enables the calculation of a set of indicators that provide additional analytical insight into the distributional dimensions of employment and wages. Five indicators are of particular relevance:

The wage inequality ratio, defined as the wage income of the richest quintile relative to the poorest (Q5/Q1), measures whether growth is equalizing or disequalizing across the wage distribution, capturing the extent to which labor market returns are concentrated at the top.

The skill premium by sex, calculated separately as the ratio of skilled to unskilled wages for female workers and for male workers, reveals whether the returns to education and skill accumulation are distributed equally across sexes, or whether skill-biased growth advantages one group over the other.

Employment intensity of output, defined as the inverse of labor productivity, measuring the number of jobs generated per unit of output. This indicator is particularly relevant

[5] Since original GTAP contains 44 industry/product categories, in certain occasions multiple GCD products/services codes needed to be matched to one GTAP industry code. For example, for beverage and tobacco products in GTAP we matched 7 different products/services from GCD database, namely, Narcotics; Tobacco; Wine; Coffee, tea and cocoa; Spirits; Beer; Mineral waters and soft drinks. As a next step, we conducted a further mapping of GTAP industry codes with UNDP classification reducing the number of industries/products from 44 to 27 used in UNDP GTAP model.

for assessing whether aggregate output growth translates into poverty-reducing employment for the households that belongs to the lowest quintile.

Employment intensity of investment, measuring the number of jobs generated per unit of investment, captures whether investment flows generate employment that reaches female and unskilled workers, or whether the gains concentrate among male and skilled workers, with direct implications for the distributional and gender impact of public and private investment decisions.

Output per worker, a measure of labor productivity disaggregated by household income quintile and by sex and skill type, complements employment intensity by showing not just how many jobs are created but how productive those jobs are. This indicator reveals whether growth is generating quality employment for lower quintiles and unskilled workers, or whether productivity gains are concentrated among skilled workers and upper income households.

These indicators contribute primarily to UNDP's J4PF agenda by revealing whether growth, investment and policy changes generate employment that reaches all workers equitably — or whether labor market gains systematically bypass unskilled workers, lower quintiles and women. In addition, the skill premium by sex — and the differential wages for male and female workers across skill categories — directly support the SP 2026-2029 gender equality accelerator by revealing whether a given shock or policy widens or narrows wage disparities between men and women, and whether the returns to skill accumulate equally across sexes.

Figure 2. The UNDP CGE model: a fully integrated distributional system

Source: Elaborated by the authors.

Appendix A provides, in detail, the equations, variables and parameters of the UNDP CGE model. Appendix B lists the sets (sectors and country/regions) used in the model, and Appendix C provides the mathematical derivations of the different functions.

4. What the model delivers: questions it can answer

The UNDP CGE model allows translating macroeconomic changes into people-centred outcomes. The sections below outline the policy questions the model can address.

4.1 What happens to the economy as a whole?

The model first establishes how a policy or external shock reshapes the overall economy, producing a consistent set of macroeconomic indicators across 125 countries/regions, including GDP, investment, consumption, government revenues, and the current account balance. These aggregate outcomes are also decomposed into their underlying components: on the demand side, the model distinguishes between household consumption, public expenditure, investment, exports, and imports, providing a clear view of whether growth is driven by domestic demand or external markets; on the supply side, it captures changes in output, value added, and intermediate consumption across sectors, reflecting the structure of production. At a more granular level, results are available for 27 industries spanning agriculture, manufacturing, energy, and services, including sectoral output, trade flows, input use (labor, capital, land, and natural resources), and production costs. Because the model explicitly represents intermediate input flows across all 27 sectors, it also captures how expansion or contraction in one industry propagates upstream and downstream through the production system — making it a direct instrument for value chain analysis. When a government pursues policies to deepen domestic value chains, increase local content, or reduce reliance on imported intermediates, the model traces how those ambitions translate into changes in inter-sectoral demand, production costs, and trade flows across the economy.

Given that the model also captures international linkages (e.g., bilateral trade, foreign investment income, remittances, and foreign aid), it is also possible to assess how global shocks transmit through trade and financial channels and how external balances adjust. This includes the capacity to assess integration into regional or global value chains, revealing how shifts in bilateral trade patterns and import competition reshape domestic production structures and the distribution of gains across households and sectors.

This sectoral perspective is central to understanding structural transformation and industrial policy. UNDP SP 2026–2029 emphasizes that reallocating resources toward higher-productivity and more sustainable activities is a key driver of inclusive growth and poverty reduction (McMillan and Rodrik, 2011; Ravallion and Chen, 2007; Beegle et al., 2013; Erumban and de Vries, 2024). By identifying which sectors expand or contract, and at what pace, the model reveals not only the direction of change but its structural location — a critical dimension for distributional analysis, given differences in factor intensity, employment composition, and trade exposure across sectors. Governments deploying subsidies, tax incentives, tariff protection, or public investment to accelerate industrialization or shift toward higher-value activities can use the model to assess the economy-wide consequences of those instruments: changes in sectoral output and production costs, fiscal balance implications, and whether the intended structural reorientation materializes or is offset by general equilibrium feedback effects — including, critically, which income groups capture the gains and which bear the costs through higher prices or displaced employment.

Shocks also generate heterogeneous adjustment patterns: an energy price increase affects energy-intensive manufacturing differently from services, while trade liberalization in agriculture has distinct implications for rural and urban labor markets. Capturing these dynamics is essential for understanding how growth translates into jobs, incomes, and welfare. It also supports the Sustainable Finance accelerator of the Strategic Plan, by tracing how changes in public and private investment flows — including those channelled through concessional finance, blended finance instruments, or official development assistance — affect sectoral output, fiscal space, and the distribution of income across households. Amid supply chain fragmentation, rising industrial policy, and persistent food and energy price spikes (UNCTAD, 2024; UN DESA, 2025), this capacity for structural diagnostics is a core requirement for evidence-based policy support.

4.2 What happens to jobs — and whose jobs?

Aggregate employment figures conceal as much as they reveal — a net gain in jobs can mask simultaneous losses for unskilled workers and gains for skilled ones. For instance, a trade liberalization that raises overall employment may simultaneously reduce unskilled jobs in previously protected industries while expanding skilled employment in export-oriented sectors — an outcome with very different implications for poverty and inequality than the headline figures suggest. This pattern is consistent with a large body of empirical evidence showing that trade liberalization and technological change tend to be skill-biased, increasing the relative demand for skilled workers and widening skill premiums (Acemoglu, 2002; Goldberg & Pavcnik, 2007; World Bank, 2019; IMF, 2026). More recent research further indicates that automation and digitalisation amplify these dynamics by contributing to labor market polarization, reinforcing disparities across skill groups (Ciarli et al., 2022; Chen et al., 2025).

By distinguishing four groups of workers — skilled men, skilled women, unskilled men, and unskilled women — and treating them as separate factors of production, the UNDP CGE model generates distinct wage and employment outcomes for each group. This allows it to capture not only the overall volume of job creation or loss, but also its composition. In doing so, the model provides a clear assessment of whether a given shock or policy supports inclusive employment, or instead concentrates gains among workers who are already better off.

This architecture directly supports the UNDP J4PF, which emphasizes the importance of tracking not just job creation but the quality and inclusivity of employment generated. The model also directly supports the Gender Equality accelerator of the UNDP Strategic Plan 2026–2029 through its sex-disaggregated labor market outcomes. By generating wage results for men and women across skill levels, it identifies whether a given scenario narrows or widens gender earnings differentials, and thus whether it advances or constrains women's economic empowerment. Newly introduced indicators — including the wage inequality ratio and the sex-disaggregated skill premium — make these dynamics directly observable in the simulation results.

4.3 What happens to household welfare — and for which income group?

The distributional layer of the UNDP CGE model addresses a core limitation of aggregate models: how shocks affect different households. By disaggregating income and consumption across quintiles, it builds on the microsimulation CGE tradition (Savard, 2003; Cockburn, 2006; Bourguignon & Savard, 2008; Decaluwé et al., 2013) to assess welfare outcomes directly at the household level.

Household welfare is determined by two forces: changes in income and changes in the cost of living. On the income side, the model tracks multiple sources across quintiles using country-specific data. This ensures that changes in factor markets translate into welfare impacts for the groups that actually earn from each source. Because lower-income households depend more on unskilled wages and transfers, while higher-income groups rely more on skilled labor and capital, the distributional impact of a policy depends critically on which income sources are affected. As a result, two scenarios can generate similar aggregate growth outcomes while producing very different distributional effects: expansion concentrated in capital-intensive sectors tends to benefit upper-income groups, whereas labor-intensive growth generates broader welfare gains. The model makes these differences explicit by producing quintile-level income and consumption changes, allowing policymakers to assess whether growth is pro-poor, distribution-neutral, or inequality-increasing (Ravallion and Chen, 2003), and to identify the structural drivers — including labor intensity, capital returns, and sectoral composition — behind these outcomes (Cockburn et al., 2015; Annabi et al., 2019). And, critically, the model identifies the source of distributional change, not merely its direction. When lower-income quintiles are losing ground relative to upper quintiles, the appropriate policy response depends on whether the driver is a commodity price shock, which calls for social protection and targeted transfers; a contraction in unskilled wages, which points toward labor market or human capital policy; or a shift in the functional distribution of income toward capital. Each diagnosis implies a distinct intervention, enabling the kind of evidence-driven policy response that the UNDP SP's systems approach demands.

Public transfers occupy a particularly important place in this framework. Unlike most CGE models, which omit social assistance entirely or subsume it within a single representative household, the UNDP CGE model explicitly represents social assistance as a distinct income flow allocated across quintiles — reflecting its design as an instrument targeted at lower-income groups. This makes it possible to simulate directly how changes to transfer programmes affect household welfare: an expansion of cash transfers to the bottom two quintiles, a reduction in social spending under fiscal consolidation, or a reform of targeting mechanisms that shifts coverage between income groups. The model can also assess revenue recycling scenarios — for instance, whether fiscal savings from energy subsidy reform are redistributed as targeted transfers, and whether that redistribution is sufficient to offset the cost-of-living increase that lower-income households face when subsidies are removed. Because public transfers are disproportionately important for the lowest quintiles, their presence or absence in a simulation fundamentally shapes how fiscal shocks, subsidy removals, and crisis responses transmit through the income distribution — and the model is specifically designed to make those dynamics visible.

On the consumption side, the model incorporates quintile-specific expenditure patterns, reflecting that poor and rich households do not consume the same bundle of goods. Lower quintiles allocate a larger share of their budgets to food and energy, making them more exposed to price shocks in these goods, while higher-income households spend relatively more on services and imported goods. Consequently, identical price changes can have regressive welfare effects, disproportionately reducing real incomes among poorer households — a pattern well documented in the empirical literature (Ivanic and Martin, 2014; IFPRI, 2023; Hirvonen et al., 2023).

4.4 What happens to poverty and inequality?

Identifying whether a policy or shock is genuinely poverty-reducing requires going beyond quintile averages to assess how the full income distribution shifts.

For any scenario the model simulates — a tariff reform, an energy subsidy removal, a cash transfer expansion, a commodity price spike — it is possible to estimate not only which quintile gains or loses, but whether the number of people living in poverty rises or falls, and by how much. The poverty threshold is fully adjustable: USD 3 per day for extreme poverty, USD 4.20 for the lower-middle income line, and USD 8.30 for the upper-middle income line — allowing the analysis to be calibrated to the country context at hand. This flexibility is particularly important across UNDP's diverse country portfolio, from least developed economies where extreme poverty remains widespread, to middle-income countries where the policy debate has shifted toward broader definitions of economic vulnerability.

This capability directly supports the Prosperity for All accelerator of the UNDP SP 2026–2029, providing governments and country offices with the evidence base to assess whether a given policy is genuinely inclusive — or whether aggregate gains come at the cost of the most vulnerable.

4.5 Who bears the burden of climate and environmental policy?

Carbon pricing, energy subsidy reform, and natural resource taxation are key fiscal instruments of climate transition in developing economies. The SP 2026–2029 commits UNDP to supporting just and sustainable transitions under global climate and biodiversity frameworks (UNDP, 2025), which requires careful assessment of their distributional effects. Without compensatory measures, these policies tend to be regressive, as lower-income households spend a larger share of their budgets on energy and energy-intensive goods. This pattern is widely documented across countries (Hodok and Kozluk, 2024; Steckel et al., 2021; Ohlendorf et al., 2021; Missbach et al., 2024).

The UNDP CGE model captures these effects through both consumption and income channels. Using quintile-specific consumption baskets, it estimates the cost-of-living impact of environmental price changes for each income group, while simultaneously assessing how sectoral shifts affect wages and employment across skill levels. This integrated approach is essential, as these channels may reinforce or offset each other depending on country structure.

The model also evaluates revenue recycling options that determine whether reforms remain regressive or can be made progressive. For example, redistributing carbon tax revenues as targeted transfers can offset cost increases for lower-income households, supporting both the Healthy Planet and Prosperity for All objectives. In addition, the model can simulate climate-related productivity losses — such as in agriculture — and trace their distributional impacts when productivity shocks are informed by external climate projections, helping identify where climate risks concentrate and informing the Crisis Resilience agenda.

4.6 Where are the effects largest — and for which country groups?

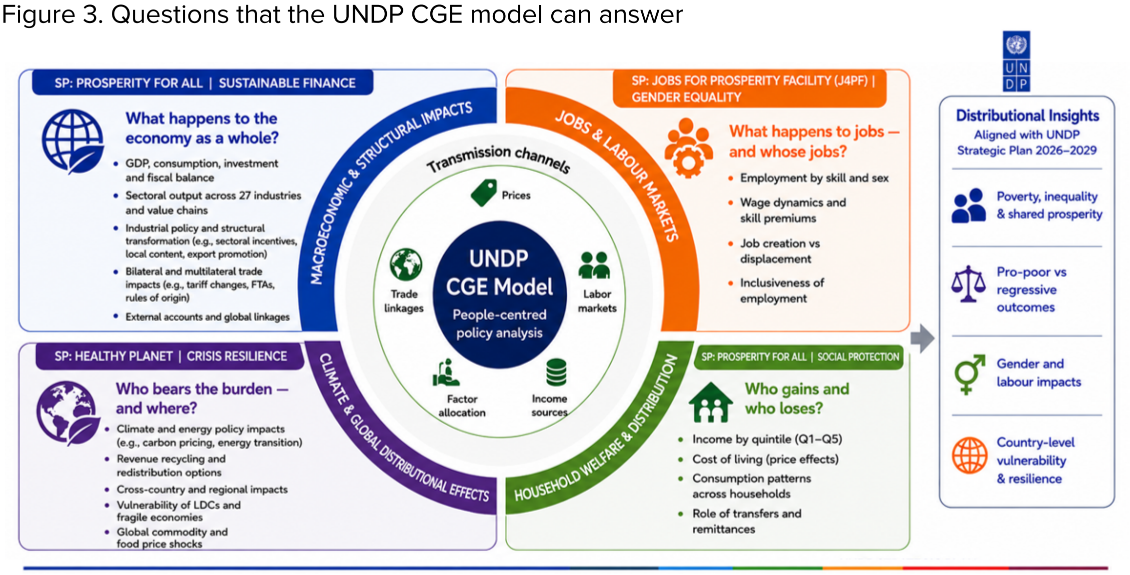
The UNDP CGE model's coverage of 125 countries enables systematic comparison of shock transmission across income levels, development groups, and regions within a single consistent framework. This comparability is central to its policy value: identifying where global shocks have the greatest impact and supporting UNDP country and regional offices in designing context-specific responses. UNDP SP's Crisis Resilience objective emphasizes support to the most vulnerable countries — including least developed countries (LDCs), fragile and conflict-affected states, and Small Island Developing States — and strengthening their capacity to absorb and recover from shocks (UNDP, 2025).

LDCs face compounded vulnerabilities operating through several channels captured by the model. Many rely heavily on a narrow set of commodity exports, making government revenues and external balances highly sensitive to terms-of-trade shocks. High trade openness also accelerates the transmission of global price changes into domestic cost-of-living pressures, disproportionately affecting lower-income households. At the same time, remittances — which reached $685 billion to low- and middle-income countries in 2024, exceeding both FDI and official aid (World Bank, 2024) — serve as a critical buffer, meaning that disruptions have immediate welfare consequences. In addition, reliance on trade taxes creates a fiscal channel through which trade reforms can constrain the financing of public services and social protection.

By generating comparable distributional results across countries, the model provides a robust evidence base to target support where vulnerability is greatest and to inform development finance decisions. This directly supports the Crisis Resilience objective and the Sustainable Finance accelerator, which call for better alignment of resources with countries' exposure to shocks and development needs (UNDP, 2025; UNCTAD, 2024).

Figure 3 summarizes how the UNDP CGE model maps the full distributional path of an economic shock, tracing impacts from the aggregate economy to individual households through five transmission channels.

Figure 3. Questions that the UNDP CGE model can answer



Source: Elaborated by the authors.

5. Linking global and national CGE models: a two-stage approach

While the UNDP CGE model operates at the global level, its outputs can generate actionable insights for national-level analysis through a structured two-stage approach. By simulating specific shocks to the global model—such as changes in trade flows, commodity prices, or sectoral productivity—it is possible to extract quantified estimates of how these shocks propagate through key economic indicators. Rather than relying on exogenous assumptions about national economic responses, these estimated shocks derived from the global model's dynamics are then fed into a national CGE framework. This approach ensures that national analysis remains grounded in plausible global economic conditions, rather than treating the national economy as isolated from international developments.

The methodological benefit of this two-stage approach is that it preserves the internal consistency of global economic transmission while allowing for detailed national-level behavioural responses that would be intractable in a fully global model. The global UNDP CGE model captures inter-country spillovers, sectoral shifts, and macro aggregates; a national CGE model then unpacks how those global shocks translate into employment, distributional, and sectoral outcomes within the specific institutional and structural context of the country in question.

6. Planned extensions, limitations, and the path forward

The UNDP World CGE Model is presented in this paper as a living analytical platform. Its current version already provides a basis for integrated, people-centred policy simulation, but the policy questions facing countries are evolving quickly.

This section outlines planned extensions to the model, discusses the main limitations that should guide interpretation of results, and identifies the path forward for strengthening the model's policy relevance and country-level use.

6.1 Planned extensions

6.1.1 A dynamic version

The most consequential planned extension is the development of a recursive dynamic version of the model. The current model is static: it compares the economy before and after a shock or policy change, but it does not trace the adjustment path over time. A recursive dynamic version would update capital stock from period to period through investment decisions and allow the economy's trajectory to be tracked across a defined simulation horizon.

This extension is especially important for analysing structural transformation. The movement of resources from low-productivity to higher-productivity activities, which is central to the pathway from poverty to prosperity, unfolds over time. Its pace depends on capital accumulation, productivity growth, skills development, labour market adjustment, and the interaction between trade, investment, and domestic production. A dynamic framework would allow users to assess not only whether a policy improves outcomes, but how quickly those outcomes emerge, who benefits during the transition, and whether short-term adjustment costs are outweighed by longer-term gains.

A dynamic version would also strengthen analysis of climate and energy policy. Many climate policies involve immediate distributional costs and longer-term economic, fiscal, and environmental benefits. For example, a carbon tax may raise energy costs in the short term while generating public revenue and supporting lower-emission development over time. A dynamic model would allow these temporal trade-offs to be examined more explicitly, including their implications for household welfare, investment, employment, and equity.

6.1.2 An environmental and emissions module

A second planned extension is the integration of an environmental and emissions module. The current model can assess the economic and distributional effects of climate-related policy instruments, but it does not yet track physical environmental outcomes such as greenhouse gas emissions, land use change, water stress, or biodiversity pressures.

This integration is directly relevant to the SP's Healthy Planet objective and to UNDP's support for countries' Nationally Determined Contributions under the Paris Agreement. The ability to simulate the joint economic, distributional, and environmental outcomes of alternative policy packages within a single consistent framework is a core requirement for evidence-based climate policy design. The emissions module could draw on sector-level emissions intensity data from the GTAP E database and the IEA World Energy Balances, providing coverage consistent with the model's country and sectoral scope.

In a subsequent phase, the environmental module could be extended to incorporate land use dynamics, linking agricultural sector expansion or contraction to changes in forest cover, biodiversity habitat, and associated carbon stocks. This extension would enable the model to assess the environmental consequences of agricultural trade policy and commodity price changes — an important dimension for LDCs whose development pathways are closely tied to land-based primary sectors.

6.1.3 Sub-national dimension

A sub-national extension is also under consideration for selected countries. While the current model supports global and national-level analysis, many policy decisions require a more granular understanding of where vulnerability is concentrated within countries.

A sub-national module could disaggregate results by region, province, or urban-rural classification where data permit. This would be particularly useful for policy questions related to social protection targeting, place-based development, infrastructure investment, jobs strategies, climate adaptation, and crisis response. It would allow policymakers to move from national averages to geographically differentiated insights, helping identify which territories are most exposed to shocks and which policy packages are most relevant for local pathways from poverty to prosperity.

6.1.4 Linkage with microsimulation models

A formal linkage between the CGE model and individual-level microsimulation frameworks is planned for selected high-priority countries. In this approach, changes in wages, employment, factor returns, commodity prices, and transfers generated by the CGE model would be passed into a microsimulation model that represents the full household income distribution.

This would allow analysis beyond the current five-quintile structure. It would support more detailed estimates of poverty headcounts, poverty gaps, inequality measures, Gini coefficients, income mobility, and distributional impacts across demographic or geographic groups. Such a linkage would be particularly valuable where high-quality household surveys are available and where governments require detailed distributional evidence for policy design.

6.2 Current model limitations

The planned extensions respond to several limitations in the current model. These limitations do not reduce the model's value, but they should guide how results are interpreted and communicated.

The UNDP CGE model is based on a static framework: it identifies where an economy settles after a shock or policy change, but does not trace the path of adjustment over time. It cannot capture the dynamics of capital accumulation, the pace of structural transformation, or the long-run compounding effects of policies whose consequences unfold across multiple periods. The dataset covers 125 countries but is anchored to a 2023 base year — before the most recent energy and food price shocks caused by geopolitical risks and military operations, and the subsequent restructuring of global supply chains. This structural lag should be kept in mind when interpreting results in today's context.

Physical environmental flows — greenhouse gas emissions, land use change, water stress — are not yet integrated, meaning the model can assess the economic and distributional consequences of climate policy instruments but cannot track the environmental outcomes those instruments are designed to achieve. There is no financial sector and no mechanism for converting quintile welfare changes into poverty headcount estimates within the model. However, where household survey data are available for a given country, poverty estimates can be produced as an integral part of the model simulation itself — rather than as a separate step applied after the simulations.

The reliability of country-specific distributional results is also conditioned by data quality. The quintile parameters that underpin the model's household welfare analysis — income shares by source, expenditure patterns by commodity — are obtained from household surveys whose availability, coverage, and methodological consistency vary considerably across countries. For many high-income and upper-middle-income countries, recent, well-documented surveys are available from national statistical offices or international harmonised databases. However, for a significant number of low-income and least developed countries, survey data are either dated — in some cases more than a decade old — incomplete in their coverage of informal income sources or inconsistently harmonised across income concepts. Where survey data are absent or unreliable, quintile shares are imputed from regional or HDI-group averages, introducing uncertainty into the country-specific distributional parameters.

This concern is compounded for sex-disaggregated employment outcomes: in countries where women's labour market participation is predominantly informal or unpaid — as in much of Sub-Saharan Africa — sex-disaggregated employment shares may not accurately reflect actual labour income distributions, and results on the gender wage gap should be interpreted with particular caution.

Countries that are not individually represented in the model — because they fall below the threshold for individual representation in GTAP 12 — are grouped into regional aggregates. These aggregates are modelled as composite economies whose structural parameters reflect population-weighted averages across their constituent countries. As a consequence, results for countries that are part of a regional aggregate are less precise than for individually modelled countries: the composite's trade patterns, sectoral structure, and household distribution may not closely reflect the characteristics of any individual country within the group. This is a particular concern for small island developing states, which are often grouped into rest-of-region categories despite having structurally distinct economic characteristics — notably extreme trade openness, high remittance dependence, and acute exposure to tourism and climate shocks.

6.3 The path forward

The path forward is to strengthen the UNDP World CGE Model as a shared analytical platform for integrated policy support. This means advancing technical extensions while also building the institutional processes needed for country-level application, validation, and use.

The first priority is to deepen the model's dynamic capabilities. A recursive dynamic version would allow UNDP and partner governments to examine medium- and long-term development pathways, including structural transformation, productivity growth, climate transitions, investment strategies, and the sequencing of policy reforms.

The second priority is to integrate environmental and emissions accounting. This would allow the model to support more complete analysis of just transitions, climate policy, green industrial strategies, energy price reforms, and NDC implementation. The value of this extension lies in assessing economic, distributional, fiscal, and environmental outcomes together rather than separately.

The third priority is to develop country-level applications with stronger household and spatial data. For selected countries, the model should be linked to household survey data, microsimulation tools, and, where possible, sub-national datasets. This would allow deeper analysis of poverty, inequality, gender, vulnerability, and territorial disparities, making the model more useful for practical policy design.

The fourth priority is to embed the model in policy dialogue. The model should not be used only to produce technical outputs. It should support structured conversations with governments and development partners on policy choices, trade-offs, and implementation options. Its greatest value lies in helping policymakers compare scenarios, understand distributional consequences, and design integrated packages that protect vulnerable groups while advancing transformation.

The fifth priority is to strengthen transparency, documentation, and collaboration. As the model evolves, clear documentation, replicable scenario protocols, country validation processes, and partnerships with national institutions and research networks will be essential. This will help ensure that the model is not only technically robust, but also trusted, usable, and relevant for decision-making.

The UNDP World CGE Model should therefore be understood as a foundation rather than a finished product. Its current version already expands the ability to analyse the distributional consequences of shocks and policies at global scale. Its future development will extend that capability across time, geography, environmental systems, and richer household distributions.

7. Conclusion

This paper has introduced the UNDP World CGE Model as an integrated, people-centred framework for policy scenario analysis. At a time when countries face overlapping shocks, constrained fiscal space, rising inequality, climate risks, and uncertain development pathways, the model responds to a central policy need: understanding not only what happens to the economy, but what happens to people.

By combining economy-wide modelling with household quintiles, gender-disaggregated labour categories, sectoral detail, trade linkages, public finance, remittances, aid flows, and poverty analysis, the model helps translate macroeconomic change into distributional and human development outcomes. It allows governments and development partners to examine who gains, who loses, through which channels, and under what policy conditions.

The model is directly relevant to UNDP's Strategic Plan and its ambition to support countries in moving from poverty to prosperity and well-being. It provides a practical tool for assessing trade-offs across growth, jobs, resilience, gender equality, fiscal policy, sustainable finance, and structural transformation. Its value lies not only in producing simulations, but in supporting more integrated policy dialogue and better-informed choices.

As a living analytical platform, the UNDP World CGE Model will continue to evolve through planned extensions, including dynamic modelling, environmental and emissions accounting, sub-national analysis, and microsimulation linkages. These developments will strengthen its ability to support country-specific policy design and long-term development planning.

Ultimately, the purpose of the model is to help ensure that policy choices are assessed by their contribution to people's lives: whether they reduce poverty, expand opportunity, strengthen resilience, and create more inclusive pathways to prosperity and well-being.

References

Acemoglu, D. (2002). Technical change, inequality, and the labor market. *Journal of Economic Literature, 40*(1), 7–72. https://doi.org/10.1257/jel.40.1.7

Acemoglu, D., Johnson, S., & Robinson, J. A. (2001). The colonial origins of comparative development: An empirical investigation. *American Economic Review, 91*(5), 1369–1401.

Aguiar, A., Chepeliev, M., Corong, E., McDougall, R., & van der Mensbrugghe, D. (2019). The GTAP Data Base: Version 10. Journal of Global Economic Analysis, 4(1), 1–27. https://www.jgea.org/ojs/index.php/jgea/article/view/77

Aguiar, A., Narayanan, B., & McDougall, R. (2022). *The GTAP Data Base: Version 11*. Center for Global Trade Analysis, Purdue University.

Aguiar, A., Narayanan, B., & McDougall, R. (2025). *GTAP 12 Data Base*. Center for Global Trade Analysis, Purdue University.

Annabi, N., Coady, D., & Al-Sadiq, A. (2019). Distributional effects of fiscal reforms: A CGE approach. *IMF Working Paper*.

Balasubramanian, V., Burchi, F., & Malerba, D. (2023). Multidimensional poverty and growth dynamics.

Banerjee, A. V., & Duflo, E. (2004). Do firms want to borrow more? Testing credit constraints using a directed lending program. *Review of Economic Studies, 71*(1), 1–30.

Banerjee, A. V., Breza, E., Duflo, E., & Kinnan, C. (2019). Can microfinance unlock a poverty trap for some entrepreneurs? *Journal of Economic Perspectives, 33*(1), 167–190.

Barro, R. J. (1991). Economic growth in a cross section of countries. *Quarterly Journal of Economics, 106*(2), 407–443.

Barrientos, A. (2010). Social protection and poverty. *Social Policy and Society, 9*(1), 1–11.

Beck, T., Demirgüç-Kunt, A., & Levine, R. (2007). Finance, inequality and the poor. *Journal of Economic Growth, 12*(1), 27–49.

Beegle, K., Hentschel, J., & Rama, M. (2013). *World Development Report 2013: Jobs*. World Bank.

Besley, T., & Burgess, R. (2000). Land reform, poverty reduction, and growth: Evidence from India. *Quarterly Journal of Economics, 115*(2), 389–430.

Bourguignon, F. (2003). The growth elasticity of poverty reduction: Explaining heterogeneity across countries and time periods.

Bourguignon, F. (2004). The poverty–growth–inequality triangle. World Bank.

Bourguignon, F., & Savard, L. (2008). Distributional effects of trade liberalization in developing countries. *World Bank Policy Research Working Paper*.

Bourguignon, F., Robilliard, A.-S., & Robinson, S. (2005). Representative versus real households in macroeconomic modeling of inequality.

Bussolo, M., De Hoyos, R., & Medvedev, D. (2010). Economic growth and income distribution: Linking macroeconomic models with household survey data. World Bank.

Calderón, C., & Servén, L. (2010). Infrastructure and economic development in Sub-Saharan Africa. *Journal of African Economies, 19*(suppl_1), i13–i87.

Chen, H., Sun, Y., & Yuan, Y. (2025). Artificial intelligence and skills: Evidence from job vacancies.

Christiaensen, L., Demery, L., & Kuhl, J. (2011). The (evolving) role of agriculture in poverty reduction. *Journal of Development Economics, 96*(2), 239–254.

Ciarli, T., Lorentz, A., Valente, M., & Savona, M. (2022). Automation, digitalisation, and labour market outcomes. *Journal of Economic Behavior & Organization, 200*, 499–535.

Cockburn, J. (2006). Trade liberalisation and poverty in Nepal: A CGE–microsimulation analysis. *Journal of Policy Modeling, 28*(8), 817–829.

Cockburn, J. et al. Macro-Micro models. Handbook of Microsimulation Modelling, 2014.

Cockburn, J., Corong, E., & Savard, L. (2015). A CGE–microsimulation framework. *World Bank Economic Review, 29*(S1), S60–S80.

Decaluwé, B., Dumont, J.-C., Savard, L., & Thorbecke, E. (2013). Poverty and inequality analysis in CGE models. *Journal of Policy Modeling, 35*(3), 388–401.

Erumban, A. A., & de Vries, G. J. (2024). Structural change and poverty reduction. *World Development, 181*, 106674.

Ferreira, F. H. G., & Ravallion, M. (2008). Global poverty and inequality: A review of the evidence. *World Bank Policy Research Working Paper No. 4623*. World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/

Fiszbein, A., & Schady, N. (2009). *Conditional cash transfers: Reducing present and future poverty*. World Bank.

Goldberg, P. K., & Pavcnik, N. (2007). Distributional effects of globalization in developing countries. *Journal of Economic Literature, 45*(1), 39–82.

Hanushek, E. A., & Woessmann, L. (2008). The role of cognitive skills in economic development. *Journal of Economic Literature, 46*(3), 607–668.

Hirvonen, K., et al. (2023). *Food price inflation and diet quality*. IFPRI.

ILO. (2026). *ILOSTAT Database*. https://rshiny.ilo.org/dataexplorer21/

IMF. (2026). *Bridging Skill Gaps for the Future: New Jobs Creation in the AI Age.* International Monetary Fund. Staff Discussion Note SDN2026/001. Washington, DC.

Ivanic, M., & Martin, W. (2014). Impacts of food price changes on poverty. *World Bank Economic Review*.

Karabarbounis, L., & Neiman, B. (2014). The global decline of the labor share. *Quarterly Journal of Economics, 129*(1), 61–103.

Kirman, A. (1992). Whom or what does the representative individual represent? *Journal of Economic Perspectives, 6*(2), 117–136.

Lemelin, A., Robichaud, V., & Decaluwé, B. (2013). The PEP World Model.

Lofgren, H., Harris, R., & Robinson, S. (2002). A standard computable general equilibrium model in GAMS. IFPRI.

Hodok, J. and T. Kozluk (2024), "Distributional impacts of energy transition pathways and climate change", *OECD Economics Department Working Papers*, No. 1820, OECD Publishing, Paris, https://doi.org/10.1787/56e93f3e-en.

Marrero, G. A., & Servén, L. (2022). Growth, inequality and poverty. *Empirical Economics, 63*, 725–791.

McMillan, M., & Rodrik, D. (2011). Globalization, structural change and productivity growth. *World Development, 39*(4), 475–492.

McMillan, M., Rodrik, D., & Verduzco-Gallo, Í. (2014). Globalization, structural change and productivity growth. *World Development, 63*, 11–32.

Missbach, L., Steckel, J.C., Vogt-Schlib, A. (2024). Cash transfers in the context of carbon pricing reforms in Latin America and the Caribbean. World Development, 173. https://doi.org/10.1016/j.worlddev.2023.106406.

Ohlendorf, N., Jakob, M., Minx, J. C., Schröder, C., Schröder, C., & Steckel, J. C. (2021). Distributional Impacts of Carbon Pricing: A Meta-Analysis. *Environmental and Resource Economics*, *78*(1), 1–42. https://doi.org/10.1007/S10640-020-00521-1

Piketty, T. (2014). *Capital in the twenty-first century*. Harvard University Press.

Rao, N. D., Min, J., & Mastrucci, A. (2017). Energy, inequality and poverty. IIASA Working Paper.

Ravallion, M. (2001). Growth, inequality and poverty. *World Development, 29*(11), 1803–1815.

Ravallion, M. (2012). Why don't we see poverty convergence? *American Economic Review, 102*(1), 504–523.

Ravallion, M., & Chen, S. (2003). Measuring pro-poor growth. *Economics Letters, 78*(1), 93–99. https://doi.org/10.1016/S0165-1765(02)00205-7

Ravallion, M., & Chen, S. (2009). China's (uneven) progress against poverty. *Journal of Development Economics, 82*(1), 1–42. https://doi.org/10.1016/j.jdeveco.2005.07.003

Ravallion, M., & Chen, S. (2007). China's progress against poverty. *Journal of Development Economics, 82*(1), 1–42.

Ross, M. (2012). *The oil curse*. Princeton University Press.

Santos, M. E., Dabus, C., & Delbianco, F. (2019). Growth and multidimensional poverty.

Savard, L. (2003). Poverty and income distribution in CGE models.

Savard, L. (2005). Poverty and inequality analysis in CGE models. *Development Policy Review, 23*(3), 313–331.

Son, H., & Kakwani, N. (2008). Poverty reduction elasticity.

Steckel, J. C., Dorband, I. I., et al. (2021). Distributional impacts of carbon pricing in developing Asia. *Nat Sustain* 4, 1005–1014. https://doi.org/10.1038/s41893-021-00758-8

Stiglitz, J. E. (2012). *The price of inequality*. W. W. Norton.

Stiglitz, J. E., Sen, A., & Fitoussi, J.-P. (2009). Report on the measurement of economic performance and social progress.

UNCTAD. (2024). *Trade and Development Report*.

UN DESA. (2025). *World Economic Situation and Prospects*.

UNDP. (2019). *Human Development Report*.

UNDP. (2025). *Strategic Plan 2026–2029*.

UNDP & OPHI. (2025). *Global Multidimensional Poverty Index 2025*.

World Bank. (2022). *Poverty and Shared Prosperity*.

World Bank. (2024). *Poverty, Prosperity, and Planet Report*.

World Bank. (2024). *Migration and Development Brief*.

Appendix A: Equations, Variables and Parameters

Equations

A.1. Production

1. $VA_{j,z} = v_{j,z}XS_{j,z}$
2. $CI_{j,z} = io_{j,z}XS_{j,z}$
3. $LDU_{j,z} = VA_{j,z}\left[\frac{\beta_{j,z}^{VAU}PVA_{j,z}}{WLU_{j,z}}\right]^{\sigma_{j,z}^{VA}}\left(TFPZ_z\,TFP_{j,z}\,B_{j,z}^{VA}B_{j,z}^{VA}\right)^{\sigma_{j,z}^{VA}-1}$
4. $KD_{Land,j,z} = VA_{j,z}\left[\frac{\beta_{j,z}^{VAD}PVA_{j,z}}{RTI_{Land,j,z}}\right]^{\sigma_{j,z}^{VA}}\left(TFPZ_z\,TFP_{j,z}\,B_{j,z}^{VA}B_{j,z}^{VA}\right)^{\sigma_{j,z}^{VA}-1}$
5. $KD_{NatRes,j,z} = VA_{j,z}\left[\frac{\beta_{j,z}^{VAN}PVA_{j,z}}{RTI_{NatRes,j,z}}\right]^{\sigma_{j,z}^{VA}}\left(TFPZ_z\,TFP_{j,z}\,B_{j,z}^{VA}B_{j,z}^{VA}\right)^{\sigma_{j,z}^{VA}-1}$
6. $KL_{j,z} = VA_{j,z}\left[\frac{\beta_{j,z}^{VAB}PVA_{j,z}}{PKL_{j,z}}\right]^{\sigma_{j,z}^{VA}}\left(TFPZ_z\,TFP_{j,z}\,B_{j,z}^{VA}B_{j,z}^{VA}\right)^{\sigma_{j,z}^{VA}-1}$
7. $PVA_{j,z}VA_{j,z} = WLU_{j,z}LDU_{j,z} + RTI_{Land,j,z}KD_{Land,j,z} + RTI_{NatRes,j,z}KD_{NatRes,j,z} + PKL_{j,z}KL_{j,z}$
8. $KD_{Capital,j,z} = KL_{j,z}\left[\frac{\beta_{j,z}^{KL}PKL_{j,z}}{RTI_{Capital,j,z}}\right]^{\sigma_{j,z}^{KL}}\left(B_{j,z}^{KL}\right)^{\sigma_{j,z}^{KL}-1}$
9. $LDS_{j,z} = KL_{j,z}\left[\frac{\left(1-\beta_{j,z}^{KL}\right)PKL_{j,z}}{WLS_{j,z}}\right]^{\sigma_{j,z}^{KL}}\left(B_{j,z}^{KL}\right)^{\sigma_{j,z}^{KL}-1}$
10. $PKL_{j,z}KL_{j,z} = WLS_{j,z}LDS_{j,z} + RTI_{Capital,j,z}KD_{Capital,j,z}$
11. $LD_{FSkLab,j,z} = LDS_{j,z}\left[\frac{\beta_{j,z}^{GS}WLS_{j,z}}{WTI_{FSkLab,j,z}}\right]^{\sigma_{j,z}^{GS}}\left(B_{j,z}^{GS}\right)^{\sigma_{j,z}^{GS}-1}$
12. $LD_{MSkLab,j,z} = LDS_{j,z}\left[\frac{\left(1-\beta_{j,z}^{GS}\right)WLS_{j,z}}{WTI_{MSkLab,j,z}}\right]^{\sigma_{j,z}^{GS}}\left(B_{j,z}^{GS}\right)^{\sigma_{j,z}^{GS}-1}$
13. $WLS_{j,z}LDS_{j,z} = \sum_{sw} WTI_{sw,j,z}LD_{sw,j,z}$
14. $LD_{FUnskLab,j,z} = LDU_{j,z}\left[\frac{\beta_{j,z}^{GU}WLU_{j,z}}{WTI_{FUnskLab,j,z}}\right]^{\sigma_{j,z}^{GU}}\left(B_{j,z}^{GU}\right)^{\sigma_{j,z}^{GU}-1}$
15. $LD_{MUnskLab,j,z} = LDU_{j,z}\left[\frac{\left(1-\beta_{j,z}^{GU}\right)WLU_{j,z}}{WTI_{MUnskLab,j,z}}\right]^{\sigma_{j,z}^{GU}}\left(B_{j,z}^{GU}\right)^{\sigma_{j,z}^{GU}-1}$
16. $WLU_{j,z}LDU_{j,z} = \sum_{su} WTI_{su,j,z}LD_{su,j,z}$
17. $DI_{i,j,z} = aij_{i,j,z}CI_{j,z}$

A.2. Income and savings

A.2.1 Households

18. $YH_{h,z} = YHL_{h,z} + YHK_{h,z} + PTR_{h,z} + \lambda_{h,z}^{RM}RMI_z$
19. $YHL_{h,z} = \sum_l W_{l,z}\left(1-unr_{l,z}\right)LSH_{h,l,z} \quad \forall\, z\, rich$
20. $YHL_{h,z} = \sum_{sw} W_{sw,z}\left(1-unr_{sw,z}\right)LSH_{h,sw,z} + W_{FunSklab,z}\left(unr_{FSklab,z}LSH_{h,FSklab,z} + LSH_{h,FunSklab,z}\right) + W_{MunSklab,z}\left(unr_{MSklab,z}LSH_{h,MSklab,z} + LSH_{h,MunSklab,z}\right) \quad \forall\, z\, poor$
21. $YHK_{h,z} = \lambda_{h,'capital',z}^{RK}RKNTOT_z + \lambda_{h,'land',z}^{RK}\sum_{k,j} R_{'land',j,z}KD_{'land',j,z} + \lambda_{h,'NatRes',z}^{RK}\sum_{k,j} R_{'NatRes',j,z}KD_{'NatRes',j,z}$
22. $YDH_{h,z} = YH_{h,z} - TDH_{h,z}$
23. $CTH_{h,z} = YDH_{h,z} - SH_{h,z} - \frac{YH_{h,z}}{\sum_{hj} YH_{hj,z}}RMO_{,z}$
24. $SH_{h,z} = PIXCON_z sh0_{h,z} + sh1_{h,z}YDH_{h,z}$

A.2.2 Government

25. $YG_z = \sum_h TDH_{h,z} + TPRODN_z + TPRCTS_z + \sum_{zj} WTR_{z,zj}$
26. $TPRODN_z = TIWT_z + TIKT_z + TIPT_z$

27. $TIWT_z = \sum_{l,j} TIW_{l,j,z}$

28. $TIKT_z = \sum_{k,j} TIK_{k,j,z}$

29. $TIPT_z = \sum_j TIP_{j,z}$

30. $TPRCTS_z = TICT_z + TIMT_z + TIXT_z$

31. $TICT_z = \sum_i TIC_{i,z}$

32. $TIMT_z = \sum_{i,zj} TIM_{i,zj,z}$

33. $TIXT_z = \sum_{i,zj} TIX_{i,z,zj}$

34. $TDH_{h,z} = ttdh_{h,z}\left[YHL_{h,z} + YHK_{h,z}\right]$

35. $TIW_{l,j,z} = ttiw_{l,j,z} W_{l,z} LD_{l,j,z}$

36. $TIK_{k,j,z} = ttik_{k,j,z} R_{k,j,z} KD_{k,j,z}$

37. $TIP_{j,z} = ttip_{j,z} PP_{j,z} XS_{j,z}$

38. $TIC_{i,z} = ttic_{i,z}\left[\begin{array}{c} PL_{i,z}DD_{i,z} + \\ \sum_{zj}\left(1 + ttim_{i,zj,z}\right) PWM_{i,zj,z} \quad TRADE_{i,zj,z} \end{array}\right]$

39. $TIM_{i,zj,z} = ttim_{i,zj,z}\, PWM_{i,zj,z}\, TRADE_{i,zj,z}$

40. $TIX_{i,z,zj} = ttix_{i,z,zj}\, PE_{i,z,zj}\, TRADE_{i,z,zj}$

41. $G_z = \sum_i PC_{i,z} CG_{i,z}$

42. $SG_z = YG_z - G_z - \sum_h PTR_{h,z} - \sum_{zj} WTR_{zj,z}$

A.2.3 Rest of the world

43. $RMI_z = \lambda_z^{RMI} \sum_{zj} RMO_{zj}$

44. $FYO_z = \lambda_z^{FYO} \sum_j R_{'capital',j,z} KD_{'capital',j,z}$

45. $FYI_z = \lambda_z^{FYI} \sum_{zj} FYO_{zj}$

46. $AIDI_z = \lambda_z^{AIDI} \sum_{zj} AIDO_{zj}$

47. $YROW_z = \sum_{i,zj}\left\{PWM_{i,zj,z}\, TRADE_{i,zj,z}\right\} + \sum_{zj} WTR_{zj,z} + RMO_{,z} + FYO_z + AIDO_z$

48. $SROW_z = YROW_z - \sum_{i,zj} PW_{i,z,zj} TRADE_{i,z,zj} - \sum_m PWMG_m MRGN_{m,z} - \sum_{zj} WTR_{z,zj} -$ $RMI_z - FYI_z - AIDI_z$

49. $SROW_z = -CAB_z$

A.3. Demand

50. $PC_{i,z}C_{i,h,z} = PC_{i,z}C_{i,h,z}^{MIN} + \gamma_{i,h,z}^{CTH}\left(CTH_{h,z} - \sum_{ij} PC_{ij,z}C_{ij,h,z}^{MIN}\right)$

51. $PC_{i,z}INV_{i,z} = \gamma_{i,z}^{INV} IT_z$

52. $DIT_{i,z} = \sum_j DI_{i,j,z}$

A.4. International trade

53. $EXT_{i,z} = \frac{XS_{i,z}}{\left(B_{i,z}^{X1}\right)^{\sigma_{i,z}^{X1}+1}}\left[\frac{PET_{i,z}}{\beta_{i,z}^{EX\_X1} P_{i,z}}\right]^{\sigma_{i,z}^{X1}}$

54. $DD_{i,z} = \frac{XS_{i,z}}{\left(B_{i,z}^{X1}\right)^{\sigma_{i,z}^{X1}+1}}\left[\frac{PL_{i,z}}{\beta_{i,z}^{D\_X1} P_{i,z}}\right]^{\sigma_{i,z}^{X1}}$

55. $MRGN_{i,z} = \frac{XS_{i,z}}{\left(B_{i,z}^{X1}\right)^{\sigma_{i,z}^{X1}+1}}\left[\frac{PWMG_{i,z}}{\left(1-\beta_{i,z}^{EX\_X1}-\beta_{i,z}^{D\_X1}\right)P_{i,z}}\right]^{\sigma_{i,z}^{X1}}$

56. $P_{j,z}XS_{j,z} = PL_{j,z}D_{j,z} + PET_{j,z}\, EXT_{j,z} + PMWG_j\, MRGN_{j,z}$

57. $TRADE_{i,z,zj} = \frac{EXT_{i,z}}{\left(B_{i,z}^{X2}\right)^{\sigma_{i,z}^{X2}+1}} \left[\frac{PE_{i,z,zj}}{\beta_{i,z,zj}^{X2} PET_{i,z}}\right]^{\sigma_{i,z}^{X2}}$

58. $PET_{i,z} EXT_{i,z} = \sum_{zj} PE_{i,z,zj} TRADE_{i,z,zj}$

59. $IMT_{i,z} = Q_{i,z} \left[\frac{\beta_{i,z}^{M1} PC_{i,z}}{PMT_{i,z}}\right]^{\sigma_{i,z}^{M1}} \left(B_{i,z}^{M1}\right)^{\sigma_{i,z}^{M1}-1}$

60. $DD_{i,z} = Q_{i,z} \left[\frac{(1-\beta_{i,z}^{M1}) PC_{i,z}}{PD_{i,z}}\right]^{\sigma_{i,z}^{M1}} \left(B_{i,z}^{M1}\right)^{\sigma_{i,z}^{M1}-1}$

61. $PC_{i,z} Q_{i,z} = PD_{i,z} DD_{i,z} + PMT_{i,z} IMT_{i,z}$

62. $TRADE_{i,zj,z} = IMT_{i,z} \left[\frac{\beta_{i,zj,z}^{M2} PMT_{i,z}}{PM_{i,zj,z}}\right]^{\sigma_{i,z}^{M2}} \left(B_{i,z}^{M2}\right)^{1-\sigma_{i,z}^{M2}}$

63. $PMT_{i,z} IMT_{i,z} = \sum_{zj} PM_{i,zj,z} TRADE_{i,zj,z}$

A.5. Prices

64. $PP_{j,z} XS_{j,z} = PVA_{j,z} VA_{j,z} + PCI_{j,z} CI_{j,z}$

65. $P_{j,z} = \left(1 + ttip_{j,z}\right) PP_{j,z}$

66. $PCI_{j,z} CI_{j,z} = \sum_i PC_{i,z} DI_{i,j,z}$

67. $WTI_{l,j,z} = \left(1 + ttiw_{l,j,z}\right) W_{l,z}$

68. $RTI_{k,j,z} = \left(1 + ttik_{k,j,z}\right) R_{k,j,z}$

69. $R_{k,j,z} = RK_{j,z}$

70. $PD_{i,z} = \left(1 + ttic_{i,z}\right) PL_{i,z}$

71. $PW_{i,z,zj} = \left(1 + ttix_{i,z,zj}\right) PE_{i,z,zj}$

72. $PWM_{i,z,zj} = PW_{i,z,zj} + \sum_m PWMG_m tmrg_{m,i,z,zj}$

73. $PM_{i,z,zj} = \left(1 + ttic_{i,z}\right) \left(1 + ttim_{i,z,zj}\right) PWM_{i,z,zj}$

74. $PK_z = \frac{1}{A_z^K} \prod_i \left[\frac{PC_{i,z}}{\gamma_{i,z}^{INV}}\right]^{\gamma_{i,z}^{INV}}$

75. $PIXGDP_z = \sqrt{\frac{\sum_j \left(PVA_{j,z} + \frac{TIP_{j,z}}{VA_{j,z}}\right) VA_{j,z}^O}{\sum_j PVA_{j,z}^O VA_{j,z}^O + TIP_{j,z}^O} \frac{\sum_j PVA_{j,z} VA_{j,z} + TIP_{j,z}}{\sum_j \left(PVA_{j,z}^O + \frac{TIP_{j,z}^O}{VA_{j,z}^O}\right) VA_{j,z}}}$

76. $PIXGDP^W = \sqrt{\frac{\sum_{j,z} \left(PVA_{j,z} + \frac{TIP_{j,z}}{VA_{j,z}}\right) VA_{j,z}^O}{\sum_{j,z} PVA_{j,z}^O VA_{j,z}^O + TIP_{j,z}^O} \frac{\sum_{j,z} PVA_{j,z} VA_{j,z} + TIP_{j,z}}{\sum_{j,z} \left(PVA_{j,z}^O + \frac{TIP_{j,z}^O}{VA_{j,z}^O}\right) VA_{j,z}}}$

77. $PIXCON_z = \frac{\sum_{i,h} PC_{i,z}\ C_{i,h,z}^O}{\sum_{ij} PC_{ij,z}^O\ C_{ij,h,z}^O}$

A.6. Equilibrium

78. $Q_{i,z} = \sum_h C_{i,h,z} + CG_{i,z} + INV_{i,z} + DIT_{i,z}$

79. $LSH_{h,l,z} = LSH_{h,l,z}^O\ LFP_{h,l,z}$

80. $LS_{l,z} = \sum_h LSH_{h,l,z}$

81. $LS_{l,z}\left(1 - unr_{l,z}\right) = \sum_j LD_{l,j,z} \quad \forall\ z\ rich$

82. $A_{l,z}^{UN} unr_{l,z}^{\sigma_z^{un}} = \frac{W_{l,z}}{PIXCON_z} \quad \forall\ z\ rich$

83. $LS_{sw,z}\left(1 - unr_{sw,z}\right) = \sum_j LD_{sw,j,z} \quad \forall\ z\ poor$

84. $LS_{FUnskLab,z} + LS_{FSkLab,z}\ unr_{FSkLab,z} = \sum_j LD_{FUnskLab,j,z} \quad \forall\ z\ poor$

85. $LS_{MUnskLab,z} + LS_{MSkLab,z}\ unr_{MSkLab,z} = \sum_j LD_{MUnskLab,j,z} \quad \forall\ z\ poor$

86. $A_{sw,z}^{UN} unr_{sw,z}^{\sigma_z^{un}} = \frac{W_{sw,z}}{PIXCON_z} \quad \forall\ z\ poor$

87. $KS_{k,z} = \sum_j KD_{k,j,z}$

88. $KS_{Capital,z} = KSP_{Capital,z}(1 - \delta_z) + \frac{IT_z}{PK_z}$ (only if FLAGK is set to 1)

89. $DEP_z = PK_z \delta_z \sum_k KS_{k,z}$
90. $RKNTOT_z = \sum_j R_{'capital',j,z} KD_{'capital',j,z} - DEP_z - FYO_z + FYI_z$
91. $IT_z = \sum_h SH_{h,z} + SG_z - CAB_z$
92. $\sum_z MRGN_{m,z} = \sum_{z,zj,ij} tmrg_{m,ij,zj,z} TRADE_{ij,zj,z}$

A.7. Other

93. $GDP_z^{BP} = \sum_j PVA_{j,z}\, VA_{j,z} + TIPT_z$
94. $GDP_z^{BP\_LS} = \frac{GDP_z^{BP} 1000000\, RES}{NB_z^{WORK}}$
95. $\frac{CAB_{z1}}{GDP_z^{BP}} = \frac{CAB_{z1}^{O}}{GDP_z^{BPO}}$ (only if *FLAGCAB* is set to 1)

Endogenous variables

$AIDI_z$	Foreign aid received by region *z*
$C_{i,h,z}$	Consumption of commodity *i* by households *h* in region *z*
$CI_{j,z}$	Total intermediate consumption of industry *j* in region *z*
$CTH_{h,z}$	Consumption budget of households *h* in region *z*
$DD_{i,z}$	Domestic demand for commodity *i* produced locally in region *z*
DEP_z	Amount of depreciation (capital consumption allowance) in region *z*
$DI_{i,j,z}$	Intermediate consumption of commodity *i* by industry j in region *z*
$DIT_{i,z}$	Total intermediate demand of commodity *i* in region *z*
$EXT_{i,z}$	Supply of composite commodity *i* by region *z* to the export market
FYI_z	Foreign investment income received by country *z*
FYO_z	Investment income paid by country z to foreigners
G_z	Current government expenditures on goods and services in region *z*
GDP_z^{BP}	Nominal GDP at basic prices
$GDP_z^{BP\_LS}$	Nominal GDP at basic prices per worker
$IMT_{i,z}$	Quantity demanded of composite imports of commodity *i* by region *z*
$INV_{i,z}$	Final demand of commodity *i* for investment purposes (GFCF) in region *z*
IT_z	Total investment expenditures in region *z*
$KD_{k,j,z}$	Demand for type *k* capital by industry *j* in region *z*
$KL_{j,z}$	Capital-Skilled workers bundle
$LD_{l,j,z}$	Demand for type *l* workers by industry *j* in region *z*
$LDS_{j,z}$	Demand for skilled workers by industry *j* in region *z*
$LDU_{j,z}$	Demand for unskilled workers by industry *j* in region *z*
$LSH_{h,l,z}$	Supply of type *l* labor by household *h* in region *z*
$MRGN_{i,z}$	Production of commodity *i* in region *z* exported as international margin services
$P_{j,z}$	Basic price of industry *j* production in region *z*
$PC_{i,z}$	Purchaser price of composite commodity *i* (including all taxes and margins) in region *z*
$PCI_{j,z}$	Intermediate consumption price index of industry *j* in region *z*
$PD_{i,z}$	Price of local product *i* sold on region *z* domestic market (including all taxes)
$PE_{i,z,zj}$	Price received for commodity *i* exported to region *zj* by region *z* (excluding export taxes)
$PET_{i,z}$	Border price of composite commodity *i* exported by region *z*
$PIXCON_z$	Consumer price index in region *z*
$PIXGDP_z$	GDP deflator in region *z*
$PIXGDP^W$	World GDP deflator
PK_z	Price of new capital in region *z*
$PKL_{j,z}$	Price of the capital – skilled workers bundle
$PL_{i,z}$	Price of local product *i* (excluding all taxes on products) in region *z*
$PM_{i,zj,z}$	Price of commodity *i* imported by region z from region *zj* (including all taxes duties and margins)
$PMT_{i,z}$	Price of composite commodity *i* imported by region *z* (including all taxes, duties and margins)
$PP_{j,z}$	Unit cost of industry *j* in region *z* excluding other taxes on production
$PVA_{j,z}$	Price of industry *j* value added in region *z*
$PW_{i,z,zj}$	World price of commodity *i* exported to country *zj* by region *z*
$PWM_{i,z,zj}$	World price of commodity *i* exported to country *zj* by region *z* including margins
$PWMG_m$	World price of margin *m*
$Q_{i,z}$	Quantity demanded of composite commodity *i* in region *z*

$R_{k,j,z}$	Rental rate of type *k* capital in industry *j* of region *z*
RMI_z	Remittances received by country *z*
RMO_z	Remittances paid by country *z*
$RK_{k,z}$	Rental rate of type *k* capital in region *z*
$RKNTOT_z$	Total capital income net of depreciation plus net investment income from the rest of the world
$RTI_{k,j,z}$	Rental rate paid by industry *j* for type *k* capital in region *z* including capital taxes
SG_z	Government savings in region *z*
$SH_{h,z}$	Household *h* savings in region *z*
$SROW_z$	Rest-of-the-world savings with respect to region *z*
TDH_z	Household income taxes in region *z*
$TIC_{i,z}$	Government revenue from indirect taxes on commodity *i* in region *z*
$TICT_z$	Total government receipts of indirect taxes on commodities in region *z*
$TIK_{k,j,z}$	Government revenue from taxes on type *k* capital used by industry *j* in region *z*
$TIKT_z$	Total government revenue from taxes on capital in region *z*
$TIM_{i,zj,z}$	Government revenue from duties on commodity *i* imported from region *zj* by region *z*
$TIMT_z$	Total government revenue from import duties in region *z*
$TIP_{j,z}$	Government revenue from taxes on industry *j* production in region *z*
$TIPT_z$	Total government revenue from production taxes in region *z*
$TIW_{l,j,z}$	Government revenue from payroll taxes on type *l* labor in industry *j* of region *z*
$TIWT_z$	Total government revenue from payroll taxes in region *z*
$TIX_{i,z,zj}$	Government revenue from export taxes on *commodity* i exported by region *z* to region *zj*
$TIXT_z$	Total government revenue from export taxes in region *z*
$TPRCTS_z$	Total government revenue from taxes on products and imports in region *z*
$TPRODN_z$	Total government revenue from other taxes on production in region *z*
$TRADE_{i,zj,z}$	Quantity of product *i* imported by country *z* from country *zj*
$unr_{l,z}$	Unemployment rate
$VA_{j,z}$	Value added of industry *j* in region *z*
$W_{l,z}$	Wage rate of type *l* labor in region *z*
$WLS_{j,z}$	Wage rate paid by industry *j* for skilled workers in region *z*
$WLU_{j,z}$	Wage rate paid by industry *j* for unskilled workers in region *z*
$WTI_{l,j,z}$	Wage rate paid *z* by industry *j* for type *l* labor in region including taxes
$XS_{j,z}$	Total output of industry *j* in region *z*
$YDH_{h,z}$	Household disposable income in region *z*
YG_z	Total government income in region *z*
$YH_{h,z}$	Household *h* total income in region *z*
$YHK_{h,z}$	Household *h* capital income in region *z*
$YHL_{h,z}$	Household *h* labor income in region *z*
$YROW_z$	Rest-of-the-world total income from region *z*

Exogenous variables

$AIDO_z$	Foreign aid paid by region *z*
$C_{i,h,z}^{MIN}$	Minimum consumption of commodity *i* by household *h* in region *z*
CAB_z	Current account balance of region *z* (if *FLAGCAB* is set to 0)
$CG_{i,z}$	Public consumption of commodity *i* in region *z*
$KD_{k,j,z}$	Demand for type *k* capital by industry *j* in region *z* (is capital is sector specific)
$KS_{k,z}$	Supply of type *k* capital in region *z* (if capital is mobile and if flagk = 0)

$KSP_{Capital,z}$	Capital stock prior to no investment
$LFP_{h,l,z}$	Labor productivity factor
NB_z^{WORK}	Number of workers
$PTR_{h,z}$	Public transfer to households *h*
$WTR_{z,zj}$	Transfers from abroad
$sh0_{h,z}$	Intercept (household *h* savings)
$sh1_{h,z}$	Slope (household *h* savings)
$TFP_{j,z}$	Total factor productivity (per industry and country - benchmark = 1)
$TFPZ_z$	Total factor productivity (per country - benchmark = 1)
$ttdh_{h,z}$	Household *h* income tax rate
$ttic_{i,z}$	Tax rate on commodity *i*
$ttik_{k,j,z}$	Tax rate on capital k used in industry *j*
$ttim_{i,zj,z}$	Rate of taxes and duties on imports of commodity *i* from country *zj*
$ttip_{j,z}$	Tax rate on the production of industry *j*
$ttiw_{l,j,z}$	Tax rate on type l worker compensation in industry *j*
$ttix_{i,z,zj}$	Export tax rate on exported commodity *i*

Parameters

A_z^K	Scale parameter (price of new capital)
$aij_{i,j,z}$	Input output coefficient
$A_{l,z}^{UN}$	Scale parameter (wage curve)
$B_{j,z}^{GS}$	Scale parameter (CES – skilled workers bundle)
$B_{j,z}^{GU}$	Scale parameter (CES – unskilled workers bundle)
$B_{j,z}^{KL}$	Scale parameter (CES – capital-skilled workers bundle)
$B_{i,z}^{M1}$	Scale parameter (CES – composite commodity)
$B_{i,z}^{M2}$	Scale parameter (CES – composite import)
$B_{j,z}^{VA}$	Scale parameter (CES – value-added)
$B_{i,z}^{X1}$	Scale parameter (CET – total output)
$B_{i,z}^{X2}$	Scale parameter (CET – composite export)
$\beta_{j,z}^{D\_X1}$	Share parameter (CET – total output - local sales)
$\beta_{j,z}^{EX\_X1}$	Share parameter (CET – total output - exports)
$\beta_{j,z}^{GS}$	Share parameter (CES – skilled workers bundle)
$\beta_{j,z}^{GU}$	Share parameter (CES – unskilled workers bundle)
$\beta_{j,z}^{KL}$	Share parameter (CES – capital-skilled workers bundle)
$\beta_{i,z}^{M1}$	Share parameter (CES – composite commodity)
$\beta_{i,zj,z}^{M2}$	Share parameter (CES – composite import)
$\beta_{j,z}^{VAB}$	Share parameter (CES – value-added, capital-skilled labor bundle)
$\beta_{j,z}^{VAD}$	Share parameter (CES – value-added, land)
$\beta_{j,z}^{VAN}$	Share parameter (CES – value-added, natural resources)
$\beta_{j,z}^{VAU}$	Share parameter (CES – value-added, unskilled workers)
$\beta_{i,z,zj}^{X2}$	Share parameter (CET - composite export)
δ_z	Depreciation rate
$FLAGCAB$	Dummy variable (1 if current account balance is proportional to GDP)
$FLAGK_{k,z}$	Dummy variable (1 if capital is impacted by investment)
$\gamma_{i,h,z}^{CTH}$	Marginal share of commodity *i* in household consumption budget
$\gamma_{i,z}^{INV}$	Share of commodity i in total investment expenditures
$io_{i,z}$	Coefficient (Leontief – intermediate consumption)
$\lambda_{h,k,z}^{RK}$	Share of type *k* capital income received by household *h*

λ_{z}^{FYI}	Share of operating surplus received from foreigners
λ_{z}^{FYO}	Share of operating surplus paid to foreigners
$\lambda_{h,z}^{RM}$	Share of remittances received by household *h*
λ_{z}^{RMI}	Share of remittances received by country *z*
$\lambda_{h,l,z}^{WL}$	Share of type *l* labor income received by household *h*
$poor_{z}$	Flag parameter (1 if country is poor)
$rich_{z}$	Flag parameter (1 if country is rich)
$\sigma_{j,z}^{GS}$	Elasticity (CES –skilled workers bundle)
$\sigma_{j,z}^{GU}$	Elasticity (CES – unskilled workers bundle)
$\sigma_{j,z}^{KL}$	Elasticity (CES – capital-skilled workers bundle)
$\sigma_{i,z}^{M1}$	Elasticity (CES – composite commodity)
$\sigma_{i,zj,z}^{M2}$	Elasticity (CES – composite import)
σ_{z}^{UN}	Elasticity (wage-curve)
$\sigma_{j,z}^{VA}$	Elasticity (CES – value-added)
$\sigma_{i,z}^{X1}$	Elasticity (CET – total output)
$\sigma_{i,z}^{X2}$	Elasticity (CET – composite export)
$tmrg_{m,i,zj,z}$	Rate of margin *m* applied to commodity *i* imported from country *zj*
$v_{j,z}$	Coefficient (Leontief – value-added)

Appendix B: Sets in the UNDP World CGE Model

Set I,J : commodities/industries

Acronym	Description
crp	Crops
anm	Animal production
frs	Forestry
fsh	Fishing
ffe	Coal, oil and gas extraction
oxt	Other extraction
fod	Food products
b_t	Beverages and tobacco products
tex	Textiles wearing and leather
wop	Wood and paper
p_c	Petroleum and coal products
chm	Chemical and pharmaceutical products
nmm	Rubber plastic and mineral products
met	Metals and metal products
ome	Machinery equipment and vehicles
omf	Manufactures n.e.c.
utl	Utilities
cns	Construction
trd	Trade
afs	Accommodation Food and service activities
otp	Transport and warehousing
ofi	Finance insurance and real estate
dwe	Dwellings
ots	Other sevices
osg	Public administration and defense
edu	Education
hht	Human health and social work activities

Set L: Labor categories

Acronym	Description
FSkLab	Female skilled labor
FUnskLab	Female unskilled labor
MSkLab	Male skilled labor
MUnskLab	Male unskilled labor

Subset SW: Skilled Labor categories

Acronym	Description
FSkLab	Female skilled labor
MSkLab	Male skilled labor

Subset UW: Unskilled Labor categories

Acronym	Description
FUnskLab	Female unskilled labor
MUnskLab	Male unskilled labor

Set K: Capital categories

Acronym	Description
Capital	Capital
Land	Land
NatRes	Natural resource

Set H: Households categories

Acronym	Description
Q1	First quintile
Q2	Second quintile
Q3	Third quintile
Q4	Fourth quintile
Q5	Fifth quintile

Set Z: Countries and regions

Single country elements of set Z:

AFG	Afghanistan	GAB	Gabon	PAN	Panama
ALB	Albania	GEO	Georgia	PRY	Paraguay
DZA	Algeria	GHA	Ghana	PER	Peru
AGO	Angola	GTM	Guatemala	PHL	Philippines
ARG	Argentina	GIN	Guinea	QAT	Qatar
ARM	Armenia	HTI	Haiti	MDA –	Republic of Moldova
AZE	Azerbaijan	HN D	Honduras	RWA	Rwanda
BHR	Bahrain	IND	India	STP	Sao Tome and Principe
BGD	Bangladesh	IDN	Indonesia	SAU	Saudi Arabia
BLR	Belarus	IRN	Iran (Islamic Republic of)	SEN	Senegal
BLZ –	Belize	IRQ	Iraq	SRB	Serbia
BEN	Benin	JAM	Jamaica	SGP	Singapore
BOL	Bolivia	JOR	Jordan	ZAF	South Africa
BWA	Botswana	KAZ	Kazakhstan	LKA	Sri Lanka
BRA	Brazil	KEN	Kenya	PSE	State of Palestine
BRN	Brunei Darussalam	KWT	Kuwait	SDN	Sudan
BFA	Burkina Faso	KGZ	Kyrgyzstan	SYR	Syrian Arab Republic
BDI	Burundi	LAO	Lao People's Democ. Republic	TJK	Tajikistan
KH M	Cambodia	LBN	Lebanon	THA	Thailand
CMR	Cameroon	LSO –	Lesotho	TGO	Togo
CAF	Central African Republic	MD G	Madagascar	TTO	Trinidad and Tobago
TCD	Chad	MWI	Malawi	TUN	Tunisia
CHL	Chile	MYS	Malaysia	TUR	Türkiye
CHN	China	MLI	Mali	TKM –	Turkmenistan
COL	Colombia	MRT	Mauritania	UGA	Uganda
CO M	Comoros	MUS	Mauritius	UKR	Ukraine
CO G	Congo	MEX	Mexico	ARE	United Arab Emirates
CRI	Costa Rica	MN G	Mongolia	TZA	United Republic of Tanzania

CIV	Côte d’Ivoire	MAR	Morocco	USA	United States of America
COD	Democratic Republic of the Congo	MOZ	Mozambique	URY	Uruguay
DOM	Dominican Republic	NAM	Namibia	UZB	Uzbekistan
ECU	Ecuador	NPL	Nepal	VEN	Venezuela (Bolivarian Republic of)
EGY	Egypt	NIC	Nicaragua	VNM	Viet Nam
SLV	El Salvador	NER	Niger	YEM	Yemen
GNQ	Equatorial Guinea	NGA	Nigeria	ZMB	Zambia
SWZ	Eswatini	OMN	Oman	ZWE	Zimbabwe
ETH	Ethiopia	PAK	Pakistan		

Elements of set Z that refer to a group of countries[6]

BTN_MDV			
BTN	Bhutan	MDV	Maldives
MMR_TLS			
MMR	Myanmar	TLS	Timor-Leste
M_AP_A	**Mixed Asia and the Pacific (East Asia)**		
PRK	Democratic People's Republic of Korea	MAC	Macao Special Administrative Region
M_AP_O	**Mixed Asia and the Pacific (Oceania)**		
ASM	American Samoa	PLW	Palau
COK	Cook Islands	PNG	Papua New Guinea
FJI	Fiji	PCN	Pitcairn
PYF	French Polynesia	WSM	Samoa
GUM	Guam	SLB	Solomon Islands
KIR	Kiribati	TKL	Tokelau
MHL	Marshall Islands	TON	Tonga
FSM	Micronesia (Federated States of)	TUV	Tuvalu
NRU	Nauru	UMI	United States Minor Outlying Islands
NCL	New Caledonia	VUT	Vanuatu
NIU	Niue	WLF	Wallis and Futuna Islands
MNP	Northern Mariana Islands		
M_AS	**Mixed Arab States**		
LBY	Libya	ESH	Western Sahara
M_ECA	**Mixed Europe and Central Asia**		
AND	Andorra	JEY	Jersey
BIH	Bosnia and Herzegovina	XKX	Kosovo (as per UNSCR 1244)
FRO	Faroe Islands	MCO	Monaco
GIB	Gibraltar	MNE	Montenegro
GGY	Guernsey	MKD	North Macedonia
VAT	Holy See	SMR	San Marino
IMN	Isle of Man		
M_LAC_C	**Mixed Caribbean**		
AIA	Anguilla	DMA	Dominica
ATG	Antigua and Barbuda	GRD	Grenada
ABW	Aruba	MSR	Montserrat
BHS	Bahamas	BLM	Saint Barthélemy
BRB	Barbados	KNA	Saint Kitts and Nevis
BES	Bonaire, Sint Eustatius and Saba	MAF	Saint Martin (French Part)
VGB	British Virgin Islands	VCT	Saint Vincent and the Grenadines
CYM	Cayman Islands	SXM	Sint Maarten (Dutch part)
CUB	Cuba	TCA	Turks and Caicos Islands
CUW	Curaçao	VIR	United States Virgin Islands
LCA	Saint Lucia		

M_LAC_LA	**Mixed Latin America**		
FLK	Falkland Islands (Malvinas)	SGS	South Georgia and the South Sandwich Islands
GUF	French Guiana	SUR	Suriname
GUY	Guyana		
M_SSA_AS	**Mixed Sub-Saharan Africa and Arab States**		
DJI	Djibouti	SYC	Seychelles
ERI	Eritrea	SOM	Somalia
MYT	Mayotte	SSD	South Sudan
M_SSA_W	**Mixed Sub-Saharan Africa (Western Africa)**		
CPV	Cabo Verde	MRT	Mauritania
GMB	Gambia	SLE	Sierra Leone

[6] Countries are grouped together according to GTAP nomenclature or because they do not appear explicitly in the list of UNDP countries.

GNB	Guinea-Bissau	SHN	Saint Helena
LBR	Liberia		
N_AP	**Other (Asia and the Pacific)**		
AUS	Australia	KOR	Korea
HKG	Hong Kong	NZL	New Zealand
JPN	Japan		
N_AS	**Other (Arab States)**		
ISR	Israel		
N_ECA	**Other (Europe)**		
AUT	Austria	LIE	Liechtenstein
BEL	Belgium	LTU	Lithuania
BGR	Bulgaria	LUX	Luxembourg
HRV	Croatia	MLT	Malta
CYP	Cyprus	NLD	Netherlands
CZE	Czech Republic	NOR	Norway
DNK	Denmark	POL	Poland
EST	Estonia	PRT	Portugal
FIN	Finland	ROU	Romania
FRA	France	RUS	Russia
DEU	Germany	SVK	Slovakia
GRC	Greece	SVN	Slovenia
HUN	Hungary	ESP	Spain
ISL	Iceland	SWE	Sweden
IRL	Ireland	CHE	Switzerland
ITA	Italy	GBR	United Kingdom
LVA	Latvia		
N_NA	**Other (North America)**		
CAN	Canada	GRL	Greenland
BMU	Bermuda	SPM	Saint Pierre and Miquelon
PRI	Puerto Rico		
N_OTH	**Other (Other)**		
ATA	Antarctica	IOT	British Indian Ocean Territory
BVT	Bouvet Island	ATF	French Southern Territories

Appendix C: Mathematical derivations

C.1. Demand functions – CES aggregator

CES aggregator functions are used to represent imperfect substitution between input in the production nested function for value-added, for capital-skilled labor bundle and for labor by gender. The same type of function is used to represent the imperfect substitution between commodities according to their origin. Deriving the demand functions that are consistent with a CES aggregator is similar in all cases, so in this section, we will do the derivation using a general case.

A CES function can be written using the following general expression:

$$(\mathrm{C1})\quad Y = B\sum_i \{\beta_i\, X_i{}^{-\rho}\}^{\frac{-1}{\rho}}$$

Where B, β_i and ρ are parameters, X_i are inputs and Y is the aggregate. More particularly, the sum of β_i is equal to 1, and ρ is related to the elasticity of substitution σ between the elements of the CES:

$$(\mathrm{C2})\quad \rho = \frac{1-\sigma}{\sigma} \quad or \quad \sigma = \frac{1}{\rho+1}$$

Let P^Y be the aggregated price of Y and P_i^X, the price of each element X_i.The purchaser optimisation problem consists of minimizing the total cost:

$$(\mathrm{C3})\quad P^Y Y = \sum_i P_i^X X_i$$

Subject to the CES equation $(\mathrm{C1})$. The problem can be written using the Lagrangian:

$$\mathcal{L} = \sum_i P_i^X X_i - \lambda\left[B\sum_i \{\beta_i\, X_i{}^{-\rho}\}^{\frac{-1}{\rho}} - Y\right]$$

The first order conditions are:

$$\frac{\partial\mathcal{L}}{\partial X_i} = P_i^X - \lambda\, B\left(\frac{-1}{\rho}\right)\sum_i \{\beta_i\, X_i{}^{-\rho}\}^{\frac{-1}{\rho}-1}\,\beta_i(-\rho)X_i{}^{-\rho-1} = 0$$

Which simplifies as:

$$\frac{\partial\mathcal{L}}{\partial X_i} = P_i^X - \lambda\, B\sum_i \{\beta_i\, X_i{}^{-\rho}\}^{\frac{-1}{\rho}-1}\,\beta_i\, X_i{}^{-\rho-1} = 0$$

Or:

$$(\mathrm{C4})\quad P_i^X = \lambda\, B\sum_i \{\beta_i\, X_i{}^{-\rho}\}^{\frac{-1}{\rho}-1}\,\beta_i\, X_i{}^{-\rho-1}$$

And the other first order condition is:

$$\frac{\partial\mathcal{L}}{\partial\lambda} = -\left[B\sum_i \{\beta_i\, X_i{}^{-\rho}\}^{\frac{-1}{\rho}} - Y\right] = 0 \Rightarrow Y = B\sum_i \{\beta_i\, X_i{}^{-\rho}\}^{\frac{-1}{\rho}}$$

Which is the same as equation $(\mathrm{C1})$. Now, the first order condition $(\mathrm{C4})$ is true for any input, so one can write the same relationship let's say for input *j* :

$$(\mathrm{C5})\quad P_j^X = \lambda\, B\sum_i \{\beta_i\, X_i{}^{-\rho}\}^{\frac{-1}{\rho}-1}\,\beta_j\, X_j{}^{-\rho-1}$$

From (C4) and (C5), we can derive relative demand:

$$\frac{P_i^X}{P_j^X} = \frac{\lambda\, B \sum_i \{\beta_i\, X_i{}^{-\rho}\}^{\frac{-1}{\rho}-1}\, \beta_i\, X_i{}^{-\rho-1}}{\lambda\, B \sum_i \{\beta_i\, X_i{}^{-\rho}\}^{\frac{-1}{\rho}-1}\, \beta_j\, X_j{}^{-\rho-1}} = \frac{\beta_i\, X_i{}^{-\rho-1}}{\beta_j\, X_j{}^{-\rho-1}}$$

$$\Rightarrow \frac{X_i{}^{-\rho-1}}{X_j{}^{-\rho-1}} = \frac{\beta_j\, P_i^X}{\beta_i\, P_j^X} \Rightarrow \frac{X_i}{X_j} = \left[\frac{\beta_j\, P_i^X}{\beta_i\, P_j^X}\right]^{\frac{1}{-\rho-1}}$$

$$\text{(C6)} \quad X_i = \left[\frac{\beta_j\, P_i^X}{\beta_i\, P_j^X}\right]^{\frac{1}{-\rho-1}} X_j$$

By replacing X_i in equation (C1) with its equivalent in equation (C6), we get:

$$Y = B \sum_i \{\beta_i\, X_i{}^{-\rho}\}^{\frac{-1}{\rho}} = B \sum_i \left\{\beta_i \left(\left[\frac{\beta_j\, P_i^X}{\beta_i\, P_j^X}\right]^{\frac{1}{-\rho-1}} X_j\right)^{-\rho}\right\}^{\frac{-1}{\rho}}$$

$$Y = B \sum_i \left\{\beta_i \left[\frac{\beta_j\, P_i^X}{\beta_i\, P_j^X}\right]^{\frac{-\rho}{-\rho-1}} X_j^{-\rho}\right\}^{\frac{-1}{\rho}} = X_j B \sum_i \left\{\beta_i \left[\frac{\beta_j\, P_i^X}{\beta_i\, P_j^X}\right]^{\frac{-\rho}{-\rho-1}}\right\}^{\frac{-1}{\rho}}$$

$$Y = X_j\, B \sum_i \left\{\beta_i \left[\frac{\beta_i\, P_j^X}{\beta_j\, P_i^X}\right]^{\frac{-\rho}{\rho+1}}\right\}^{\frac{-1}{\rho}} = X_j\, B \sum_i \left\{(\beta_i)^{1-\frac{-\rho}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\ \ \left[\frac{P_j^X}{\beta_j}\right]^{\frac{-\rho}{\rho+1}}\right\}^{\frac{-1}{\rho}}$$

$$Y = X_j \left[\frac{P_j^X}{\beta_j}\right]^{\frac{1}{\rho+1}} B \sum_i \left\{(\beta_i)^{1-\frac{-\rho}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\}^{\frac{-1}{\rho}} = X_j \left[\frac{P_j^X}{\beta_j}\right]^{\frac{1}{\rho+1}} B \sum_i \left\{(\beta_i)^{\frac{1}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\}^{\frac{-1}{\rho}}$$

By isolating X_j we get:

$$\text{(C7)} \quad X_j = \frac{Y}{B} \left[\frac{P_j^X}{\beta_j}\right]^{\frac{-1}{\rho+1}} \sum_i \left\{(\beta_i)^{\frac{1}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\}^{\frac{1}{\rho}}$$

As *j* and *i* refer to the same element, equation (3) can be written as:

$$P^Y Y = \sum_i P_i^X X_i = \sum_j P_j^X X_j$$

Replacing X_j in the previous equation by its equivalent in equation (7) we get:

$$P^Y Y = \sum_j P_j^X \frac{Y}{B} \left[\frac{P_j^X}{\beta_j}\right]^{\frac{-1}{\rho+1}} \sum_i \left\{(\beta_i)^{\frac{1}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\}^{\frac{1}{\rho}} = \frac{Y}{B} \sum_j P_j^X \left[\frac{P_j^X}{\beta_j}\right]^{\frac{-1}{\rho+1}} \sum_i \left\{(\beta_i)^{\frac{1}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\}^{\frac{1}{\rho}}$$

$$P^Y = \frac{1}{B} \sum_j P_j^X \left[\frac{P_j^X}{\beta_j}\right]^{\frac{-1}{\rho+1}} \sum_i \left\{(\beta_i)^{\frac{1}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\}^{\frac{1}{\rho}} = \frac{1}{B} \sum_j (\beta_j)^{\frac{1}{\rho+1}} (P_j^X)^{\frac{\rho}{\rho+1}} \sum_i \left\{(\beta_i)^{\frac{1}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\}^{\frac{1}{\rho}}$$

Since:

$$\sum_i \left\{(\beta_i)^{\frac{1}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\} \equiv \sum_j \left\{(\beta_j)^{\frac{1}{\rho+1}}\ \ (P_j^X)^{\frac{\rho}{\rho+1}}\right\}$$

We get:

$$P^Y = \frac{1}{B}\sum_i \left\{(\beta_i)^{\frac{1}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\}^{1+\frac{1}{\rho}} = \frac{1}{B}\sum_i \left\{(\beta_i)^{\frac{1}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\}^{\frac{\rho+1}{\rho}}$$

$$\text{(C8)}\quad (B\,P^Y)^{\frac{1}{\rho+1}} = \sum_i \left\{(\beta_i)^{\frac{1}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\}^{\frac{1}{\rho}}$$

The right hand side of equation (C8) appears also in equation (C7):

$$\text{(C7)}\quad X_j = \frac{Y}{B}\left[\frac{P_j^X}{\beta_j}\right]^{\frac{-1}{\rho+1}} \sum_i \left\{(\beta_i)^{\frac{1}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\}^{\frac{1}{\rho}}$$

So equation (C7) can be rewritten as:

$$X_j = \frac{Y}{B}\left[\frac{P_j^X}{\beta_j}\right]^{\frac{-1}{\rho+1}} \sum_i \left\{(\beta_i)^{\frac{1}{\rho+1}}\ \ (P_i^X)^{\frac{\rho}{\rho+1}}\right\}^{\frac{1}{\rho}} = \frac{Y}{B}\left[\frac{P_j^X}{\beta_j}\right]^{\frac{-1}{\rho+1}} (B\,P^Y)^{\frac{1}{\rho+1}} = \frac{Y}{B}\left[\frac{\beta_j}{P_j^X}\right]^{\frac{1}{\rho+1}} (B\,P^Y)^{\frac{1}{\rho+1}}$$

$$X_j = Y\left[\frac{\beta_j}{P_j^X}\right]^{\frac{1}{\rho+1}} (P^Y)^{\frac{1}{\rho+1}}\,(B)^{\frac{1}{\rho+1}-1} = Y\left[\frac{\beta_j\,P^Y}{P_j^X}\right]^{\frac{1}{\rho+1}} (B)^{\frac{1}{\rho+1}-1}$$

Using the relationship between ρ and σ from equation (C2):

$$\text{(C9)}\quad X_j = Y\left[\frac{\beta_j\,P^Y}{P_j^X}\right]^{\sigma} (B)^{\sigma-1}$$

Which is the demand for input X_j.

C.2. CES redundancy

Equation (C1) from previous section determines how to compute Y while equation (C3) determines how to compute the aggregated price P^Y:

$$\text{(C1)}\quad Y = B\sum_i \{\beta_i\,X_i{}^{-\rho}\}^{\frac{-1}{\rho}}$$

$$\text{(C3)}\quad P^Y Y = \sum_i P_i^X X_i$$

We derived the demand function for each input as:

$$\text{(C9)}\quad X_i = Y\left[\frac{\beta_i\,P^Y}{P_i^X}\right]^{\sigma} (B)^{\sigma-1}$$

We cannot use in the model all of these expressions as one is redundant. Indeed, let's say that in the model we explicitly have the demand functions for all input X_i. Using equations (C9) and (C3) we get:

$$P^Y Y = \sum_i P_i^X X_i = \sum_i P_i^X Y\left[\frac{\beta_i\,P^Y}{P_i^X}\right]^{\sigma} (B)^{\sigma-1} = (B)^{\sigma-1} Y (P^Y)^{\sigma} \sum_i P_i^X \left[\frac{\beta_i}{P_i^X}\right]^{\sigma}$$

$$P^Y = (B)^{\frac{1}{\rho+1}-1} (P^Y)^{\frac{1}{\rho+1}} \sum_i P_i^X \left[\frac{\beta_i}{P_i^X}\right]^{\frac{1}{\rho+1}} = (B)^{\frac{-\rho}{\rho+1}} (P^Y)^{\frac{1}{\rho+1}} \sum_i P_i^X \left[\frac{\beta_i}{P_i^X}\right]^{\frac{1}{\rho+1}}$$

$$P^Y = (B)^{\frac{-\rho}{\rho+1}}(P^Y)^{\frac{1}{\rho+1}}\sum_i [\,\beta_i\,]^{\frac{1}{\rho+1}}[\,P_i^X\,]^{\frac{\rho}{\rho+1}} \Rightarrow (P^Y)^{\frac{\rho}{\rho+1}} = (B)^{\frac{-\rho}{\rho+1}}\sum_i [\,\beta_i\,]^{\frac{1}{\rho+1}}[\,P_i^X\,]^{\frac{\rho}{\rho+1}}$$

Putting both side at the power $\frac{-1}{\rho}$ gives:

$$\text{(C10)}\quad (P^Y)^{\frac{-1}{\rho+1}} = (B)^{\frac{1}{\rho+1}}\left\{\sum_i [\,\beta_i\,]^{\frac{1}{\rho+1}}[\,P_i^X\,]^{\frac{\rho}{\rho+1}}\right\}^{\frac{-1}{\rho}}$$

Let's now develop the right-hand side of equation (C1) using equation (C9):

$$B\sum_i\{\beta_i\, X_i{}^{-\rho}\}^{\frac{-1}{\rho}} = B\sum_i\left\{\beta_i\left[Y\,\left[\frac{\beta_i\,P^Y}{P_i^X}\right]^{\sigma}(B)^{\sigma-1}\right]^{-\rho}\right\}^{\frac{-1}{\rho}} = Y\,(P^Y)^{\sigma}B(B)^{\sigma-1}\sum_i\left\{\beta_i\left[\,\left[\frac{\beta_i}{P_i^X}\right]^{\sigma}\right]^{-\rho}\right\}^{\frac{-1}{\rho}}$$

$$= Y\,(P^Y)^{\frac{1}{\rho+1}}(B)^{\frac{1}{\rho+1}}\sum_i\left\{\beta_i\,\left[\frac{\beta_i}{P_i^X}\right]^{\frac{-\rho}{\rho+1}}\right\}^{\frac{-1}{\rho}} = Y\,(P^Y)^{\frac{1}{\rho+1}}(B)^{\frac{1}{\rho+1}}\sum_i\left\{[\,\beta_i\,]^{\frac{1}{\rho+1}}[\,P_i^X\,]^{\frac{\rho}{\rho+1}}\right\}^{\frac{-1}{\rho}}$$

The last portion of the expression is the right-hand side of equation (C10). Thus:

$$Y\,(P^Y)^{\frac{1}{\rho+1}}(B)^{\frac{1}{\rho+1}}\sum_i\left\{[\,\beta_i\,]^{\frac{1}{\rho+1}}[\,P_i^X\,]^{\frac{\rho}{\rho+1}}\right\}^{\frac{-1}{\rho}} = Y\,(P^Y)^{\frac{1}{\rho+1}}(P^Y)^{\frac{-1}{\rho+1}} = Y$$

Which shows that given equation (C3) and (C9), equation (C1) is redundant. Likewise, we could demonstrate that given equations (C1) and (C9), equation (C3) is redundant. In other words, as long as equation (C9) is given, one can either choose to withdraw equation (C3) or equation (C1) as one will be redundant. In the UNDP model, we chose to use the price equations and not the CES aggregator function to reduce the non-linearity of the model and facilitate the numerical resolution.

C.3. Supply functions – CET aggregator

CET aggregator functions are used to represent imperfect substitution possibilities between for the producer when it comes to selling its commodities on the different markets. Deriving the supply functions that are consistent with a CET aggregator is similar in all cases, so in this section, we will do the derivation using a general case.

A CET function can be written using the following general expression:

$$(\mathrm{C11})\quad Y = B\sum_i \{\beta_i\, {X_i}^{\rho}\}^{\frac{1}{\rho}}$$

Where B, $\beta_i$and ρ are parameters, X_i are possible outputs and Y is the aggregate. More particularly, the sum of β_i is equal to 1, and ρ is related to the elasticity of transformation σ between the elements of the CET:

$$(\mathrm{C12})\quad \rho = \frac{1+\sigma}{\sigma} \quad or \quad \sigma = \frac{1}{\rho - 1}$$

Let P^Ybe the aggregated price of Y and P_i^X, the price obtained for the sale of each element X_i.The producer optimisation problem consists of maximizing total sales:

$$(\mathrm{C13})\quad P^Y Y = \sum_i P_i^X X_i$$

Subject to the CET equation (C11). The problem can be written using the Lagrangian:

$$\mathcal{L} = \sum_i P_i^X X_i - \lambda\left[B\sum_i \{\beta_i\, {X_i}^{\rho}\}^{\frac{1}{\rho}} - Y\right]$$

The first order conditions are:

$$\frac{\partial \mathcal{L}}{\partial X_i} = P_i^X - \lambda\, B\left(\frac{1}{\rho}\right)\sum_i \{\beta_i\, {X_i}^{\rho}\}^{\frac{1}{\rho}-1}\, \beta_i(\rho){X_i}^{\rho-1} = 0$$

Which simplifies as:

$$\frac{\partial \mathcal{L}}{\partial X_i} = P_i^X - \lambda\, B\sum_i \{\beta_i\, {X_i}^{\rho}\}^{\frac{1}{\rho}-1}\, \beta_i\, {X_i}^{\rho-1} = 0$$

Or:

$$(\mathrm{C14})\quad P_i^X = \lambda\, B\sum_i \{\beta_i\, {X_i}^{\rho}\}^{\frac{1}{\rho}-1}\, \beta_i\, {X_i}^{\rho-1}$$

And the other first order condition is:

$$\frac{\partial \mathcal{L}}{\partial \lambda} = -\left[B\sum_i \{\beta_i\, {X_i}^{\rho}\}^{\frac{1}{\rho}} - Y\right] = 0 \Rightarrow Y = B\sum_i \{\beta_i\, {X_i}^{\rho}\}^{\frac{1}{\rho}}$$

Which is the same as equation (C11). Now, the first order condition (C14) is true for any output, so one can write the same relationship let's say for input *j* :

$$(\mathrm{C15})\quad P_j^X = \lambda\, B\sum_i \{\beta_i\, {X_i}^{\rho}\}^{\frac{1}{\rho}-1}\, \beta_j\, {X_j}^{\rho-1}$$

From (14) and (15), we can derive relative supply:

$$\frac{P_i^X}{P_j^X} = \frac{\lambda\, B\sum_i \{\beta_i\, {X_i}^{\rho}\}^{\frac{1}{\rho}-1}\, \beta_i\, {X_i}^{\rho-1}}{\lambda\, B\sum_i \{\beta_i\, {X_i}^{\rho}\}^{\frac{1}{\rho}-1}\, \beta_j\, {X_j}^{\rho-1}} = \frac{\beta_i\, {X_i}^{\rho-1}}{\beta_j\, {X_j}^{\rho-1}}$$

$$\Rightarrow \frac{{X_i}^{\rho-1}}{{X_j}^{\rho-1}} = \frac{\beta_j\, P_i^X}{\beta_i\, P_j^X} \Rightarrow \frac{X_i}{X_j} = \left[\frac{\beta_j\, P_i^X}{\beta_i\, P_j^X}\right]^{\frac{1}{\rho-1}}$$

$$\text{(C16)} \quad X_i = \left[\frac{\beta_j\, P_i^X}{\beta_i\, P_j^X}\right]^{\frac{1}{\rho-1}} X_j$$

By replacing X_i in equation (C11) with its equivalent in equation (C16), we get:

$$Y = B\sum_i \{\beta_i\, {X_i}^{\rho}\}^{\frac{1}{\rho}} = B\sum_i \left\{\beta_i\left(\left[\frac{\beta_j\, P_i^X}{\beta_i\, P_j^X}\right]^{\frac{1}{\rho-1}} X_j\right)^{\rho}\right\}^{\frac{1}{\rho}}$$

$$Y = B\sum_i \left\{\beta_i\left[\frac{\beta_j\, P_i^X}{\beta_i\, P_j^X}\right]^{\frac{\rho}{\rho-1}} {X_j}^{\rho}\right\}^{\frac{1}{\rho}} = X_j B\sum_i \left\{\beta_i\left[\frac{\beta_j\, P_i^X}{\beta_i\, P_j^X}\right]^{\frac{\rho}{\rho-1}}\right\}^{\frac{1}{\rho}}$$

$$Y = X_j\left[\frac{\beta_j}{P_j^X}\right]^{\frac{1}{\rho-1}} B\sum_i \left\{\beta_i\left[\frac{P_i^X}{\beta_i}\right]^{\frac{\rho}{\rho-1}}\right\}^{\frac{1}{\rho}} = X_j\left[\frac{\beta_j}{P_j^X}\right]^{\frac{1}{\rho-1}} B\sum_i \left\{[\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X\,]^{\frac{\rho}{\rho-1}}\right\}^{\frac{1}{\rho}}$$

By isolating X_j we get:

$$\text{(C17)} \quad X_j = \frac{Y}{B}\left[\frac{P_j^X}{\beta_j}\right]^{\frac{1}{\rho-1}} \sum_i \left\{[\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X\,]^{\frac{\rho}{\rho-1}}\right\}^{\frac{-1}{\rho}}$$

As *j* and *i* refer to the same elements, equation (C13) can be written as:

$$P^Y Y = \sum_i P_i^X X_i = \sum_j P_j^X X_j$$

Replacing X_j in the previous equation by its equivalent in equation (C17) we get:

$$P^Y Y = \sum_j P_j^X \frac{Y}{B}\left[\frac{P_j^X}{\beta_j}\right]^{\frac{1}{\rho-1}} \sum_i \left\{[\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X\,]^{\frac{\rho}{\rho-1}}\right\}^{\frac{-1}{\rho}} = \frac{Y}{B}\sum_j P_j^X \left[\frac{P_j^X}{\beta_j}\right]^{\frac{1}{\rho-1}} \sum_i \left\{[\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X\,]^{\frac{\rho}{\rho-1}}\right\}^{\frac{-1}{\rho}}$$

$$P^Y = \frac{1}{B}\sum_j P_j^X \left[\frac{P_j^X}{\beta_j}\right]^{\frac{1}{\rho-1}} \sum_i \left\{[\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X\,]^{\frac{\rho}{\rho-1}}\right\}^{\frac{-1}{\rho}} = \frac{1}{B}\sum_j\, [\,\beta_j\,]^{\frac{-1}{\rho-1}}[P_j^X\,]^{\frac{\rho}{\rho-1}} \sum_i \left\{[\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X\,]^{\frac{\rho}{\rho-1}}\right\}^{\frac{-1}{\rho}}$$

Since:

$$\sum_i \left\{(\beta_i)^{\frac{-1}{\rho-1}}\;\; (P_i^X)^{\frac{\rho}{\rho-1}}\right\} \equiv \sum_j \left\{(\beta_j)^{\frac{-1}{\rho-1}}\;\; (P_j^X)^{\frac{\rho}{\rho-1}}\right\}$$

We get:

$$P^Y = \frac{1}{B}\sum_i \left\{[\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X\,]^{\frac{\rho}{\rho-1}}\right\}^{1+\frac{-1}{\rho}} = \frac{1}{B}\sum_i \left\{[\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X\,]^{\frac{\rho}{\rho-1}}\right\}^{\frac{\rho-1}{\rho}}$$

$$\text{(C18)} \;\; (BP^Y)^{\frac{-1}{\rho-1}} = \sum_i \left\{[\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X\,]^{\frac{\rho}{\rho-1}}\right\}^{\frac{-1}{\rho}}$$

The right-hand side of equation (C18) appears also in equation (C17):

$$(\mathrm{C17})\quad X_j = \frac{Y}{B}\left[\frac{P_j^X}{\beta_j}\right]^{\frac{1}{\rho-1}} \sum_i \left\{[\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X\,]^{\frac{\rho}{\rho-1}}\right\}^{\frac{-1}{\rho}}$$

So equation (17) can be rewritten as:

$$X_j = \frac{Y}{B}\left[\frac{P_j^X}{\beta_j}\right]^{\frac{1}{\rho-1}} (BP^Y)^{\frac{-1}{\rho-1}} = \frac{Y}{B}\left[\frac{P_j^X}{\beta_j P^Y}\right]^{\frac{1}{\rho-1}} (B)^{\frac{-1}{\rho-1}} = \frac{Y}{(B)^{1+\frac{1}{\rho-1}}}\left[\frac{P_j^X}{\beta_j P^Y}\right]^{\frac{1}{\rho-1}}$$

Using the relationship between ρ and σ from equation (C12):

$$(\mathrm{C19})\quad X_j = \frac{Y}{(B)^{1+\sigma}}\left[\frac{P_j^X}{\beta_j P^Y}\right]^{\sigma}$$

Which is the supply function for output X_j.

C.4. CET redundancy

Equation (C11) from previous section determines how to compute Y while equation (C13) determines how to compute the aggregated price P^Y:

$$\text{(C11)}\quad Y = B\sum_i \{\beta_i\, X_i{}^{\rho}\}^{\frac{1}{\rho}}$$

$$\text{(C13)}\quad P^Y Y = \sum_i P_i^X X_i$$

We derived the demand function for each input as:

$$\text{(C19)}\quad X_i = \frac{Y}{(B)^{1+\sigma}}\left[\frac{P_i^X}{\beta_i P^Y}\right]^{\sigma}$$

We cannot use in the model all of these expressions as one is redundant. Indeed, let's say that in the model we explicitly have the demand functions for all input X_i. Using equations (C19) and (C13) we get:

$$P^Y Y = \sum_i P_i^X X_i = \sum_i P_i^X \frac{Y}{(B)^{1+\sigma}}\left[\frac{P_i^X}{\beta_i P^Y}\right]^{\sigma} = \frac{Y}{(B)^{1+\sigma}}\left[\frac{1}{P^Y}\right]^{\sigma}\sum_i P_i^X\left[\frac{P_i^X}{\beta_i}\right]^{\sigma}$$

$$P^Y Y = \frac{Y}{(B)^{1+\frac{1}{\rho-1}}}\left[\frac{1}{P^Y}\right]^{\frac{1}{\rho-1}}\sum_i P_i^X\left[\frac{P_i^X}{\beta_i}\right]^{\frac{1}{\rho-1}} = \frac{Y}{(B)^{\frac{\rho}{\rho-1}}}\left[\frac{1}{P^Y}\right]^{\frac{1}{\rho-1}}\sum_i P_i^X\left[\frac{P_i^X}{\beta_i}\right]^{\frac{1}{\rho-1}}$$

$$P^Y\,[\,P^Y\,]^{\frac{1}{\rho-1}} = [\,P^Y\,]^{\frac{\rho}{\rho-1}} = \frac{1}{(B)^{\frac{\rho}{\rho-1}}}\sum_i P_i^X\left[\frac{P_i^X}{\beta_i}\right]^{\frac{1}{\rho-1}} = (B)^{\frac{-\rho}{\rho-1}}\sum_i P_i^X\left[\frac{P_i^X}{\beta_i}\right]^{\frac{1}{\rho-1}}$$

$$[\,P^Y\,]^{\frac{\rho}{\rho-1}} = (B)^{\frac{-\rho}{\rho-1}}\sum_i [\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X]^{\frac{\rho}{\rho-1}}$$

Putting both side at the power $\frac{1}{\rho}$ gives:

$$\text{(C20)}\ [\,P^Y\,]^{\frac{1}{\rho-1}} = (B)^{\frac{-1}{\rho-1}}\left\{\sum_i [\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X]^{\frac{\rho}{\rho-1}}\right\}^{\frac{1}{\rho}}$$

Let's now develop the right-hand side of equation (C11) using equation (C19):

$$B\sum_i \{\beta_i\, X_i{}^{\rho}\}^{\frac{1}{\rho}} = B\sum_i\left\{\beta_i\left[\frac{Y}{(B)^{1+\sigma}}\left[\frac{P_i^X}{\beta_i P^Y}\right]^{\sigma}\right]^{\rho}\right\}^{\frac{1}{\rho}} = \left[\frac{1}{P^Y}\right]^{\sigma} B\,\frac{Y}{(B)^{1+\sigma}}\sum_i\left\{\beta_i\left[\left[\frac{P_i^X}{\beta_i}\right]^{\sigma}\right]^{\rho}\right\}^{\frac{1}{\rho}}$$

$$= \left[\frac{1}{P^Y}\right]^{\frac{1}{\rho-1}} B\,\frac{Y}{(B)^{1+\frac{1}{\rho-1}}}\sum_i\left\{\beta_i\left[\left[\frac{P_i^X}{\beta_i}\right]^{\frac{1}{\rho-1}}\right]^{\rho}\right\}^{\frac{1}{\rho}} = Y\left[\frac{1}{P^Y}\right]^{\frac{1}{\rho-1}}(B)^{\frac{-1}{\rho-1}}\sum_i\left\{\beta_i\left[\frac{P_i^X}{\beta_i}\right]^{\frac{\rho}{\rho-1}}\right\}^{\frac{1}{\rho}}$$

$$= Y\left[\frac{1}{P^Y}\right]^{\frac{1}{\rho-1}}(B)^{\frac{-1}{\rho-1}}\sum_i\left\{[\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X]^{\frac{\rho}{\rho-1}}\right\}^{\frac{1}{\rho}}$$

The last portion of the expression is the right-hand side of equation (20). Thus:

$$Y\left[\frac{1}{P^Y}\right]^{\frac{1}{\rho-1}}(B)^{\frac{-1}{\rho-1}}\sum_i\left\{[\,\beta_i\,]^{\frac{-1}{\rho-1}}[\,P_i^X]^{\frac{\rho}{\rho-1}}\right\}^{\frac{1}{\rho}} = Y\left[\frac{1}{P^Y}\right]^{\frac{1}{\rho-1}}[\,P^Y\,]^{\frac{1}{\rho-1}} = Y$$

Which shows that given equations (C13) and (C19), equation (C11) is redundant. Likewise, we could demonstrate that given equations (C11) and (C19), equation (C13) is redundant. In other words, as long as equation (C19) is given, one can either choose to withdraw equation (C13) or equation (C11) as one will be redundant. In the UNDP model, we chose to use the price equations and not the CET aggregator function to reduce the non-linearity of the model and facilitate the numerical resolution.

C.5. Demand for consumer goods

The utility function of the representative household is a Stone-Geary utility function[7]:

$$U = \prod_i (C_i - C_i^{MIN})^{\gamma_i^{CTH}} \quad \text{where} \quad \sum_i \gamma_i^{CTH} = 1$$

Utility function is equivalent to:

$$\text{(C21)} \quad ln\,U = \sum_i \gamma_i^{CTH}\, ln(C_i - C_i^{MIN})$$

The representative household maximizes utility subject to the budget constraint:

$$\text{(C22)} \quad \sum_i PC_i C_i = CTH$$

This optimisation problem can de written using the following Lagrangian:

$$\mathcal{L} = \sum_i \gamma_i^{CTH}\, ln(C_i - C_i^{MIN}) - \lambda\left(\sum_i PC_i C_i - CTH\right)$$

From which we derive the first-order conditions:

$$\frac{\partial \mathcal{L}}{\partial C_i} = \frac{\gamma_i^{CTH}}{C_i - C_i^{MIN}} - \lambda PC_i = 0$$

Which is equivalent to:

$$\text{(C23)} \quad \lambda PC_i (C_i - C_i^{MIN}) = \gamma_i^{CTH}$$

The second first order condition is given by:

$$\frac{\partial \mathcal{L}}{\partial \lambda} = \sum_i PC_i C_i - CTH = 0 \ \Rightarrow \sum_i PC_i C_i = CTH$$

Which is equivalent to the budget constraint given by equation (C22).

Summing equation (C23)over *i*

$$\sum_i \lambda PC_i (C_i - C_i^{MIN}) = \sum_i \gamma_i^{CTH}$$

And since $\sum_i \gamma_i^{CTH} = 1$:

$$\sum_i \lambda PC_i (C_i - C_i^{MIN}) = 1 \ \Rightarrow \sum_i PC_i (C_i - C_i^{MIN}) = \frac{1}{\lambda} \Rightarrow \sum_i PC_i C_i - \sum_i PC_i C_i^{MIN} = \frac{1}{\lambda}$$

Using the budget constraint (C22) we get:

$$\sum_i PC_i C_i - \sum_i PC_i C_i^{MIN} = CTH - \sum_i PC_i C_i^{MIN} = \frac{1}{\lambda}$$

If we isolate λ in the latter expression:

$$\lambda = \frac{1}{CTH - \sum_i PC_i C_i^{MIN}}$$

And use is in equation (C23), we get:

[7] Indices regarding region (z) and households (h) have been remove to simplify the notation.

$$\lambda PC_i(C_i - C_i^{MIN}) = \gamma_i^{CTH} \Longrightarrow \frac{PC_i(C_i - C_i^{MIN})}{CTH - \sum_i PC_i C_i^{MIN}} = \gamma_i^{CTH}$$

Rearranging:

$$PC_i(C_i - C_i^{MIN}) = \gamma_i^{CTH}\left[CTH - \sum_i PC_i C_i^{MIN}\right]$$

$$PC_i C_i = PC_i C_i^{MIN} + \gamma_i^{CTH}\left[CTH - \sum_i PC_i C_i^{MIN}\right]$$

Which is the demand function used in the model.

Appendix D: Poverty estimation – example for Angola

Step 1. Input data (from the UNDP CGE model)

Average daily income per capita ($) in each quintile of Angola's population:

Quintile	Average daily income (US$)
Q1 (poorest 20%)	1.2201
Q2	1.9790
Q3	3.1186
Q4	4.9006
Q5 (richest 20%)	19.4571

Step 2. Mean income and the target slope z/μ̄

Each quintile is exactly 20% of the population, so the overall mean is the simple average:

μ̄ = (1.2201 + 1.9790 + 3.1186 + 4.9006 + 19.4571) / 5 = $6.135 / day

With z = $3.00:

z / μ̄ = 3.00 / 6.135 = 0.4889

Step 3. Lorenz ordinates

Each quintile's income share is its mean divided by the sum of all means. Cumulating gives:

p (population share)	L(p) (cumulative income share)
0.00	0.0000
0.20	0.0398
0.40	0.1043
0.60	0.2060
0.80	0.3657
1.00	1.0000

Reading this row: *Angola is highly unequal — the bottom 80% of the population earns only 36.6% of total income, while the top 20% earns 63.4%*

Step 4 — OLS fit of $\eta = L - p$ on $(1, p, p^2)$

Regressing η on the six rows of the design matrix yields:

$a \approx 0.0193$

$b \approx -1.4061$

$c \approx 1.0220$

Hence the fitted Lorenz curve and its derivative are:

$L(p) \approx 0.0193 - 0.4061 \cdot p + 1.0220 \cdot p^2$

$L'(p) \approx -0.4061 + 2.0440 \cdot p$

Step 5 — Solve $L'(p^*) = z/\bar{\mu}$ for p^*

$-0.4061 + 2.0440 \cdot p^* = 0.4890$

$p^* = (0.4890 + 0.4061) / 2.0440 = 0.438$

Result: $H \approx$ 44.0% of Angolans live below \$3.00/day

Sanity check

Q1 averages \$1.22/day, well below the \$3.00 line — all of Q1 (the bottom 20%) is poor. Q2 averages \$1.98/day, still below the line — most of Q2 is poor. Q3 averages \$3.12/day, Just above — most of Q3 is not poor, but the lower portion is. So all of Q1 + all of Q2 (= 40%) are poor, plus a small slice of Q3. Our estimate of 43.8% lands exactly there: 40% from the bottom two quintiles plus about 4 percentage points from the lower part of Q3.

Sensitivity to the poverty line

Once the curve has been fitted, re-reading the headcount at any threshold requires only Step 5:

Poverty line z	z / μ̄	Estimated headcount
\$2.15 / day (extreme poverty)	0.350	~37%
\$3.65 / day (lower-middle income)	0.595	~49%
\$6.85 / day (upper-middle income)	1.117	~75% (capped)