Microsimulations and Macro-Micro Analysis

Jann Lay

Kiel Institute for the World Economy

Overview

1. Introduction
2. Microsimulation models
   - What is a microsimulation?
   - Micro-accounting models
   - Behavioral microsimulations
   - Dynamic microsimulations
3. Macro-micro models
   - Why, what, and when?
   - "Sequential" macro-micro models
   - "Fully-integrated" macro-micro models

Distributional and poverty impact analysis: Counterfactual macro models

- CGE models
- Rely on representative agents
- Ex-post (decomposition of shocks) and ex-ante analysis
- Examples
  - Trade policy
  - Resource (aid) booms and Dutch Disease
  - Pension and tax reforms

Ditributional and poverty impact analysis: Micro approaches

- Analysis of micro databases
  - household surveys
  - tax and social security records
- Using a wide range of techniques
  - Descriptive
  - Econonmetric
  - Simulation
- Use of information on individuals or households
- Typically ex-post, some ex-ante applications

Classes of micro approaches

- Applications and examples

a) Treatment effects, Comparison of treated and non-treated groups
   - E.g. IFPRI evaluation of PROGRESA/OPORTUNIDADES

b) Incidence analysis
   - Public incidence analysis (benefit and tax incidence)
   - Incidence of price reforms
   - Rather descriptive techniques

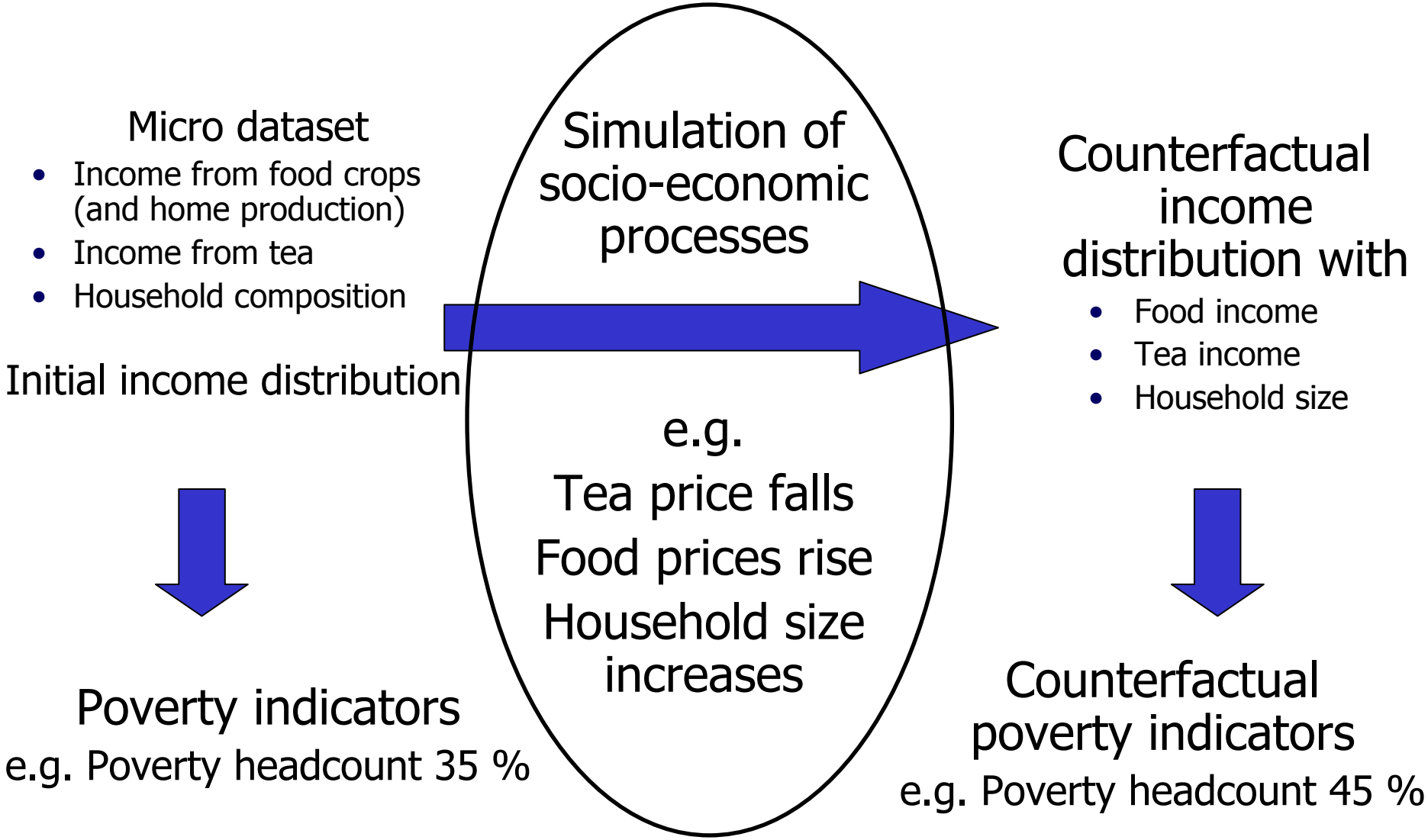
c) Microsimulation models

Microsimulation models

What is a microsimulation?

- A microsimulation is a model based on a dataset that contains information on individual microeconomic agents (individuals, households, firms)
- Allows to simulate the effect of policies on individuals
- Typical: Household survey data with information on
  - Socio-economic characteristics of each individual
  - Employment status and corresponding income
  - Household expenditure

Schematic representation of a microsimulation



Microsimulation models for developing countries

- Most microsimulation models for high-income countries
  - Date back to the 1960s
  - Focus on incidence of tax and social policies
  - Examples: STINMOD (Australia), DYNACAN (Canada), Euromod (EU) etc.
- Microsimulation models for developing countries
  - Relatively recent
  - Focus on income generation (labor market)
  - Applied not only to public policy
  - No need for "multi-purpose" tax and transfer models

Classes of microsimulation models

- Micro-accounting (arithmetical) models
  - Capture 1st order effects
  - No behavioral response of microeconomic agent
- Behavioral models
  - Capture 2nd order effects
  - Microeconomic agents change behavior in response to price changes
  - Can be "reduced-form" or "structural"
- "Dynamic" vs. "static" models
  - Typically: "dynamic" = Time dimension, "aging" of information
  - Sometimes: "behavioral" = "dynamic"

Micro-accounting models: Theoretical foundation

- Basis of every microsimulation: reference distribution computed from survey data
- To provide a simple formal framework:
  - Indirect utility of household i $V_i(p, y_i) = U\left[x^M(p, y_i)\right]$
  - Effect of a marginal change in income $\Delta V_i = V_y^i \Delta y_i$
  - "Equivalent" variation of income $\Delta y_i^* = \Delta V_i / V_y^i$
- Complete equivalence between welfare change and change in income metric (once marginal utility of income has been set)

Impact of a price change

- Policy change that affects prices $\Delta V_i = \sum_j V_{ij} \Delta p_j$
- Shepard's lemma $V_j = -V_y^i x_j^M (p, y_i)$
- Using $\Delta y_i^* = \Delta V_i / V_y^i$
- Gives $\Delta y_i^* = -\sum_j x_j^i \Delta p_j$

- Change in welfare income metric due to price change equal to change in cost of consumption basket

Implications

- Theoretical "justification" of the micro-accounting approach
- Can be generalized
  - "consumption" of labor or other factors
  - households being a net suppliers of goods
- Note: Consistent with existence of changes in behavior
- Message: Behavioral change can be ignored at the margin

Micro-accounting in practice

1. Prepare the dataset, e.g.
   - Composition of household income
     - Unskilled/skilled labor income
     - Capital income
     - Land income
     - Taxes, transfers, and subsidies
   - Consumption patterns
2. Perform an experiment, e.g. increase in a specific transfer by 10 percent and/or decrease in food prices by 10 percent
3. Compare initial and counterfactual income distributions

Some applications

- Many tax and social security microsimulation models have micro-accounting features
  - EUROMOD, STINMOD
- Tax and social policy changes, e.g.
  - Atkinson, Bourguignon, Chiappori (1988): Comparison of incidence of European tax and benefit systems
- Developing country applications, e.g.
  - McCulloch (2003): The impact of structural reforms on poverty
- Some macro-micro applications (example and further applications later)

Micro-accounting

- Advantages
  - Account for household heterogeneity (factor endowments, taxes and transfers, and consumption patterns)
  - Analysis of policy-relevant correlates from survey information, e.g. regions where certain types of households are concentrated
  - Relatively easy to implement

- Disadvantages
  - Not adequate for non-marginal changes
  - Typically, households' factor endowments fixed – only the returns change (labor supply!)

Behavioral models

- Households respond to changes in prices/endowments
- Non-marginal effects
- Types of responses
  - Consumption: Quantity changes
  - Labor market
    - Labor supply
    - Occupational/sectoral choices (formal vs. informal)
    - Migration
  - Demographic behavior: Fertility and mortality
  - Education: Schooling choices
- Operationalization: Estimation of econometric model or calibration (or both)

Reduced form vs. structural econometric models

- Reduced form
  - Ad-hoc specification: Put all relevant variables on the right hand side (rhs) of the equation
- Structural model
  - Specific functional form to be estimated
- Example: Rural-urban migration
  - Direct and "earnings potential" effect of education
  - Structural model: Rural-urban earnings differential on rhs
    - Estimate two coefficients
    - the coefficient of earnings differences between rural an urban areas and another one for the direct effect
  - Reduced form model: Just education on the rhs
- Structural models: Identification problems

Behavioral models in practice

1. Prepare the database
2. Specify the logical economic structure of the model
3. Estimate (or calibrate) the behavioral relationships, e.g.
   - Occupational choice model (inactive – informal – formal)
4. Perform experiment, e.g.
   - 10 % decrease of formal employment
5. Compare initial and counterfactual income distributions

Example: Income generation model for Bolivia

1. Logic structure of the model: Make occupational choices (formal vs. informal employment) and earn wages/profits accordingly
2. Estimated model:

- Component I: Choice model formal vs. informal employment
  - Estimated separately for heads, spouses, and others using logit
- Component II: Income equations
  - Unskilled/skilled (formal) wages
  - Informal profits

Example of estimation results: Income equations

	log unskilled	log skilled wage	informal profits
education	0.084	0.152	0.059
	(9.16)**	(13.53)**	(8.64)**
exp	0.051	0.057	0.038
	(11.20)**	(7.96)**	(8.44)**
exp2	-0.001	-0.001	-0.001
	(9.54)**	(4.72)**	(8.20)**

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

A flavor of simulation results

	P0	P1	Theil
Initial	*50.8*	*23.5*	*63.3*
	Point change		
5 % point decline in formal share unskilled	0.7	0.5	-1.2
5% point decline in formal share skilled	1.7	0.9	1.2
10 % increase unskilled wages	-0.9	-0.7	-1.1
10 % increase skilled wages	-0.7	-0.4	2.4
10 % increase in informal profits	-1.6	-1.1	-1.3

Some applications

- Tax and benefit reforms
  - With focus on labor supply response
    - E.g. Blundell et. al (2000): Impact of working families tax credit
  - Numerous studies on indirect tax reforms with focus on consumption responses (based on estimated demand systems)
- Developing country applications, e.g.
  - Ferreira and Leite (2002): Distributional effects of educational expansion in Brazil
  - Bourguignon, Ferreira, Leite (2003): Distributional and poverty effects of Bolsa Escola
- Some macro-micro applications (later)

Problems and disadvantages of behavioral microsimulations

- Models require substantial investment
  - No "multi-purpose" microsimulation model
  - In some instances, micro-accounting methods may be more practical
- Models based on estimated relationship: Lucas critique applies and should be taken serious
  - Non-marginal changes
  - Long time spans

Problems and disadvantages of behavioral microsimulations

- Assumption 1: Time effect = Cross-sectional effect
  - Models estimated on cross-sections, but simulations dynamic
- Assumption 2: Transition modeled based on state comparisons
  - Choice models often based on state comparisons (informal vs. formal) … not necessarily appropriate to model transition (from informal to formal)
- Labor supply models and Roy-type income generation model possibly inappropriate for rural settings
  - Lack of markets
  - Income diversification
  - Cumulative dynamics

Dynamic microsimulations

- Add a time dimension, "aging" of information
- Model changes in demo-economic behavior and demographic processes
  - Age structure
  - Human capital accumulation
- Typically based on various data sources
  - Standard household surveys
  - Demographic and health surveys
  - Census information
  - Population projections
- May have behavioral and "accounting" components
- Can be combined with income generation models

Dynamic microsimulations in practice

1. Prepare and combine datasets
2. Define procedures to "age" information
   - Specify and estimate behavioral relationships
   - Introduce "static" procedures, e.g. reweighting of household weights
3. Validation
4. Perform experiments
5. Compare initial and counterfactual income distributions

Example: Dynamic microsimulation for Côte d'Ivoire

- Dynamic microsimulation model for Côte d'Ivoire
- For each year of a period of 15-25 years, the model produces income distributions
- Model simulates on individual level
  - Fertility
  - Marriage
  - Household formation
  - Mortality
  - Migration
  - School enrollment of children
  - Labor supply and earnings
- Validated on historical data

A flavor of simulation results

- Dynamic microsimulation used to analyse economic impact of educational policies – Grimm (2005)
- A flavor of results: Only reforms that include a huge adult literacy program focused on women and the rural population will dramatically reduce illiteracy
- Growth effects of such a program
  - Growth gain (obviously) depends on the changes in the returns to education
    - 0.3 point gain if returns to education are constant
    - -0.9 point loss if returns decrease
    - 1.8 point gain if returns increase
  - Growth gains are 0 if informal sector share remains constant

Some applications

- Several dynamic microsimulation models for tax and social policy analysis for developed economies
- To my knowledge: Except for Cogneau and Grimm (2002) and Grimm (2005) none in developing countries

Problems of dynamic microsimulations

- Projection of long-term demo-economic developments without modeling "growth"
  - Structural change
  - Interaction between growth and endowments (e.g. changes in educational endowments not exogenous)
- The "constant parameter" assumption may be even more problematic
  - Model parameters are often estimated from cross-sectional data
- Lack of focus
  - Possibly overambitious to aim at an empirical model of socio-economic change in all its facets

Macro-micro models

Why combine macro and micro tools?

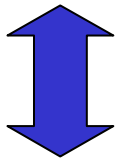
- Account for heterogeniety
  - MACRO models …use representative agents and fail to account for intra-group inequality
  - MICRO models …take into account the full heterogeniety of the poplulation
- Capture non-linearities
  - MACRO models … have difficulties to capture non-linearities of individual behaviour
  - MICRO models … can easily model discrete choices on individual level

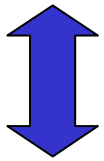
Why combine macro and micro tools?

- Model transmission channels and perform counterfactual analysis
  - MICRO models … are typically reduced form and therefore difficult to use for counterfactual analyses
  - MACRO (CGE) models … model transmission channels explicitly
- More solid database
  - Reconciliation of national accounts and household survey data
  - Informing macro data by micro sources and vice versa (SAM construction)

What a macro-micro model captures?

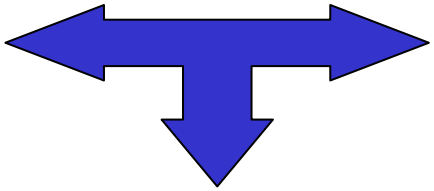
- Macro level: General equilibrium effects
  - Macroeconomic constraints





- Factor markets:
  Changes in factor prices
  - Segmentation
  - Resource endowments

- Goods markets:
  Changes in goods prices
  - Segmentation
  - Price setting



- Household/individual level: Heterogeneity
  - Human/physical capital, land endowments
  - Demographic composition
  - Preferences
  - Market access

When to apply macro-micro models?

- Poverty and distributional impact analysis when
  - external shocks/macro policy changes
  - social (micro) processes and micro policy changes

  are expected to have general equilibrium effect
- External shocks / macro policy changes
  - Commodity price shocks, resource booms
  - Huge aid inflows (Scaling up ODA!)
  - Droughts
- Social (micro) processes and micro policy changes
  - Demographic transition
  - Expansion of education
  - HIV-AIDS
  - Large-scale cash-transfer programs

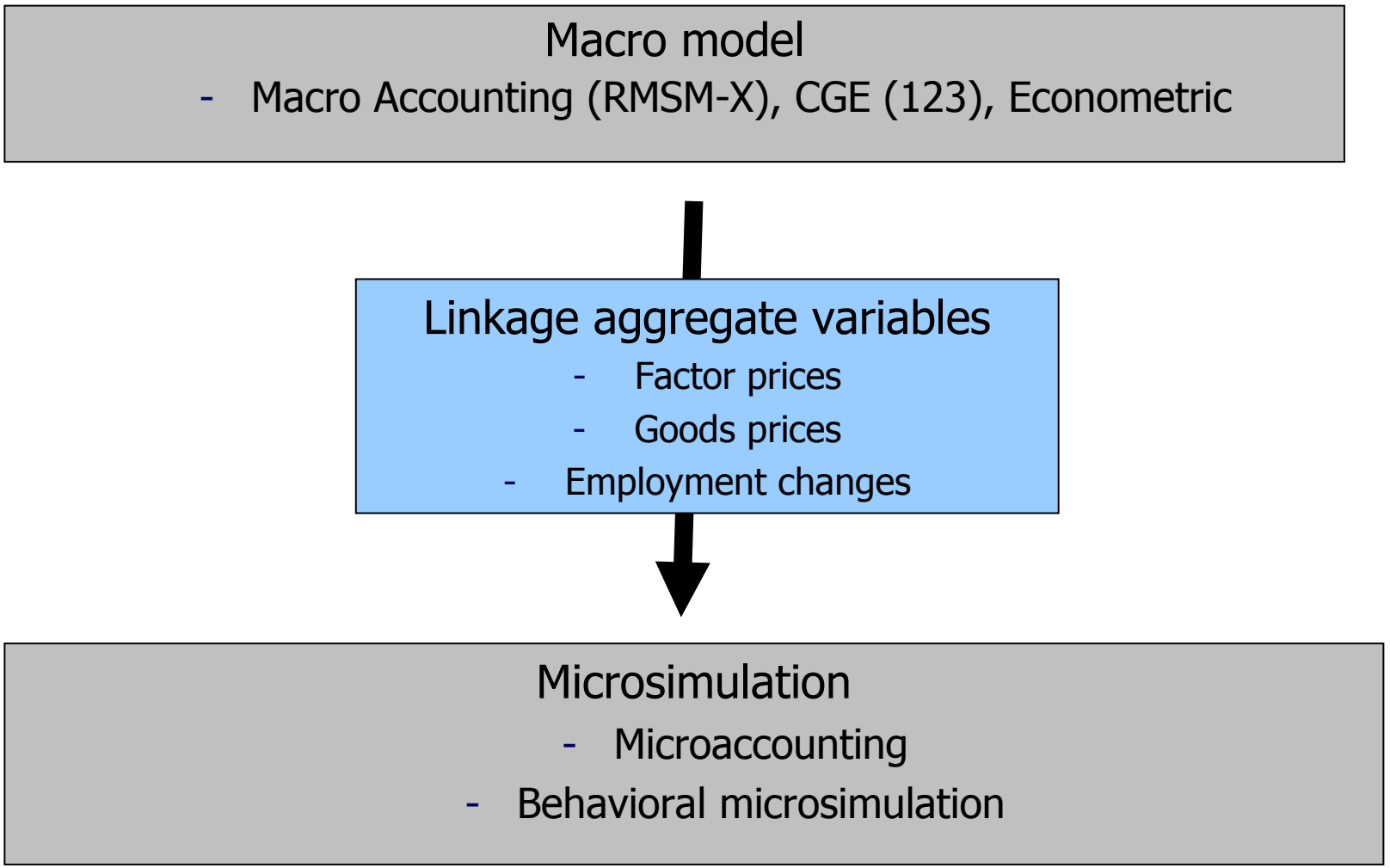
Classes of Macro-micro models

1. Without feedback from the microsimulation to the macro model (sequential model)

   a) With micro-accounting micro module
   b) With behavioral micro module

2. With feedback (integrated model)
   - Requires a "structural" microsimulation (why?)

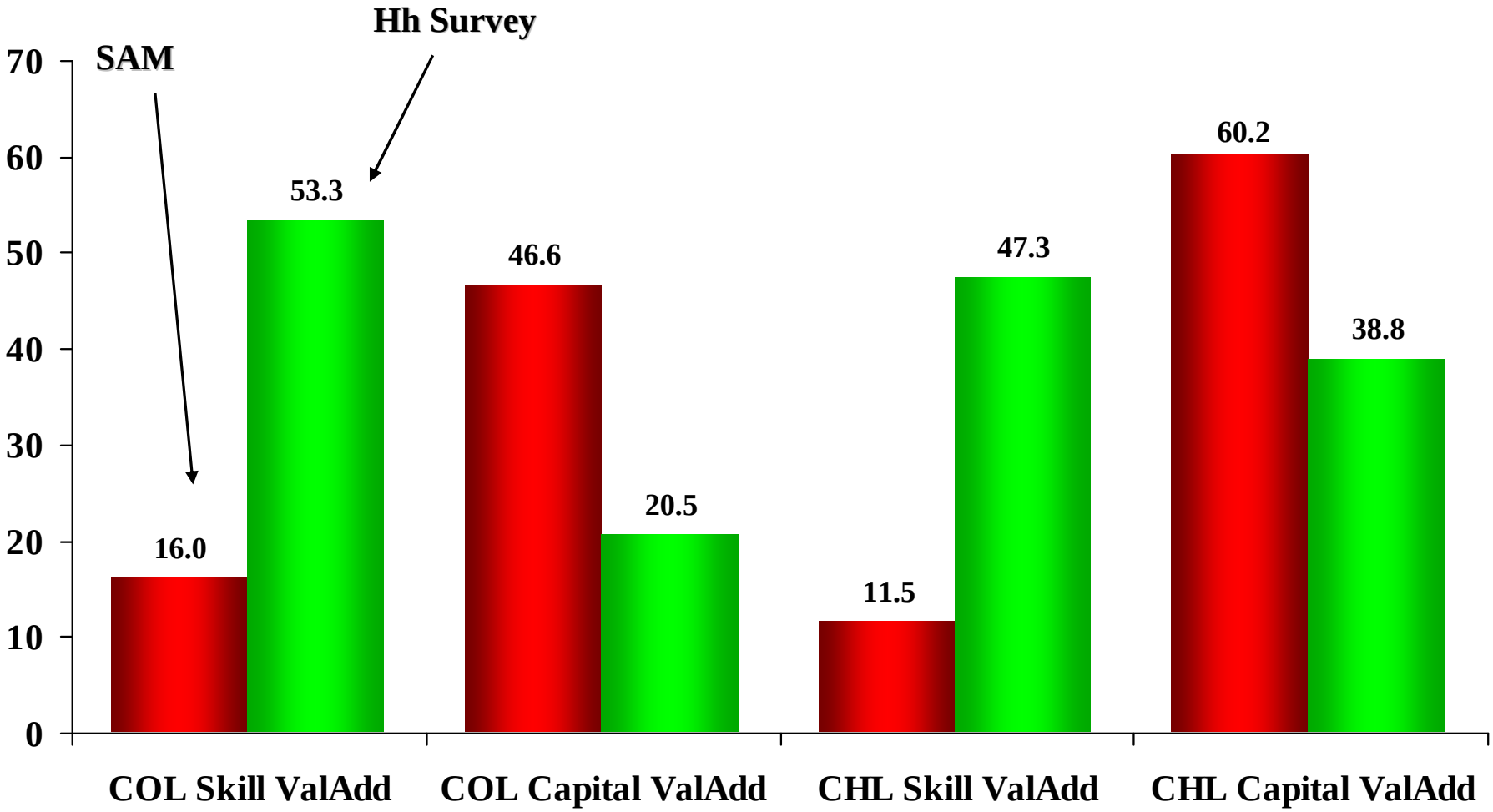
Schematic representation of a sequential macro-micro model



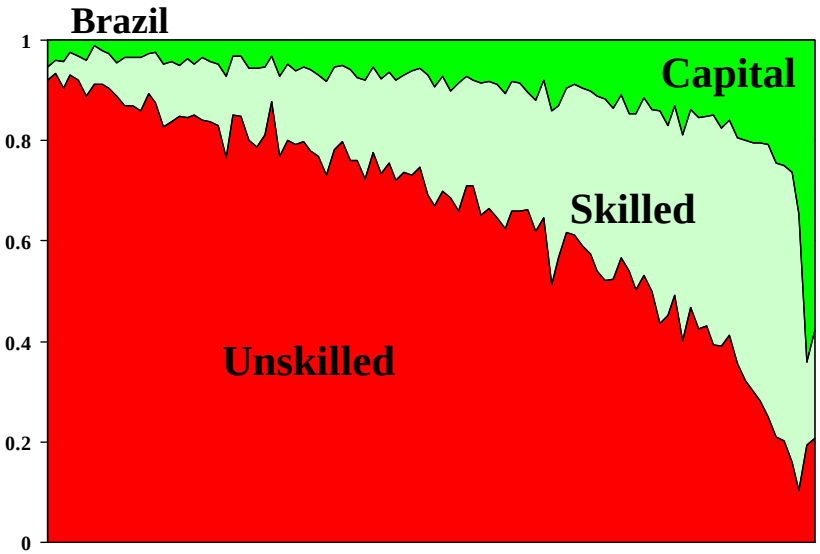
A CGE plus micro-accounting model for Latin America

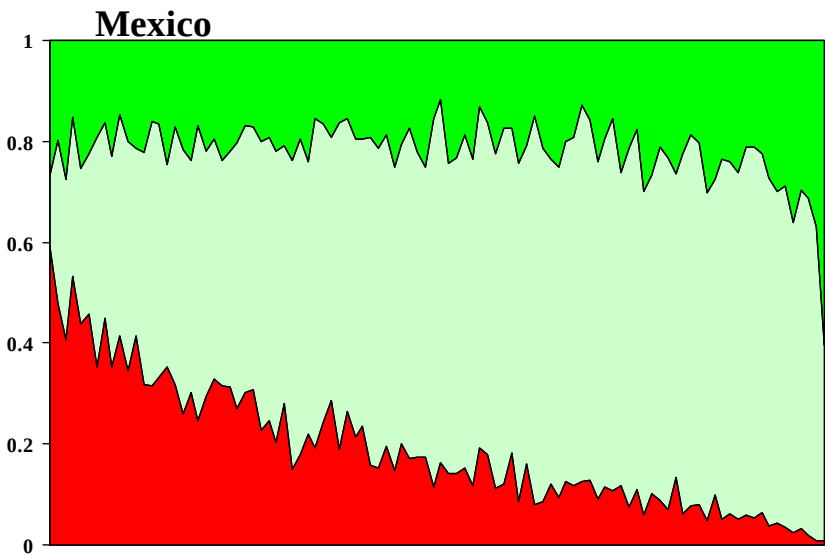
- Global CGE-model used to simulate different trade liberalization scenarios for Latin America
- Micro-accounting models for
  - Brazil
  - Chile
  - Colombia
  - Mexico
- Link variables
  - Urban and rural wage rates for skilled and unskilled
  - Urban capital rental rate
  - Rural composite capital+land remunerations
  - Food prices
  - Non-Food prices
  - Real per capita income

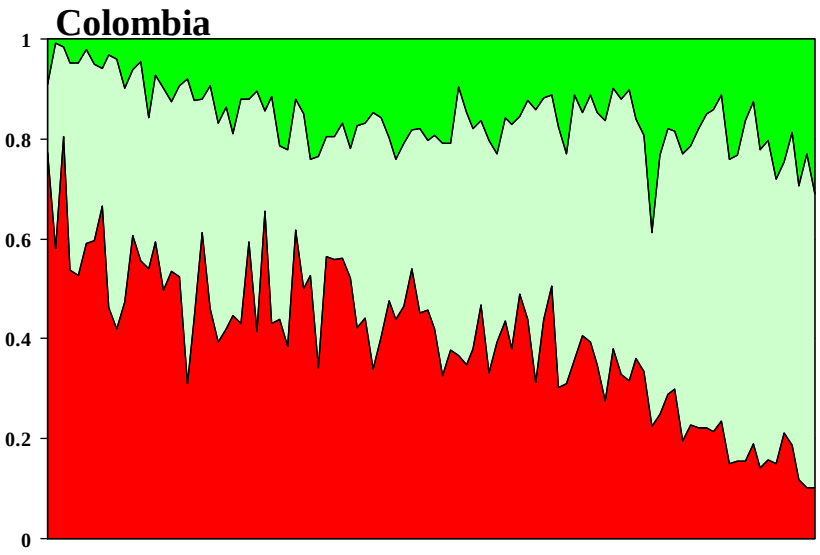
Initial data inconsistencies: factor shares in SAM's value added and household incomes

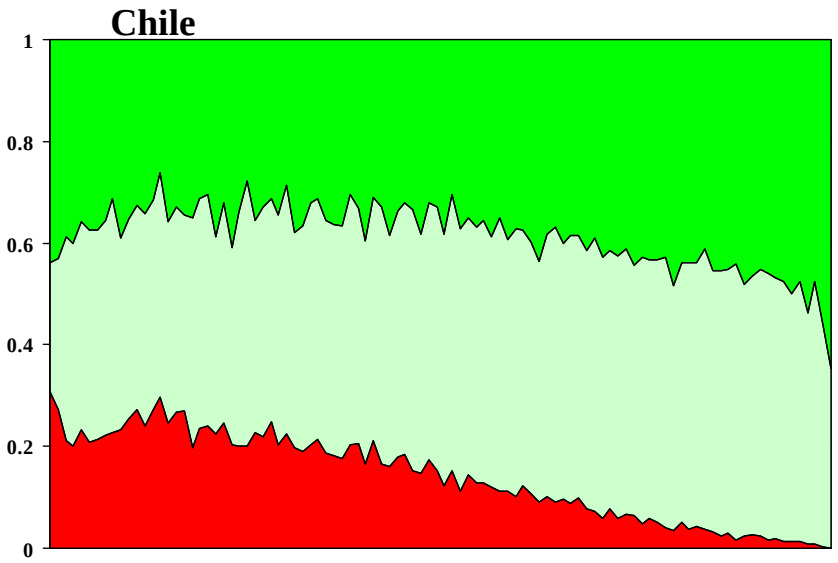


Factor shares by per capita income percentiles:









A flavor of results: Headcount-growth elasticities under different lib scenarios

		Full Dist	Dist Neutral growth
Brazil	FTAA	-1.0	-1.0
	FullLib	-1.2	
Mexico	FTAA	0.3	-3.5
	FullLib	-1.2	
Colombia	FTAA	-0.9	-0.8
	FullLib	-0.6	
Chile	FTAA	-1.8	-1.7
	FullLib	-1.8	

Further applications

- More applications on developing countries
  - Chen and Ravalllion (2003). Impact of China's WTO accession on household welfare
  - Friedman and Levinsohn (2002): Impact of Indonesian crisis on poverty

A CGE plus behavioural micro model for Brazil

- Macro model: Standard recursive dynamic CGE-model
- Labor market: Unskilled and skilled
  - Unskilled labor imperfectly mobile between agricultural and non-agricultural sectors
  - Skilled labor perfectly mobile
  - Segmentation assumptions supported by econometric evidence
- Imperfect mobility of unskilled labor modeled by very simple function

$$MIGR_l = \chi_l^m \left[\left(\frac{AWAGE_{Nagri,l}}{AWAGE_{Agri,l}} \right)^{\omega_l^m} - 1 \right]$$

The link between the macro and the micro model

- Link variables (endogenously determined in the CGE):
  - Factor prices for agricultural and non-agricultural labor
  - Factor prices for skilled labor
  - Sectoral (agriculture vs. non-agriculture) composition of the unskilled workforce
- In addition, we simulate that unskilled and skilled labor supplies grow at different rates
- *The microsimulation is "forced" to reproduce the changes in the link variables given by the CGE*
- On the microlevel we take into account the cumulative changes between 2001 and 2015
  - Simulation of one counterfactual cross-section

Components of the microsimulation

1. Reweighting procedure to account for changes in the skill composition of the workforce
2. Mover-stayer model that explains the choice of *moving out* of agriculture or *staying* there
   - Used later to simulate WHO moves out of agriculture
   - Estimated separately for household heads and non-heads (logit)
   - Uses data from "employment history" of the PNAD

$$\Pr ob(move_{msh} = 1 \mid X_{msh})_{msh} = F(\alpha_{msh} + X_{msh}\beta_{msh} + \varepsilon_{msh})$$

3. Earnings equations
   - Used later to simulate new incomes
   - Estimated using Ordinary Least Squares

$$\ln w_{uagr} = \alpha_{uagr} + X_{uagr}\beta_{uagr} + uw_{uagr}$$

How the simulation works

1. Reweighting to account for the change in the skilled/unskilled labor ratio
2. Unskilled labor moves out of agriculture until the new share of unskilled labor in agriculture given by the CGE is reproduced
3. Wages/profits are adjusted according to the CGE results taking into account
   - the changes in the skill composition
   - the sectoral movements of unskilled labor from agriculture into non-agricultural sectors

What kind of behaviour is modelled?

- Determinants of the choice to move or not

	• Heads	• Non-heads
Positive	Education	Education Head's choice
Negative	Age Landowner Livestock owner	Age Non-remunerated Landowner Livestock owner

Some results: What is passed to the microsimulation in a Business as Usual (BaU) scenario

- Exogenous (also in the CGE) assumption on changes in skill composition:
  - Growth of skilled labor 2.0% annually
  - Growth of unskilled labor 1.6% annually
- Variables determined in the CGE

1. Labor demand in agriculture stagnates
   - Employment in agriculture declines by 5 % points
2. Annual real wage growth rates:
   - Unskilled in agriculture: 1.7 %
   - Unskilled in non-agriculture: 0.9 %
   - Skilled: 1.3 %

Micro results BaU

	All households		Non-agricultural households		Agricultural households	
	2001 level	2001-15 change	2001 level	2001-15 change	2001 level	2001-15 change
PC income	314.9	1.5	351.9	1.2	148.3	2.3
Gini	58.6	-0.1	57.1	0.6	56.6	-0.7
P0	23.6	-5.6	18.6	-3.1	46.2	-13.8
P1	9.6	-3.0	7.1	-1.6	21.0	-8.0
P2	5.3	-1.8	3.7	-0.9	12.3	-5.2
Population %	100		81.8	3.3	18.2	-3.3
Contr. to P0			64.4	8.8	35.6	-8.8

Further applications

- Robilliard, Bourguignon, Robinson (2001): Poverty and distributional impact of the Indonesian crisis
- Bussolo, Lay (2003): Poverty impacts of trade liberalization in Colombia

Integrated macro-micro models

- Fully integrate behavioral microsimulations into an economy-wide modelling framework
- Several attempts, different approaches
  - Cogneau and Robilliard (2006)
    - Madagascar, poverty alleviation programs
    - Complex income generation model, less sophisticated macro model
  - Rutherford, Shepotylo, Tarr (2004)
    - Russia, poverty effects of WTO accession
    - Increase the number of "representative households" to 50000
- Field for future research despite (or because of) the many difficulties involved