

Validating multi-regional economic models with hindcast experiments: the role of global agricultural market integration

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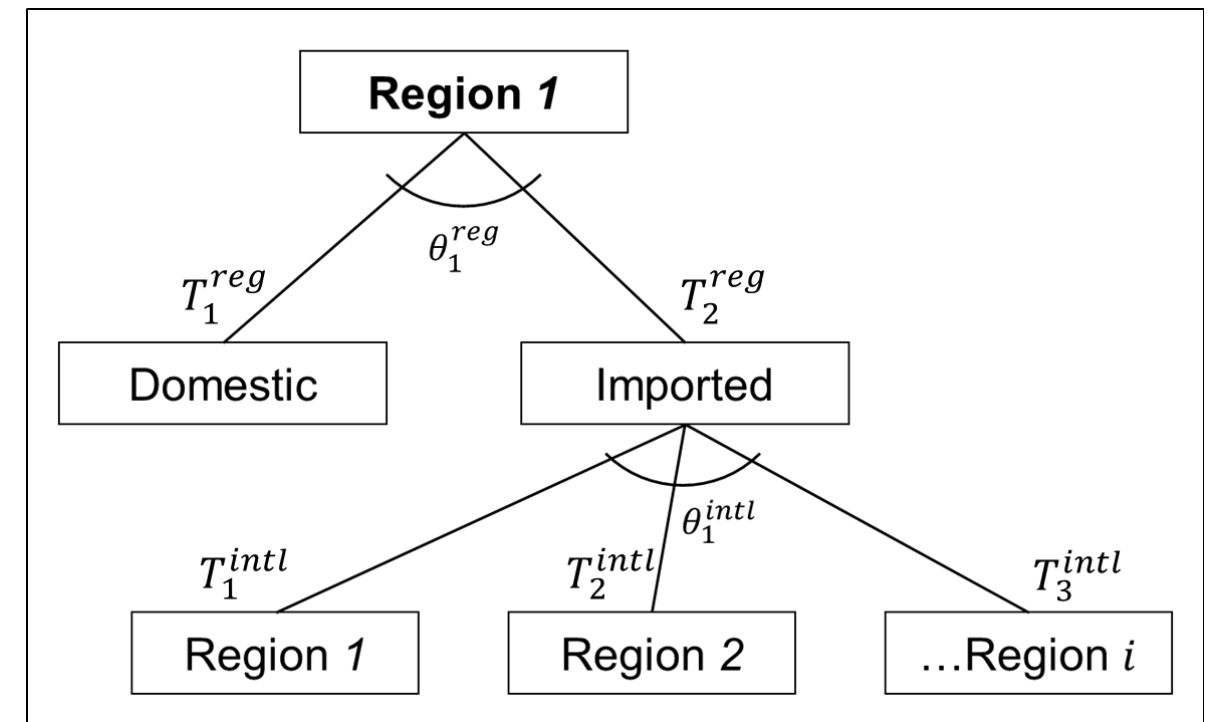
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Background

- AgMIP intercomparison models (von Lampe et al. 2014)

Model	Type	Trade	Data
AIM	CGE	Armington	GTAP
MAGNET	CGE	Armington	GTAP
ENVISAGE	CGE	Armington	GTAP
GTEM	CGE	Armington	GTAP
FARM	CGE	Armington	GTAP
EPPA	CGE	Armington	GTAP
IMPACT	PE	HOV	FAOSTAT & GTAP
MAGPIE	PE	HOV & Self-sufficiency	FAOSTAT & GTAP
GLOBIOM	PE	HOV & Non-linear transport cost	FAOSTAT, UN COMTRADE, & MAcMap-HS6
GCAM	PE	Updated from HOV to a logit-based Armington	FAOSTAT & others

- Widely used integrated assessment model
 - Used for SSP & RCP developments (projects to 2100 with 5-year steps)
 - PE with detailed representation of agricultural and energy sectors
 - ✓ Land, water, climate systems
- Armington approach for trade
 - Product differentiation by origin
 - Explain price difference with preference bias
 - Trade responses to price changes

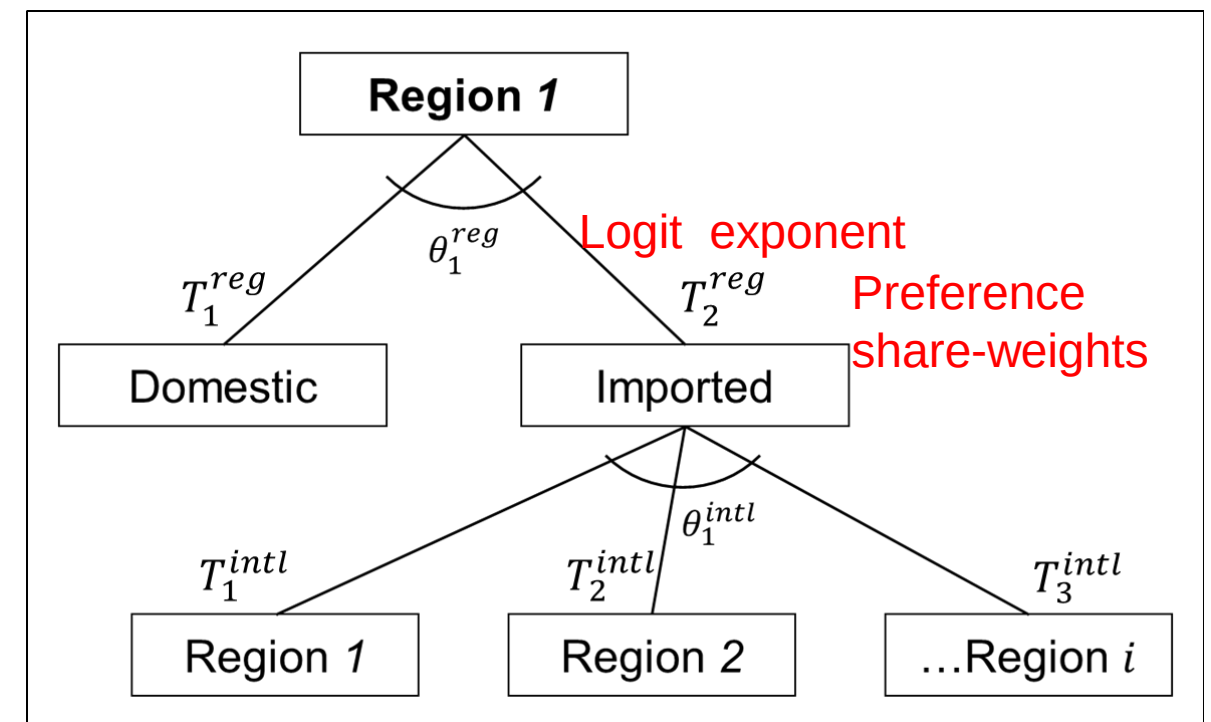


logit-based Armington in GCAM

- CES-based Armington vs. logit-based Armington
- Similar:

$$Q_i = f(P_i, \theta, T_i)$$

- Logit sharing function trace physical volume better
- Connections to the Ricardian trade model
 - Derived from extreme value function
 - Micro-level heterogeneity on the demand side
- Armington concerns
 - Preference parameters (T_i) calibrated to base year
 - Fixed in future periods



Question

- Should T_i be fixed over time?
 - I.e., can we use 1995 preference to represent 2015?
- Preference parameters capture:
 - Distance, culture (language), and adjacency
 - Other factors (e.g., imperfect information and non-tariff barriers)
- **Problems** from fixed preference
 - “Missing globalization” issue
 - Affect the estimation of trade elasticity ($\theta^{reg}, \theta^{intl}$)

Market integration scenarios

- Bias erosion (Liu et al. 2004)
 - Preference distributions shift to converge, no scale
 - $T_{i,n} = T_{i,0}^{\frac{1}{\delta_n}}$
 - δ_n is converging (or diverging) rate of preference parameters (T_i)
 - $\delta_t > 1$: reduction of preference bias over time (integration)
- Full homogenization (see paper for details)
 - *Dynamic trend from Armington to fully integrated world market (HOV)*
 - Bias erosion + scaling distribution
- Default
 - No scale or shift in preference distributions

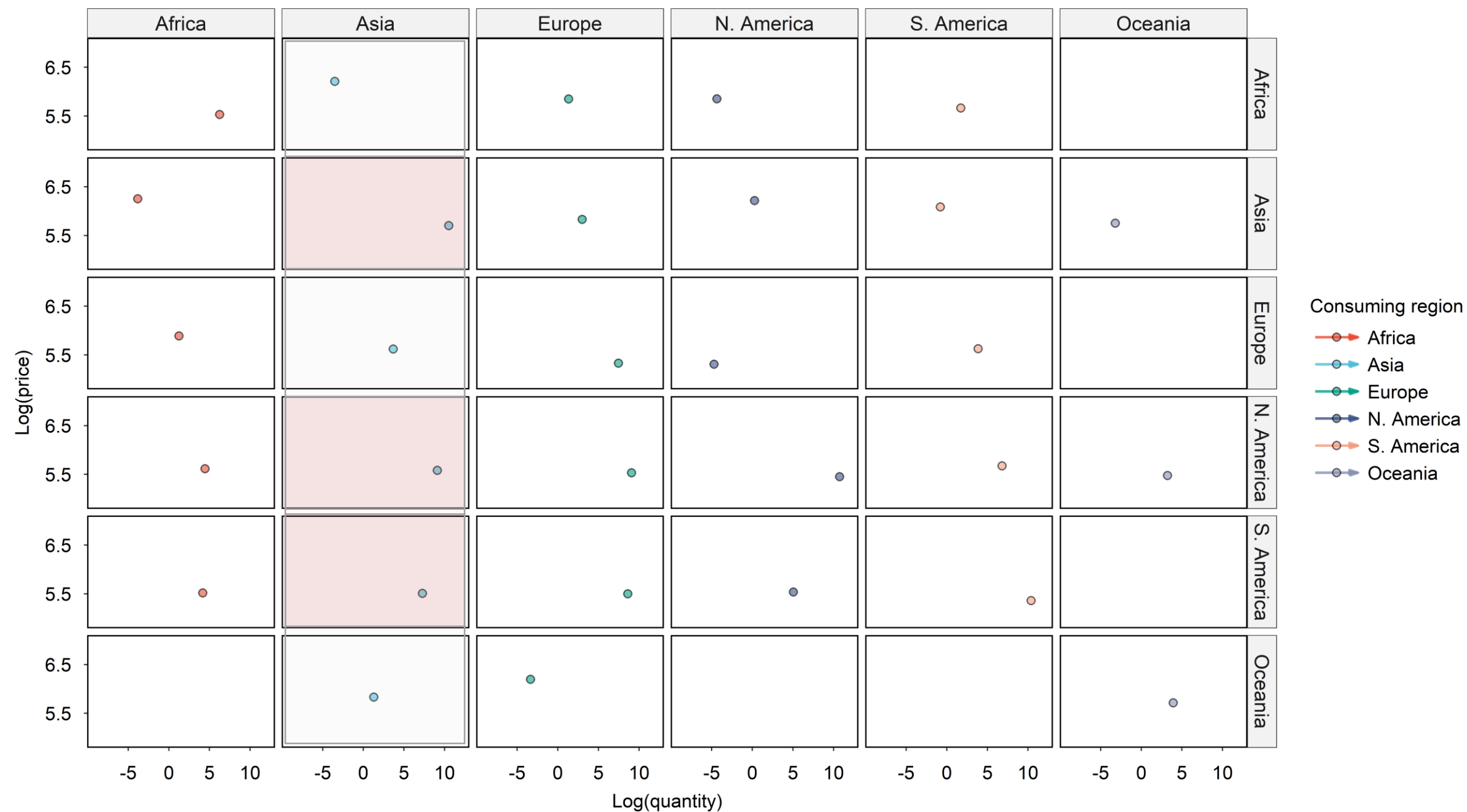
Objective

- Explore the trend and impact of the global agricultural market integration implied by dynamic changes in Armington parameters with hindcast experiments
- Hindcast experiments
 - 1995 – 2015 (5-year step)
 - Fit best parameters & compare historical integration scenarios
- Test implications (future bias erosion) in GCAM

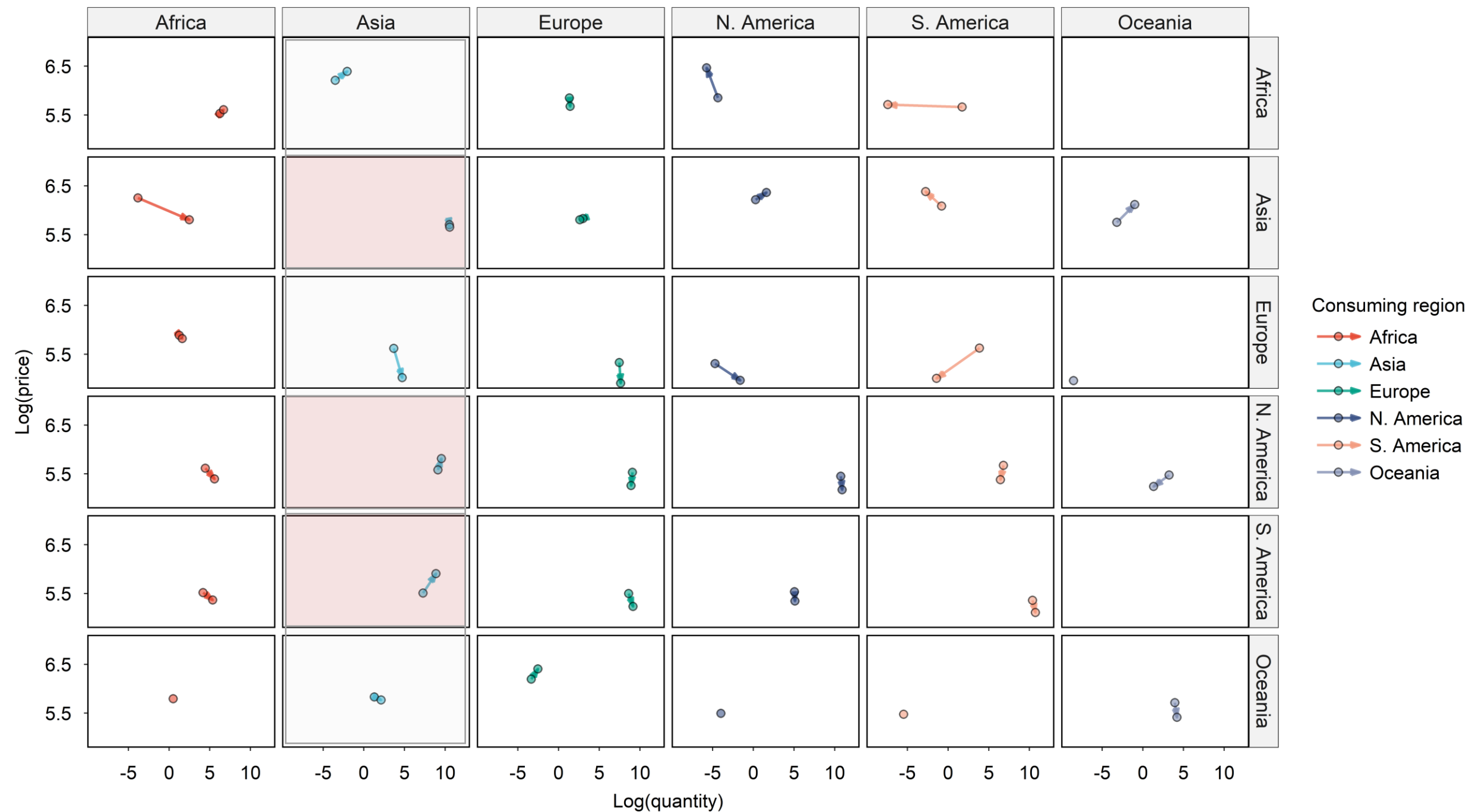
Hindcast model

- 6 x 6 model of bilateral ag trade
 - 6 regions (continents)
 - 6 crops (corn, wheat, rice, soybeans, rapeseed, others)
 - Two-level logit-based Armington trade
 - Supply from a logit land allocation in each region
 - CES demand
- Exogeneous variable
 - Total cropland supply and total crop consumption expenses
 - Yield
 - Bilateral transport margin & tariffs
 - Biofuel mandates
- FAO data: 1995 – 2015 (5 yr step)
- R package
 - Solvers in R

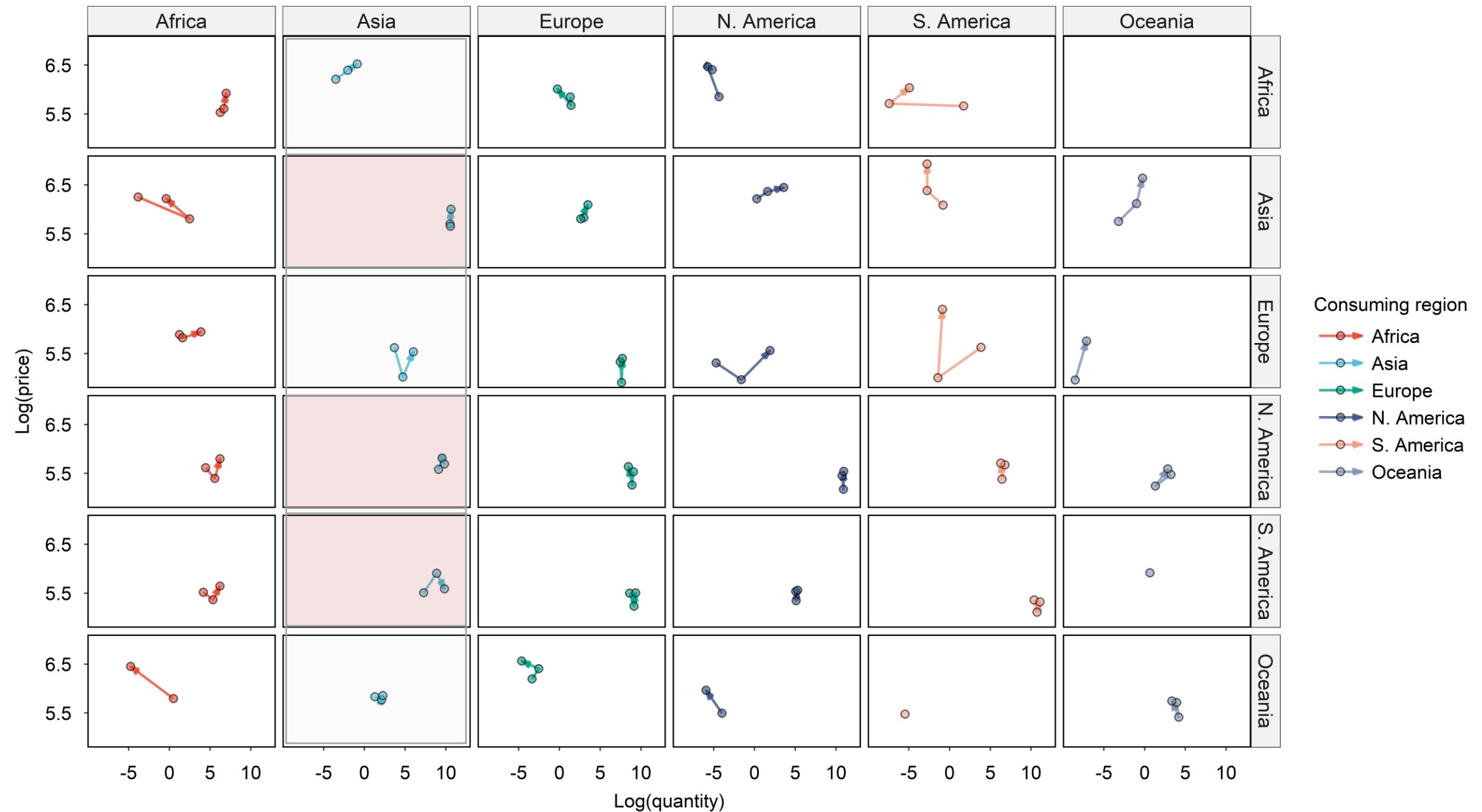
Soybeans market equilibrium, 1995



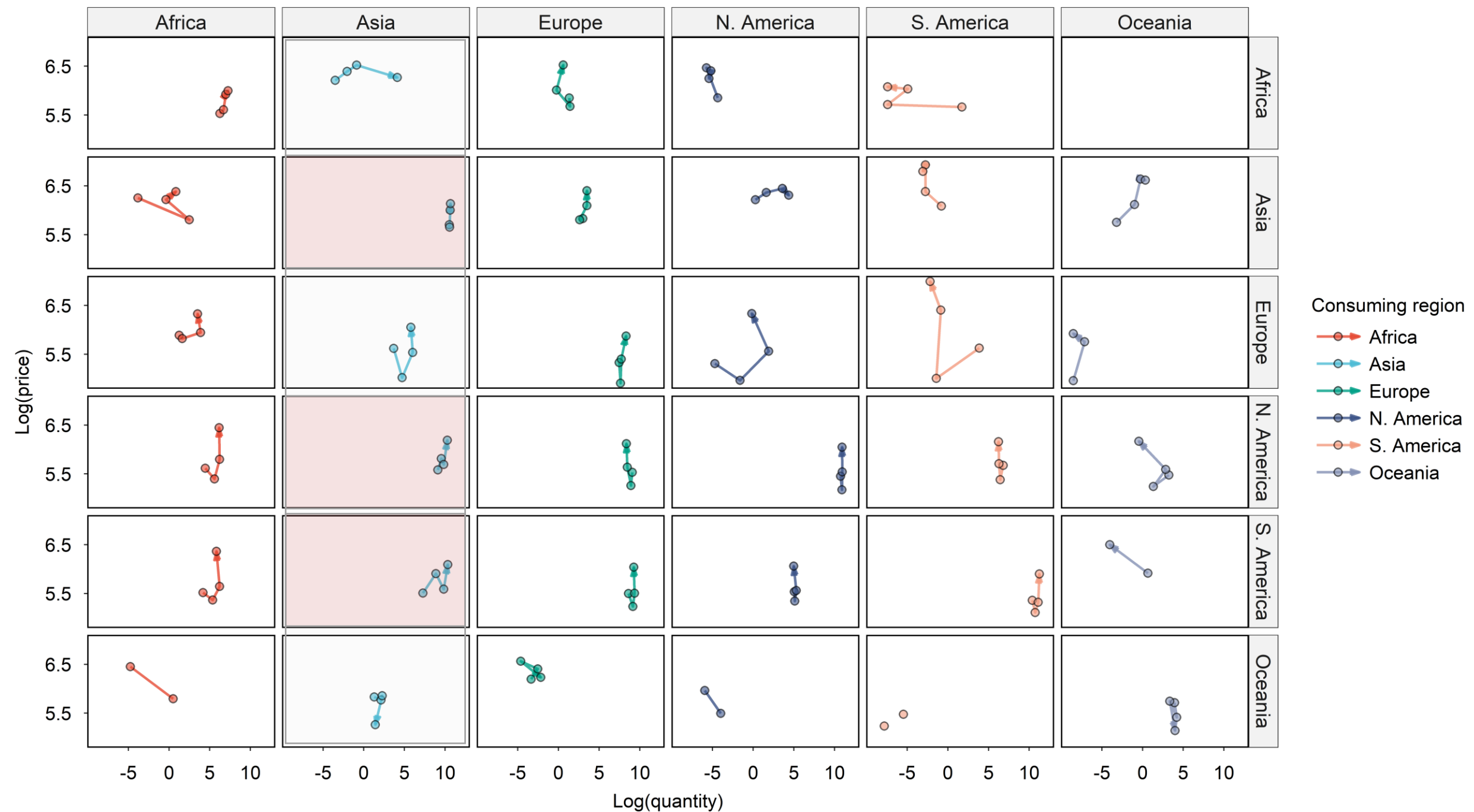
Soybeans market equilibrium, 1995-2000



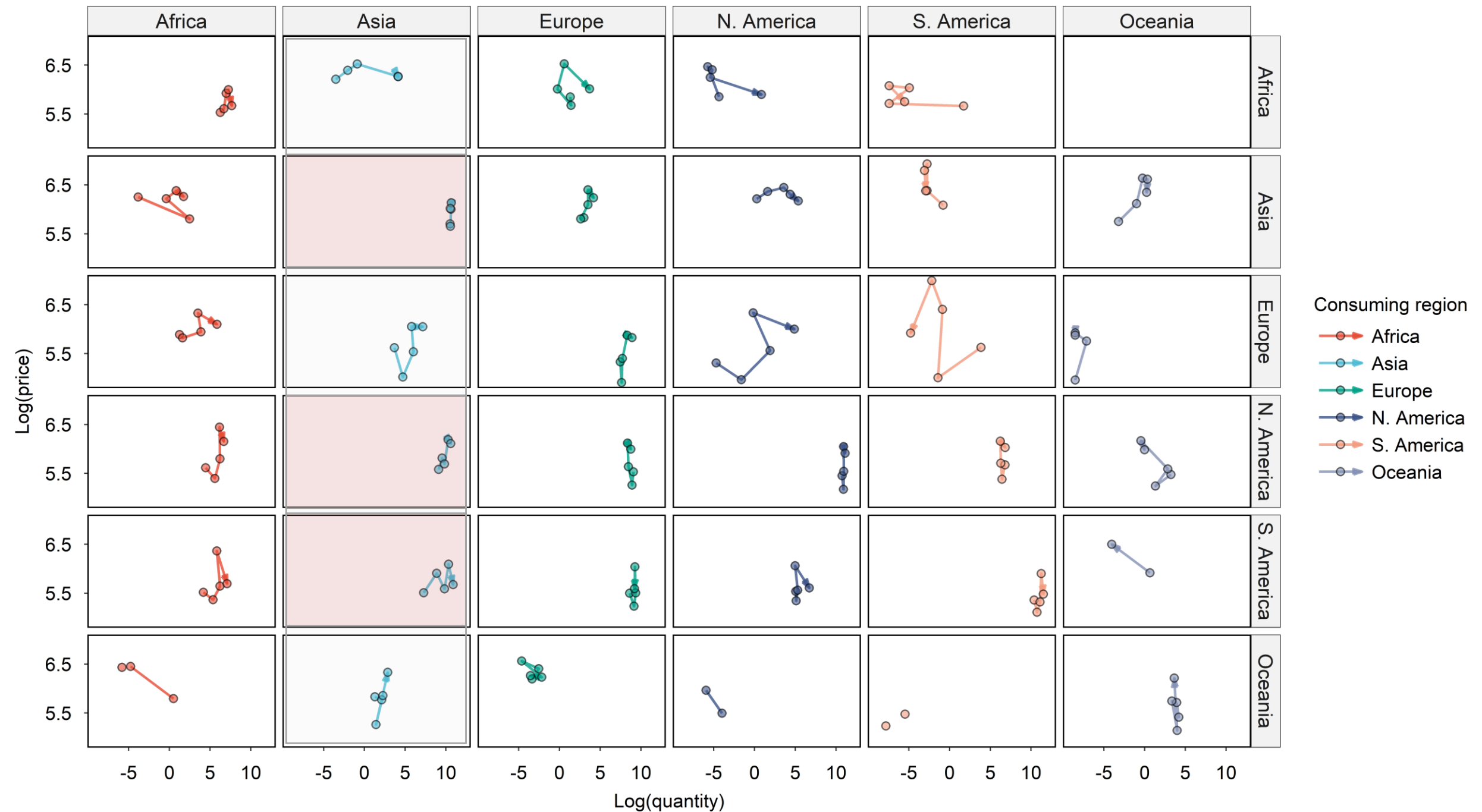
Soybeans market equilibrium, 1995-2005



Soybeans market equilibrium, 1995-2010



Soybeans market equilibrium, 1995-2015



Hindcast optimization

- Weighted mean square logarithmic error (WMSE)
 - Measures weighted mean squared “distance” between estimated and observed market equilibriums
 - Consumption shares as weights
- A second solver in the package to minimize WMSE by changing
 - δ_n for 2000 – 2015
 - Armington elasticities (two logit exponents)

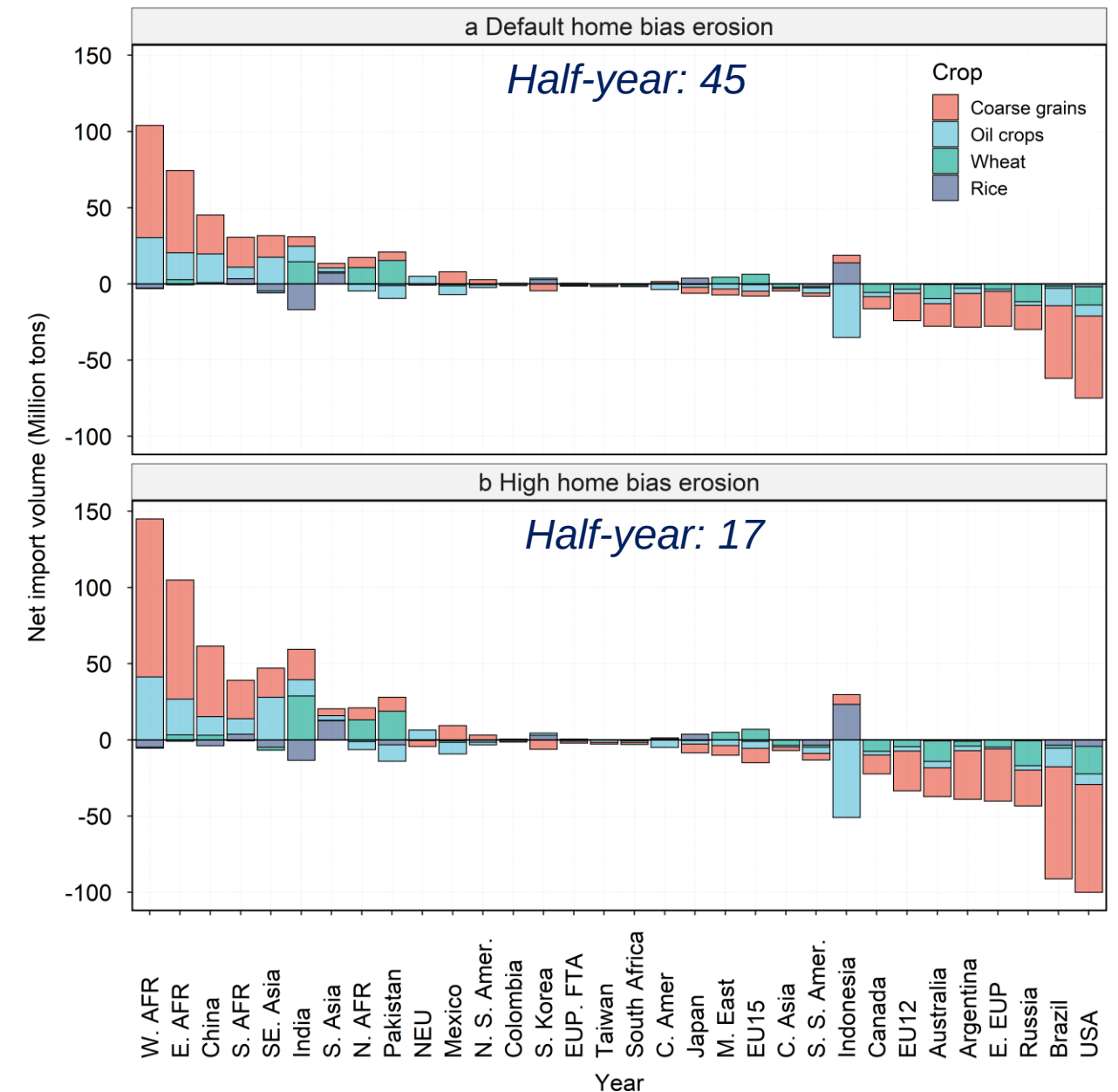
Results

Integration scenario	Regional logit	International logit	Integration parameter				WMSE
			2000	2005	2010	2015	
No integration	3	6	-	-	-	-	1.351
No integration	1.38	1.48	-	-	-	-	0.577
Bias erosion	0.84	1.45	1.15	1.20	1.22	1.37	0.495

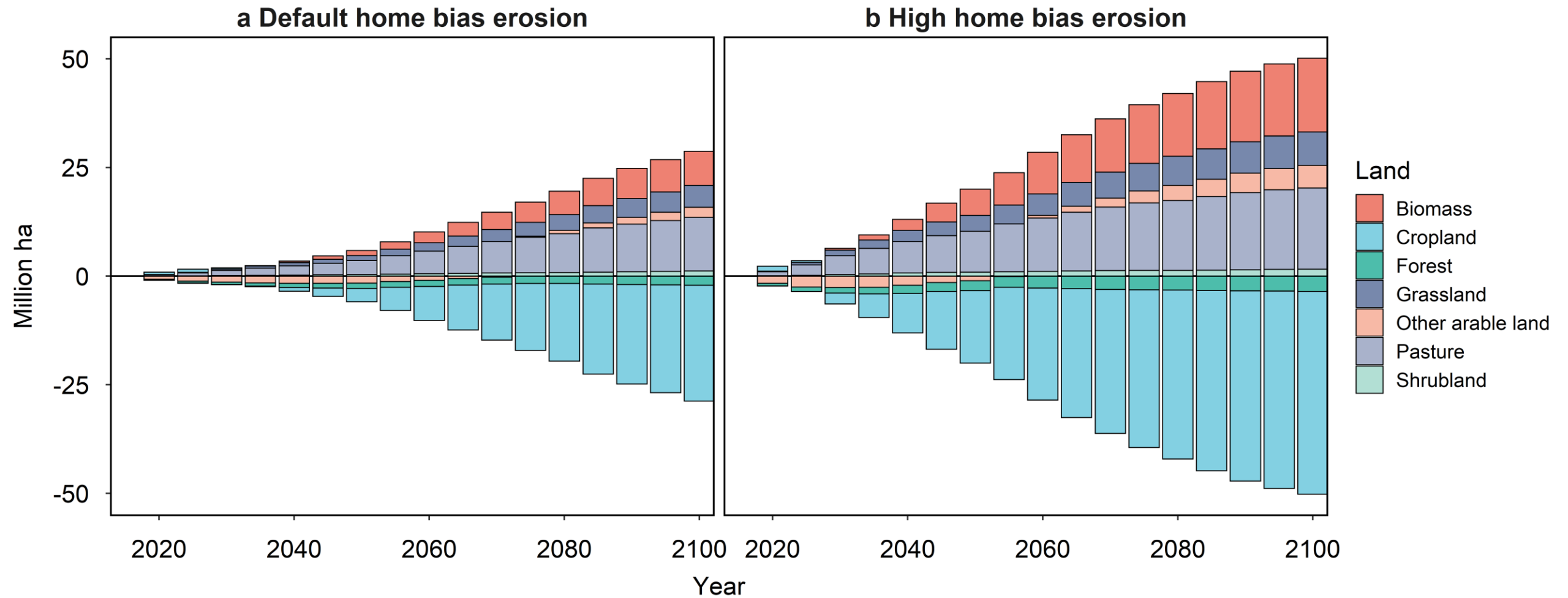
- 1995 – 2015: home bias erosion with a rate of 1.37 (0.05)
 - Half – life of ~ 45 years
 - 95% confidence: 37 - 57 years

Impacts of bias erosion on net trade in 2100

- With the trend of bias erosion
 - More balanced accessibility to both domestic and international markets
- Shifts of agricultural production to more productive regions
 - e.g., the USA and Brazil
- World average yield increased
 - ~ 3% in the default scenario
 - ~ 4.3% in the high scenario



Global land use change by 2100



- Saved 27 (default) – 47 (high) million ha (Mha) of cropland by 2100

Future studies

- Crop-specific trade parameters or region-specific market integration parameters
 - With more coverage of regions and crops
- Bias erosion in the international (macro) Armington nest
- The role of bias erosion in projections under alternative scenarios

Summary

- Dynamic reconciliation between Armington and integrated world market
- Develop market integration scenarios & test with hindcast experiments
 - More sensitivity tests around parameters and base year
- Allowing the dynamic trend of market integration implied by bias erosion showed important implications
 - estimating trade elasticities
 - long-term agroeconomic projections
- Practical method to consider a broader aspect of global market integration in evaluating long-term socioeconomic scenarios



Thank you

Base year sensitivity

	Base year 1995		Base year 2000		Base year 2005		Base year 2010		Base year 2015	
	est.	s.e.	est.	s.e.	est.	s.e.	est.	s.e.	est.	s.e.
θ^D	0.84	(0.15)	0.78	(0.11)	0.35	(0.11)	0.68	(0.13)	0.72	(0.13)
θ^M	1.45	(0.13)	0.90	(0.10)	0.93	(0.12)	0.85	(0.13)	1.08	(0.14)
δ_{1995}	1	-	0.98	(0.03)	0.99	(0.03)	1.07	(0.03)	1.01	(0.03)
δ_{2000}	1.15	(0.05)	1	-	1.00	(0.02)	1.10	(0.03)	1.02	(0.03)
δ_{2005}	1.20	(0.05)	1.04	(0.03)	1	-	1.07	(0.03)	1.01	(0.03)
δ_{2010}	1.22	(0.05)	1.05	(0.03)	1.02	(0.02)	1	-	0.95	(0.02)
δ_{2015}	1.37	(0.05)	1.17	(0.03)	1.14	(0.02)	1.13	(0.03)	1	-
WMSE	0.495		0.251		0.213		0.232		0.274	
$\frac{\delta_{2015}}{\delta_{1995}}$	1.37		1.20		1.15		1.06		0.99	

hindcast (forward projection) vs. backcast (backward projection)

Aggregation and “ghost share”

- Aggregation matters
 - Likely larger trade responses with more disaggregated regions and crops
 - More pronounced impacts from future integration
- Bilateral trade data with zero flows in 1995 (in thousand tons)

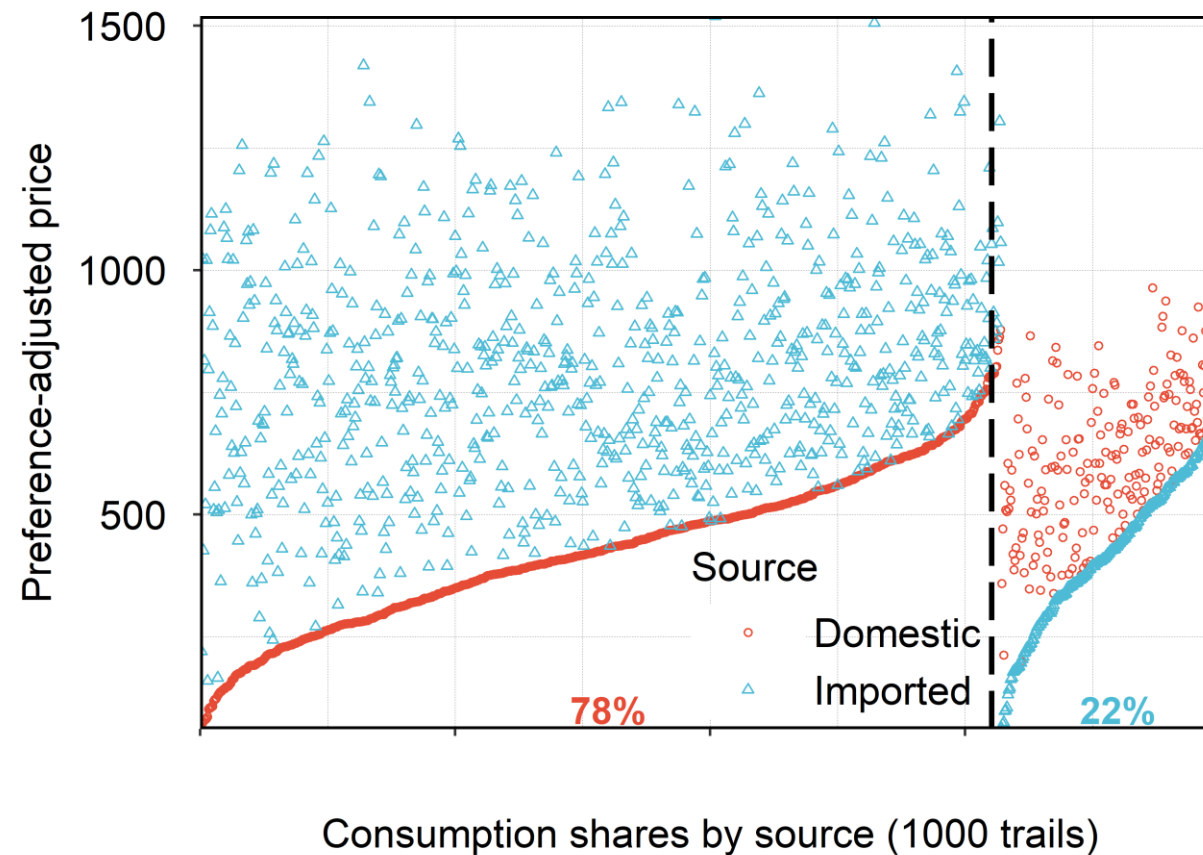
Import region	Export region	Crop	Year				
			1995	2000	2005	2010	2015
Asia	Africa	Rapeseed	0.00	0.02	0.07	3.38	0.04
Oceania	S. America	Soybeans	0.00	0.00	1.91	0.02	0.00
Africa	Oceania	Soybeans	0.00	1.65	0.01	0.00	0.00
Oceania	Africa	Rice	0.00	0.01	0.19	0.06	0.03
Africa	Oceania	Rapeseed	0.00	0.00	0.05	0.03	0.19
Oceania	S. America	Rapeseed	0.00	0.00	0.00	0.06	0.04
Oceania	Asia	Rapeseed	0.00	0.00	0.00	0.00	0.04
N. America	Oceania	Soybeans	0.00	0.02	0.00	0.00	0.00

Motivation

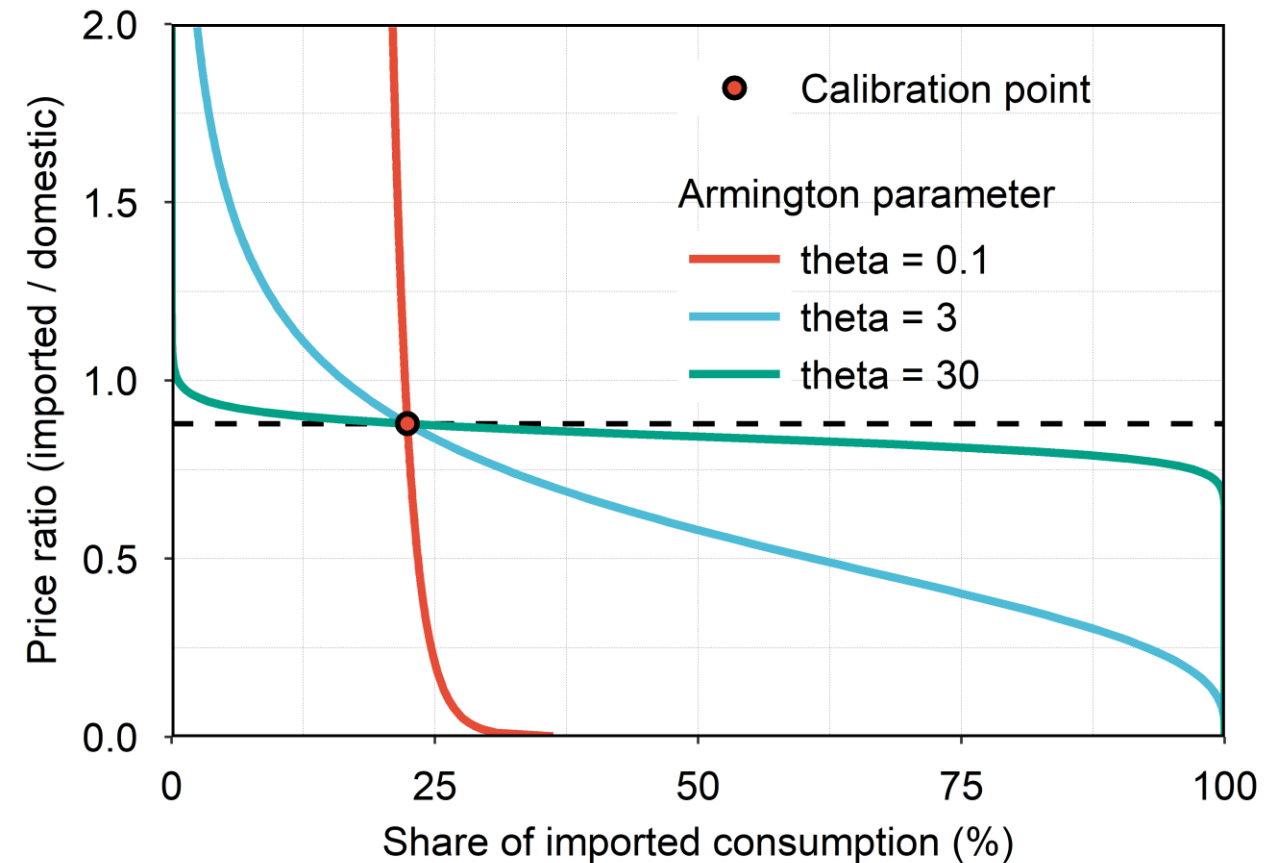
- Trade modeling
 - At the core of all multiregional economic models
 - Interdependency of regional supply and demand
 - Challenge in model validation and trade parameter estimation
- “Missing globalization” issue (Donaldson, 2015)
 - Crop consumption: total (+60%) vs. imported (+150%) in 1995 - 2015
 - Underestimate trade expansion and gains from market integration
- Econometric vs. hindcast
 - Inconsistent mapping & spotty coverage
 - Hindcast evaluation
 - Can we generalize existing approach to capture the faster trade growth?

Calibration and responses

a. Preference calibration ($\theta = 3$)



b. Trade responses

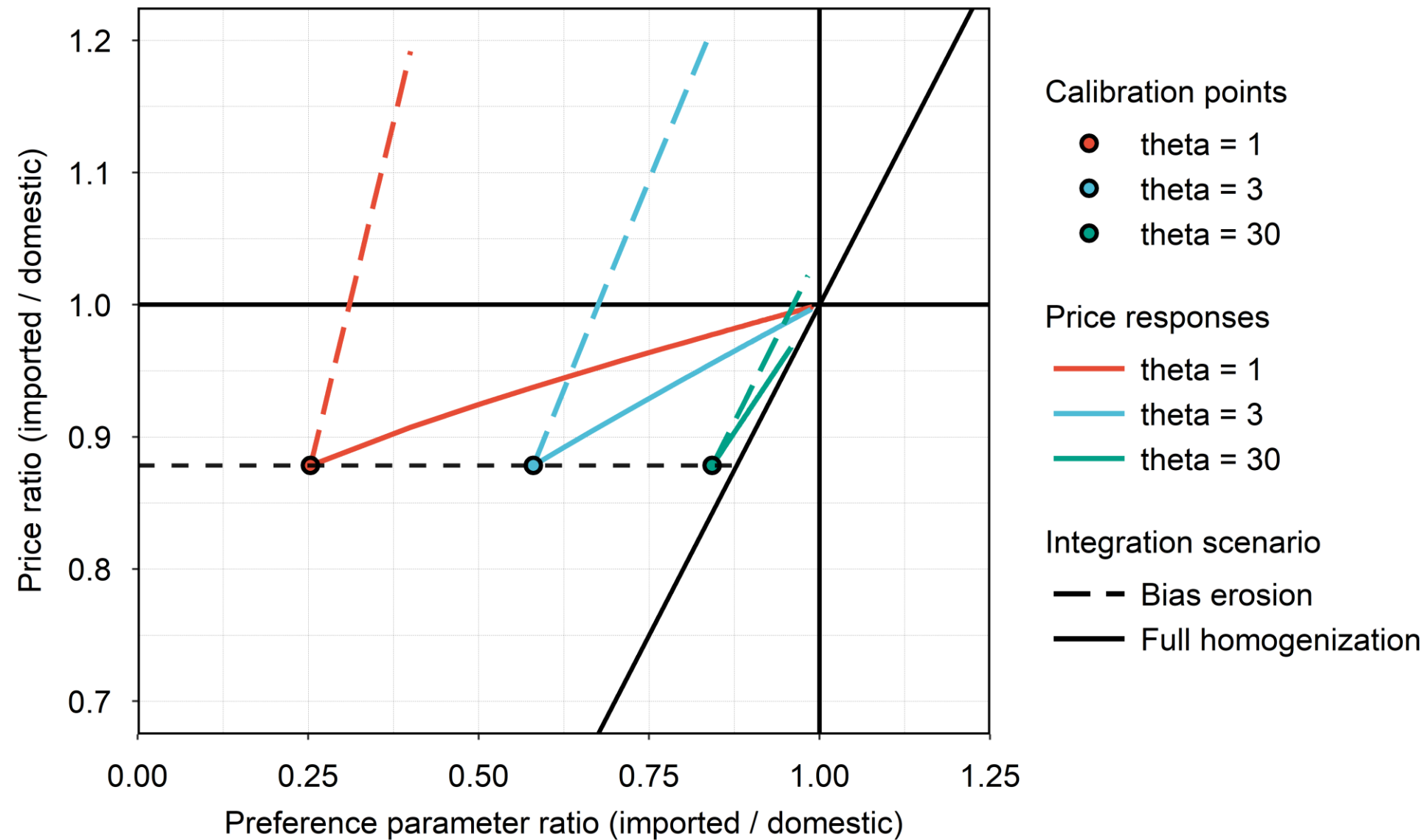


Logit approach (discrete choice modeling):

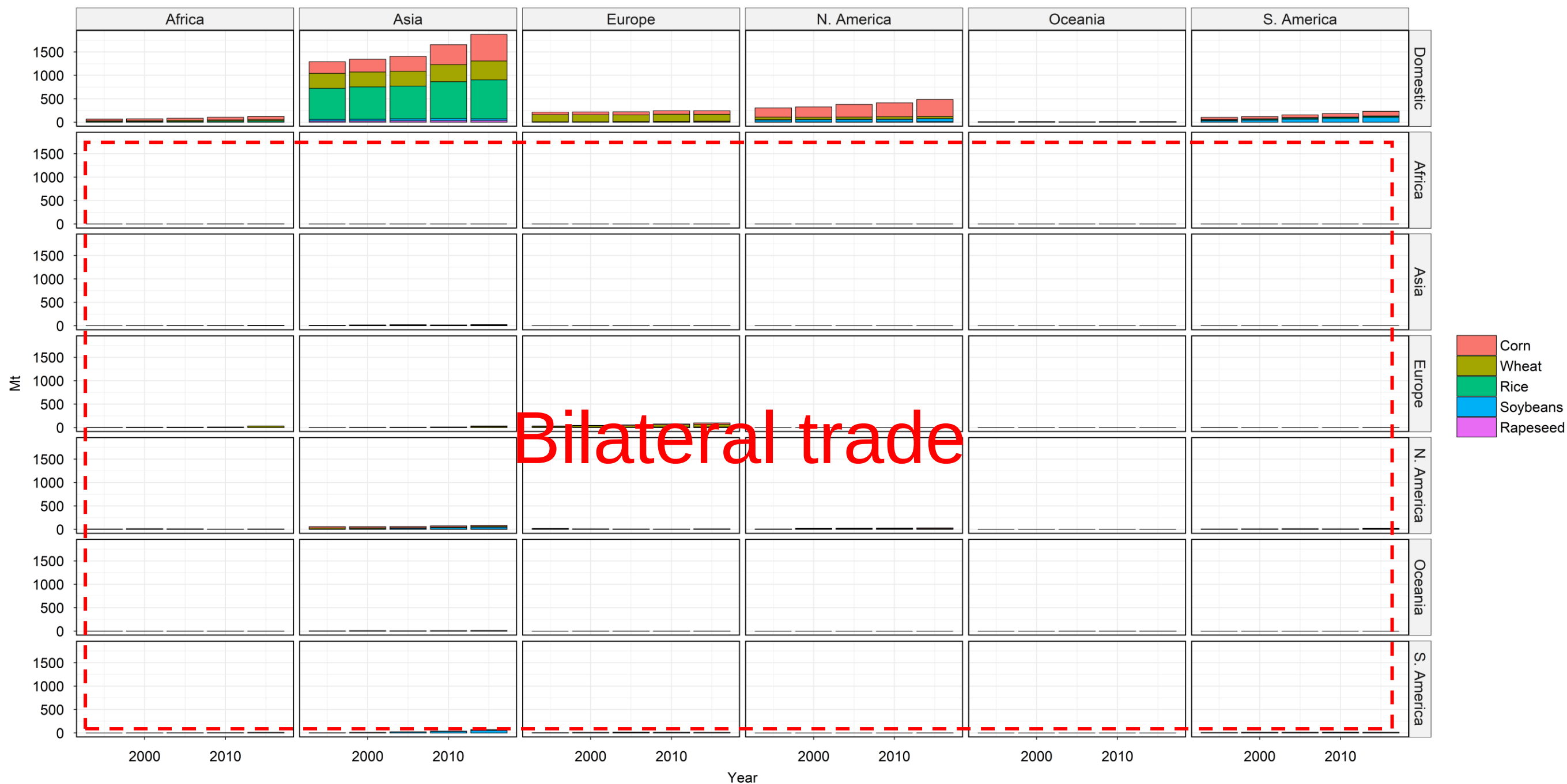
θ is scale parameter, inverse measure of heterogeneity

T_i are location parameters, measure of relative preference

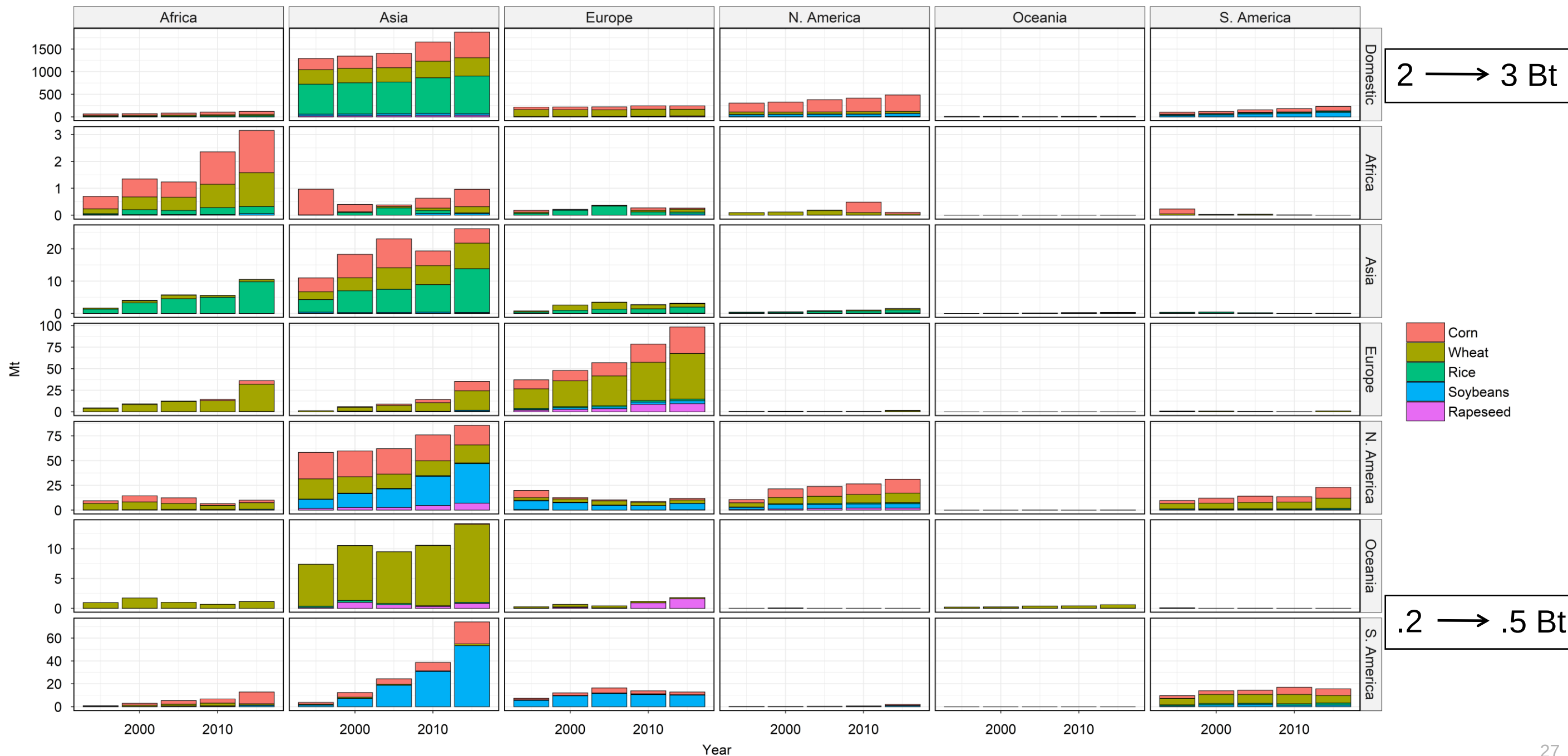
Integration scenarios



Crop consumption & trade (1995 – 2015): fixed_scale



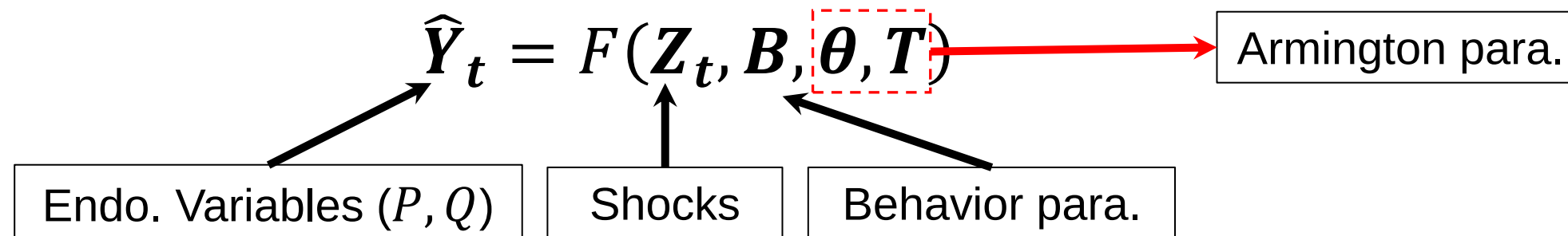
Crop consumption & trade (1995 – 2015): free_scale



Study	Time period & step	Model	Hindcast focus	Evaluation measure
Kehoe et al. 1995	1985 - 1987; 1 & 2-year	Constructed GE	Spain; all 12 sectors	weighted correlation coefficient
Gehlhar 1997	1982 - 1992; single	GTAP	Global (6 regions) ; export share of all 7 traded sectors	correlation & beta b/t changes
Arndt et al. 2002*	1992 - 1996; annual	Constructed GE	Mozambique; macroeconomics and trade	correlation and pseudo R-squared
Kehoe et al. 2003	1988 - 1999; single	Constructed GE	GDP-weighted trade flows	R-squares
Liu et al. 2004	1986 - 1995; 3-year	GTAP	Global (10 regions) ; import and export volume of all 8 traded sectors	R-squares
Guivarch et al. 2009	2003 - 2006; annual	IMACLIM-R	Global (Indian-focused); GDP and sector output growth	Difference
Ruijven et al. 2010a & b	1970 - 2003; annual	IMAGE/TIMER	Global; Transport & building	Normalised Root Mean Square Error
Dixon and Rimmer 2010	1998 - 2005; single	USAGE	USA; all 503 sectors	Weighted average error
Beckman et al. 2011	2001 - 2006; single	GTAP-E	Global; energy sectors	Difference
Baldos and Hertel 2013*	1961 - 2006; single	SIMPLE	Global; agriculture & land use	Difference
Chaturvedi et al. 2013	1990 - 2010; 5-year	GCAM-USA	USA; building	Difference
Hong et al. 2014	1995 - 2010; annual	single region (South Korea) GE	South Korea; outputs of 27 sectors	Mean absolute deviation (MAD) and mean absolute percentage error (MAPE)
van Dijk et al. 2016	2001 - 2007; single	MAGNET	Global; all 22 sectors	Mean absolute error; modified index of agreement
Fujimori et al. 2016*	1981 - 2010; annual	AIM/CGE	Global; energy sectors	Root Mean Square percentage errors (RMSPE)
Calvin et al. 2017	1990 - 2010; annual	GCAM	Global; Agriculture & land use	Normalized Mean Absolute Error & others

Calibration and problem

- Economic equilibrium model with Armington trade



- Preference parameters are calibrated to base year data

$$\hat{Y}_{baseyr} = F(Z_{baseyr}, B, \theta, T) = Y_{baseyr}$$

Import tariffs

- Will directly affect the calibration of preference parameters

