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Agricultural Productivity in China: Parametric Distance Function

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Outline

- Agriculture in China
- Theoretical framework
- Data
- Curvature condition and hypothesis test
- Empirical results
- Conclusion and reflection

Agriculture in China

	1980	1990	2000	2010	2011
GDP per capita (2005 PPP)	524	1,101	2,668	6,819	7,418
Agriculture in GDP (%)	30	27	15	10	10
Urbanization (%)	19	26	36	50	51
Agriculture export (Bill. $)	4	10	16	52	65
Agriculture in export (%)	24	16	7	3	3
Agriculture import (Bill. $)	6	8	20	108	145
Agriculture in import (%)	32	15	9	8	8

Source: World Bank (2013), WTO (2013)

Agriculture Still Important in China

- Top grain producer in the world
- Fan et al. (2004), investment in agriculture and rural area
  - Enhance agricultural production
  - Ensure food security
  - Reduce rural poverty
  - Reduce regional inequality
  - Create new employment opportunities
- World Bank (2009) agricultural and rural development key in poverty reduction
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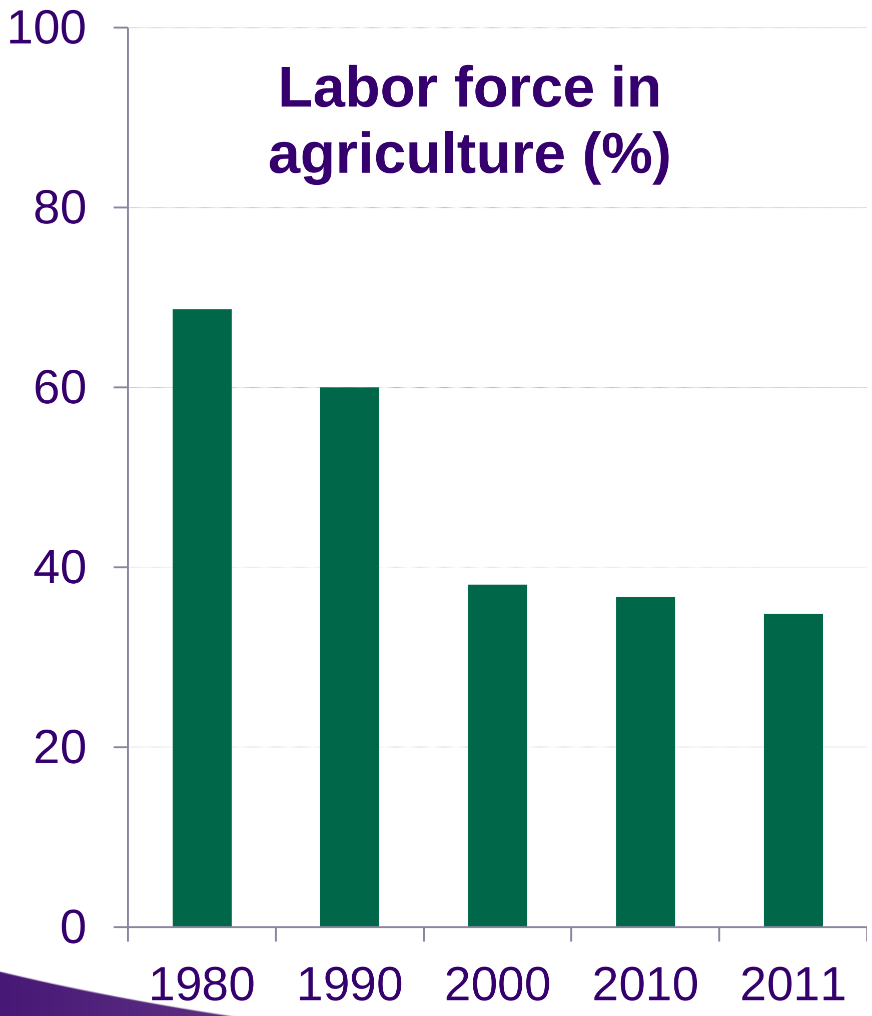
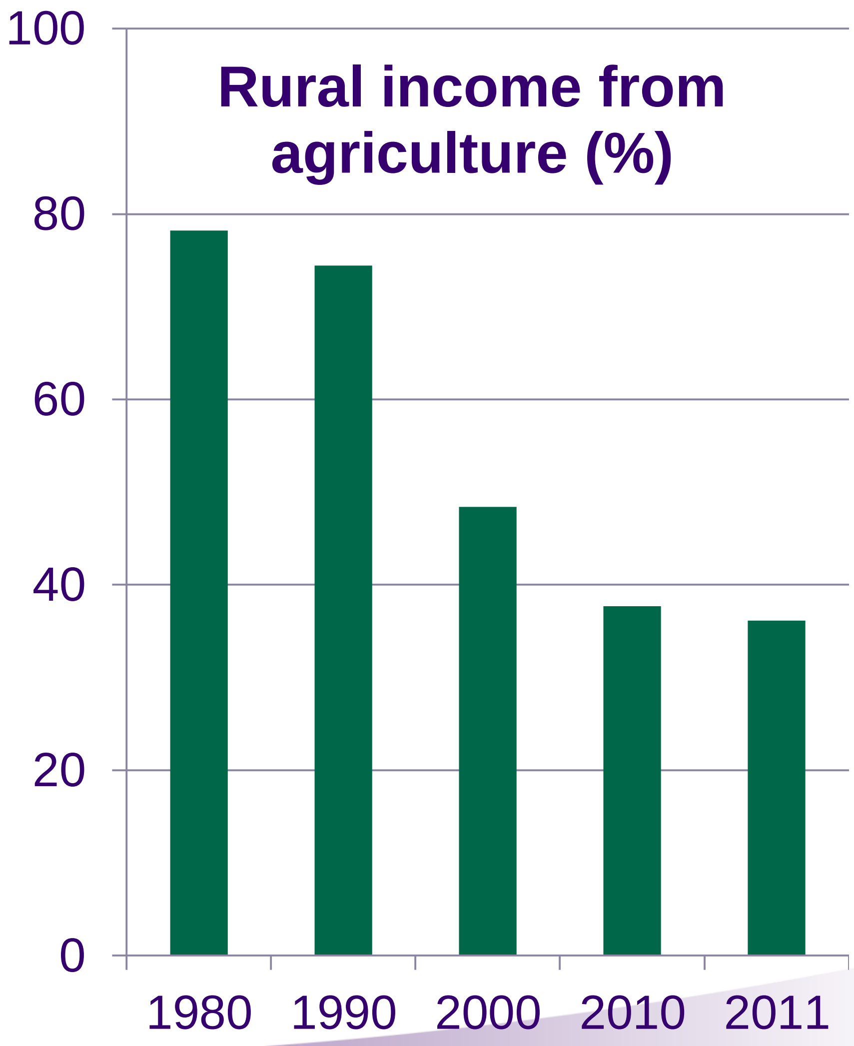
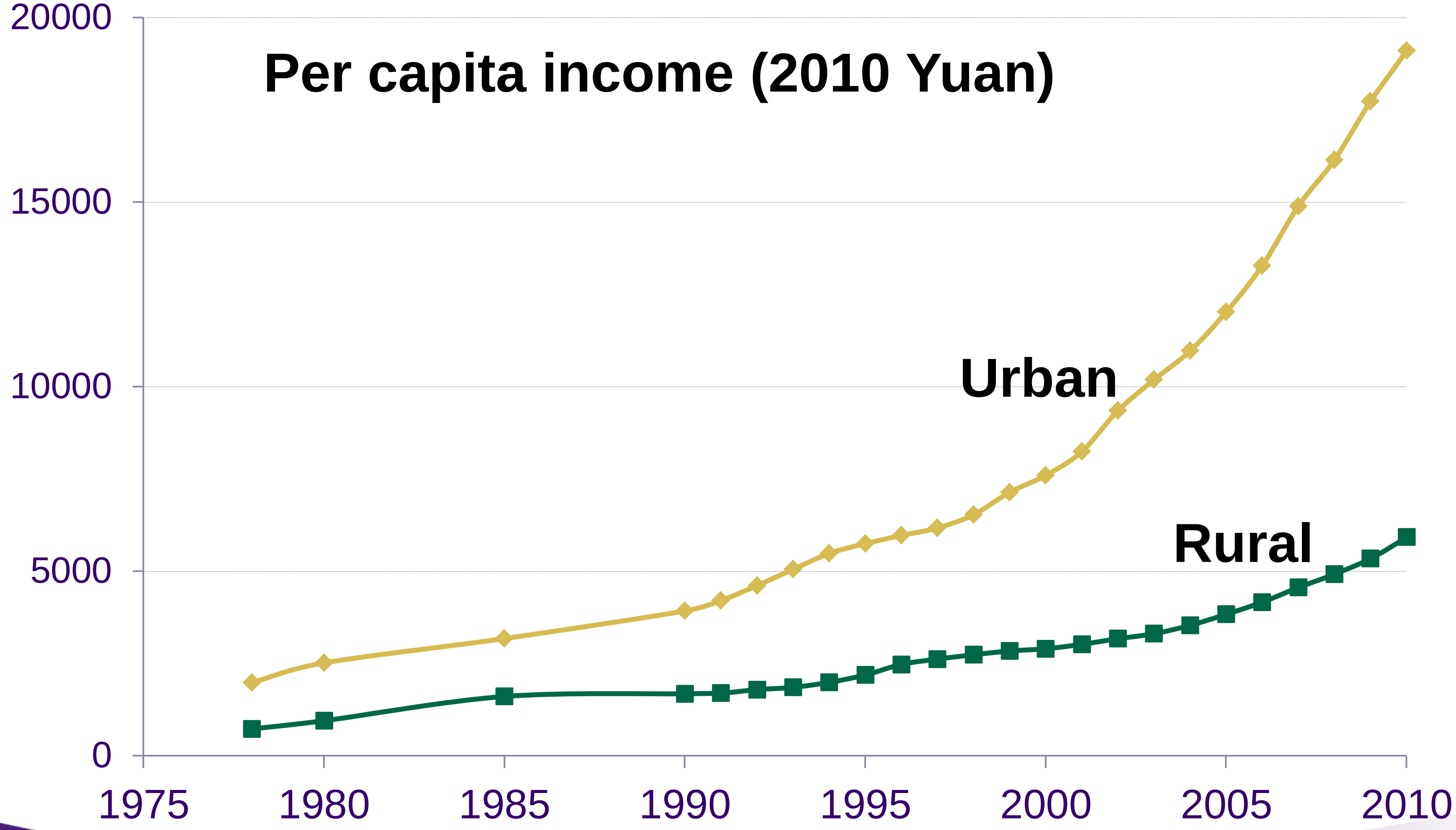
Agriculture in Employment and Income





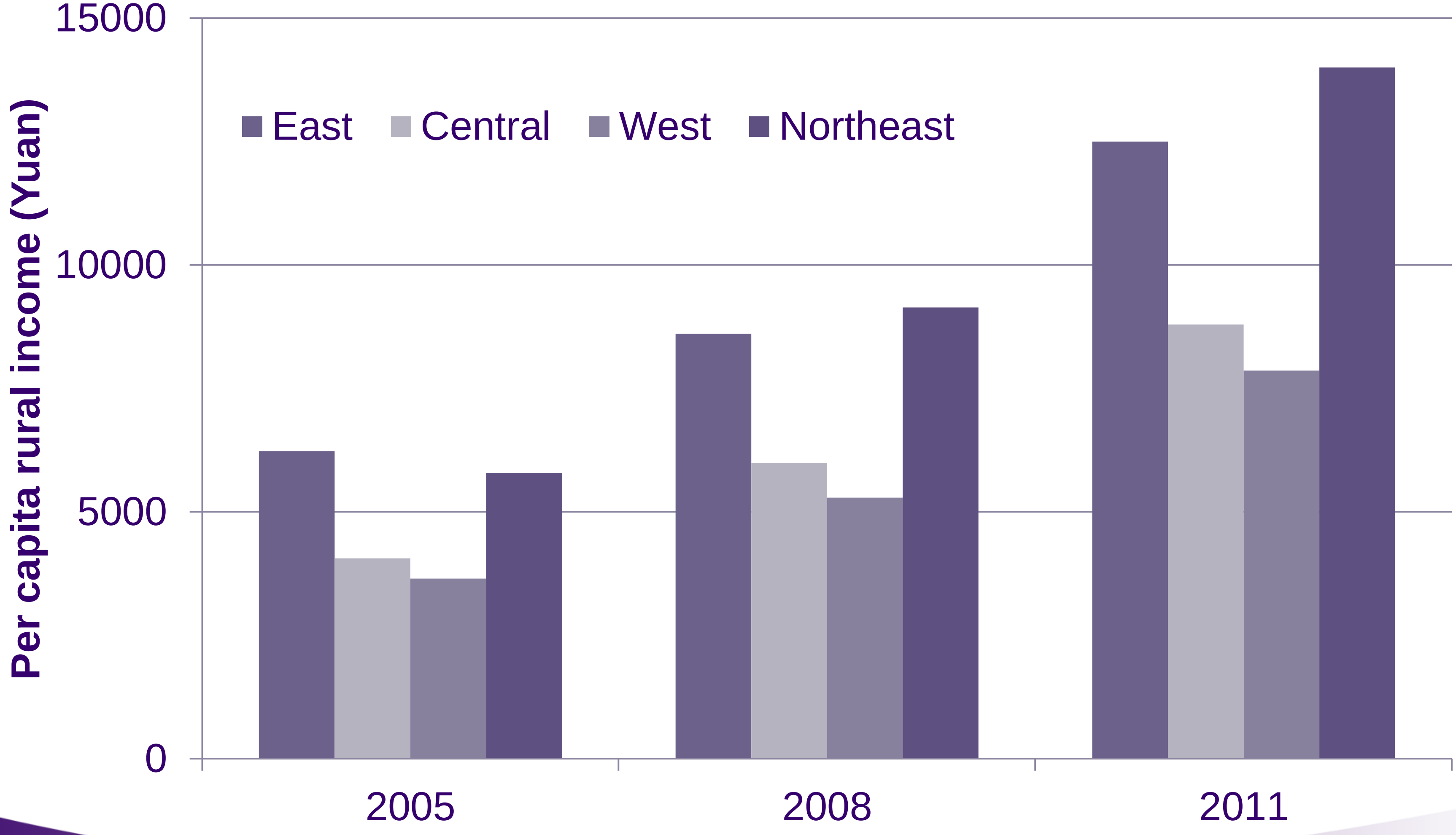
Source: China Statistical Yearbook

Rural-urban Inequality



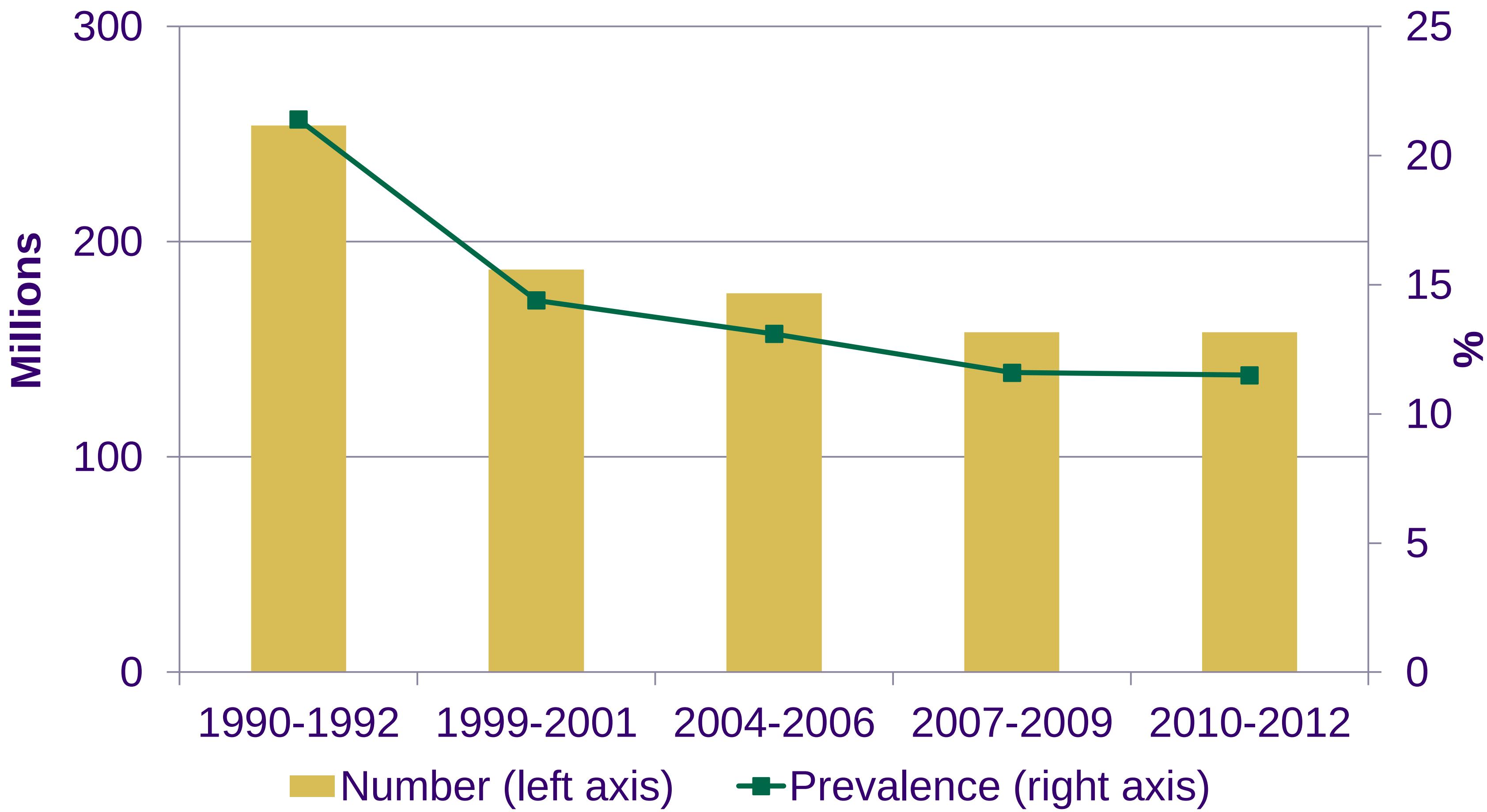
Source: China Statistical Yearbook

Regional Inequality in Rural Area



Source: China Statistical Yearbook

Undernourishment Declined, But….



Source: FAOSTAT (2013)

Food Security Calls For Productivity

- Demand side
  - Urbanization
  - Income growth
- Supply side
  - Dwindling water resources
  - Tight land constraint
  - Frequent natural calamities
  - Climate change
- Agricultural productivity the only way to ensure national food security

Productivity

- Productivity change: ratio of change in outputs to change in inputs
- Malmquist index for total factor productivity (TFP)
- Further decomposed into technical change (TC) and efficiency change (EC)
- Rich literature on alternative measure and decomposition of Malmquist
- Include technical bias and scale efficiency change
- Extend the methodology of Balk (2001) and Färe et al. (1997)

Theoretical Framework - Decomposition

TFP

Technical change (TC)

technology regress/progress ⟺ TC<>1

Efficiency change (EC)

fall behind/catch up with frontier ⟺ EC<>1

Scale efficiency change (SEC)

scale efficiency decrease/increase ⟺ SEC<>1

Output mix effect (OME)

output mix changes -> scale efficiency decrease/increase ⟺ OME<>1

Theoretical Framework - Decomposition

TC

- **Technical change magnitude (TCM)**
  input requirement set expand/shrink ⟺ TCM<>1
- **Output bias index (OB)**
  magnitude of output-based technical change decrease/increase ⟺ OB<>1
- **Input bias index (IB)**
  magnitude of input-based technical change decrease/increase ⟺ IB<>1

Data

- 4 output: crop, livestock, fishery, and forestry, valued at constant 2010 billion Yuan
- 4 input: area, labor, machinery, and fertilizer
- Rural infrastructure: irrigation
- Agricultural policies: market openness, taxation
- 31 provinces
- 1978-2010 annual data

Agriculture Growth 1978-2010

- Output growth driven by modern inputs + TFP

Output	growth (%)	Input	growth (%)	Infra. & policy	growth (%)
Crop	4.5	Land	0.3	Irrigation	1.0
Livestock	8.5	Labor	1.7	Market openness	8.6
Forestry	4.8	Machinery	6.3	Tax rate	-2.6
Fishery	12.7	Fertilizer	5.3		

Estimation - Output Distance Function

- Translog $ln\mathrm{D}_{\mathrm{o}}^{\mathrm{t}}(\mathrm{x}^{\mathrm{t}}, \mathrm{y}^{\mathrm{t}}) = \mathrm{f}(ln\mathrm{x}^{\mathrm{t}}, ln\mathrm{y}^{\mathrm{t}}, t)$
- Satisfy linear homogeneity in y, symmetry
- Normalize output (Coelli and Perelman 2000)
- Transform into production stochastic frontier

$$-lny_1^t = TL\left(x^t, {}^{y_m}\!/_{y_1}, t; \pi\right) + u^t + v^t$$

- stochastic term u_{it}=f(infrustructure, policy), left truncated at 0
- Assembling parts of TFP can be computed
- and TFP=TCM*OB*IB*EC*SEC*OME

Estimation Results

	Estimate	Std. err.	Parameter	Estimate	Std. err.
β_1	-0.575	(0.437)	γ_{22}	-0.026	(0.027)
β_2	-0.617	(0.150)***	γ_{23}	0.016	(0.036)
β_3	0.798	(0.163)***	γ_{31}	0.061	(0.052)
α_1	0.862	(0.629)	γ_{32}	-0.021	(0.016)
α_2	-3.242	(0.352)***	γ_{33}	0.091	(0.031)***
α_3	0.079	(0.422)	γ_{41}	-0.228	(0.067)***
α_4	1.293	(0.535)**	γ_{42}	-0.002	(0.026)
β_{11}	0.061	(0.089)	γ_{43}	0.148	(0.034)***
β_{12}	0.082	(0.015)***	τ_{1t}	0.008	(0.005)*
β_{13}	0.010	(0.030)	τ_{2t}	-0.001	(0.002)
β_{22}	-0.030	(0.008)***	τ_{3t}	-0.004	(0.003)*
β_{23}	-0.032	(0.012)***	δ_{1t}	-0.019	(0.009)**
β_{33}	0.042	(0.020)**	δ_{2t}	0.015	(0.006)***
α_{11}	-0.425	(0.181)**	δ_{3t}	-0.002	(0.005)
α_{12}	0.497	(0.106)***	δ_{4t}	0.008	(0.007)
α_{13}	-0.094	(0.105)	θ_t	0.029	(0.038)
α_{14}	-0.018	(0.108)	θ_{tt}	-0.002	(0.001)***
α_{22}	-0.314	(0.095)***	α_0	4.313	(1.802)**
α_{23}	0.205	(0.081)**			
α_{24}	-0.212	(0.077)***	φ_1	0.011	(0.017)
α_{33}	-0.098	(0.077)	φ_2	-0.007	(0.005)
α_{34}	0.037	(0.072)	φ_3	-0.188	(0.051)***
α_{44}	-0.050	(0.091)	φ_0	-3.725	(0.750)***
γ_{11}	0.304	(0.086)***			
γ_{12}	0.099	(0.032)***	$ln\sigma_v^2$	-4.247	(0.074)***
γ_{13}	-0.241	(0.043)***	χ	0.687	
γ_{21}	-0.132	(0.061)**	log likelihood	493.9	

Curvature Condition

Condition	Elasticity/Hessian	Satisfied
Monotonicity (nondecreasing in livestock)	0.26	✓
Monotonicity (nondecreasing in fishery)	-0.03	
Monotonicity (nondecreasing in livestock)	0.07	✓
Monotonicity (nonincreasing in land)	-0.12	✓
Monotonicity (nonincreasing in labor)	-0.44	✓
Monotonicity (nonincreasing in machinery)	-0.07	✓
Monotonicity (nonincreasing in fertilizer)	-0.34	✓
Homogeneity of degree 1 in outputs	1	✓
Convexity in outputs	negative semidefinite	✓
quasi-convexity in inputs	2/3 eigenvalue positive	Partial ✓

Hypothesis Test – LR test

Null hypothesis	Conclusion
No technical inefficiency	Inefficiency exists
No heterogeneous inefficiency effect	Inefficiency heterogeneous
No technical change	TC exists
Production technology exhibits input Hicks neutrality (no input bias)	Input Hicks neutral – input mix does not contribute to TC
Output Hicks neutrality (no output bias)	Output not Hicks neutral
Input and output Hicks neutrality	Technology not Hicks neutral
Input-output separability	4 outputs cannot be consistently aggregated into a single index
Cobb-Douglas functional form	C-D form not fit for the analysis
Constant returns to scale	Scale inefficiency exists
Mean returns to scale = 0.967	Decreasing returns to scale

Empirical Results

Malmquist and components	Mean (base=1)	Interpretation
Productivity (TFP)	1.020	TFP grows at 2 percent annually (close to USDA (2013), Nin-Pratt et al. (2009), smaller than Jin (2010), Zhang&Brummer (2011)
Technical efficiency (TE)	0.884	Huge efficiency gap
Technical efficiency change (EC)	0.997	Declining efficiency
Technical change (TC)	1.023	Technology main driver of TFP growth
Technical change magnitude (TCM)	1.024	Technology change
Output bias (OB)	1.000	Globally neutral production frontier - no preferred output and input mix for TFP gain
Input bias (IB)	1.000	
Scale efficiency change (SEC)	1.001	Output mix marginally close to optimal
Output-mix effect (OME)	1.000	No SEC from a change in output mix

Empirical Results

- Improved policy environment lift efficiency

Efficiency Term	Coefficient	Std. Err.
Irrigation	0.011	(0.017)
Market openness	-0.007	(0.005)
Policy support	-0.188	(0.051)***
Constant	-3.725	(0.750)***

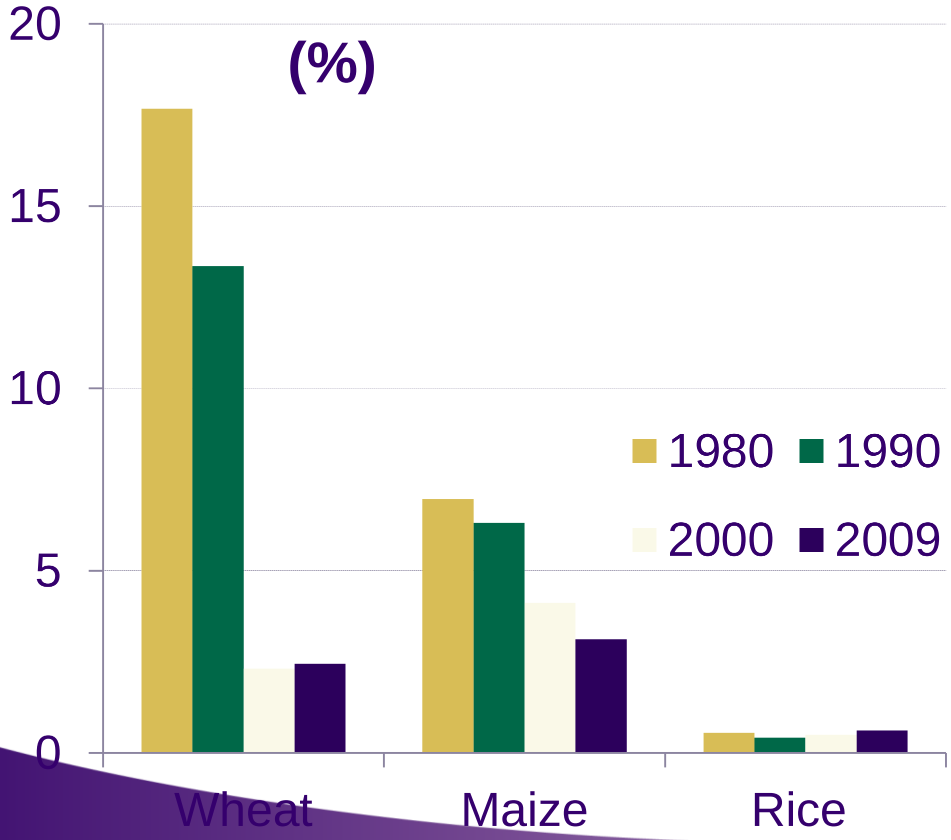
- Northern regions performs better: improved efficiency + technical change

Conclusion and Reflection

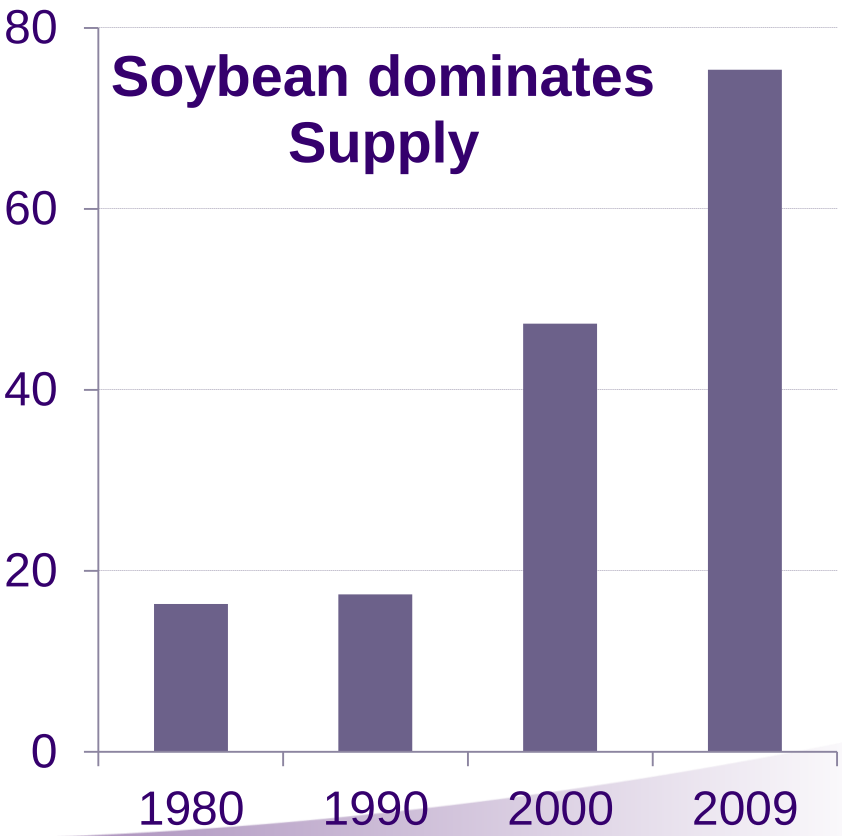
- Further decompose Malmquist TFP index
- Examine technology bias and scale efficiency
- Translog output distance function fully exploits data without distortion
- Chinese agricultural sector TFP grows at 2% per year, driven by TC
- But low efficiency can dampen the efforts of reform in stimulating production
- No significant technical bias, marginal scale efficiency

Domestic Supply

Cereal mostly self sufficient



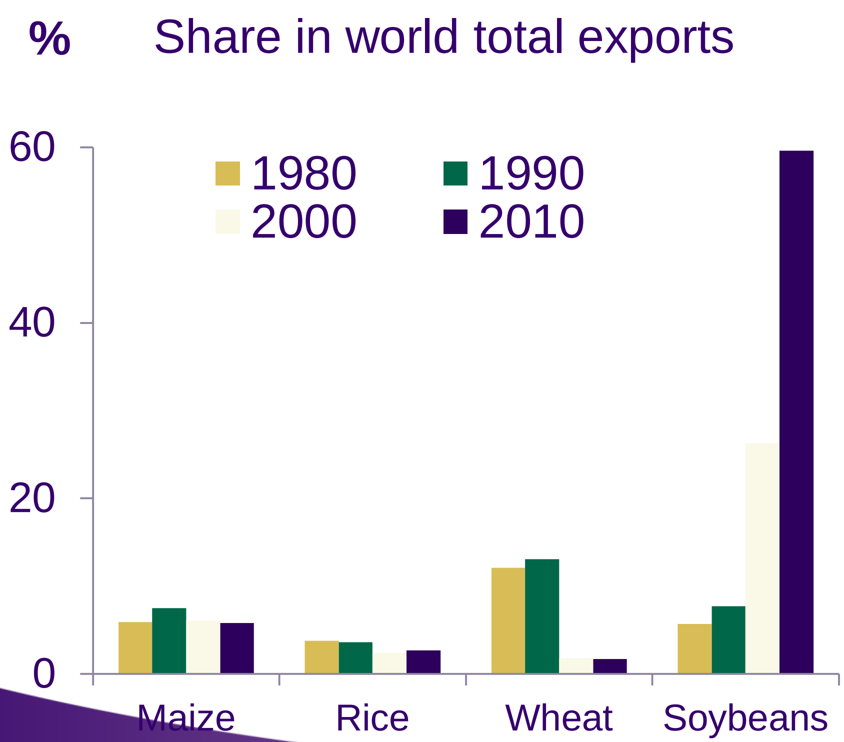
Top agricultural import: Soybean (26.7% in 2012)



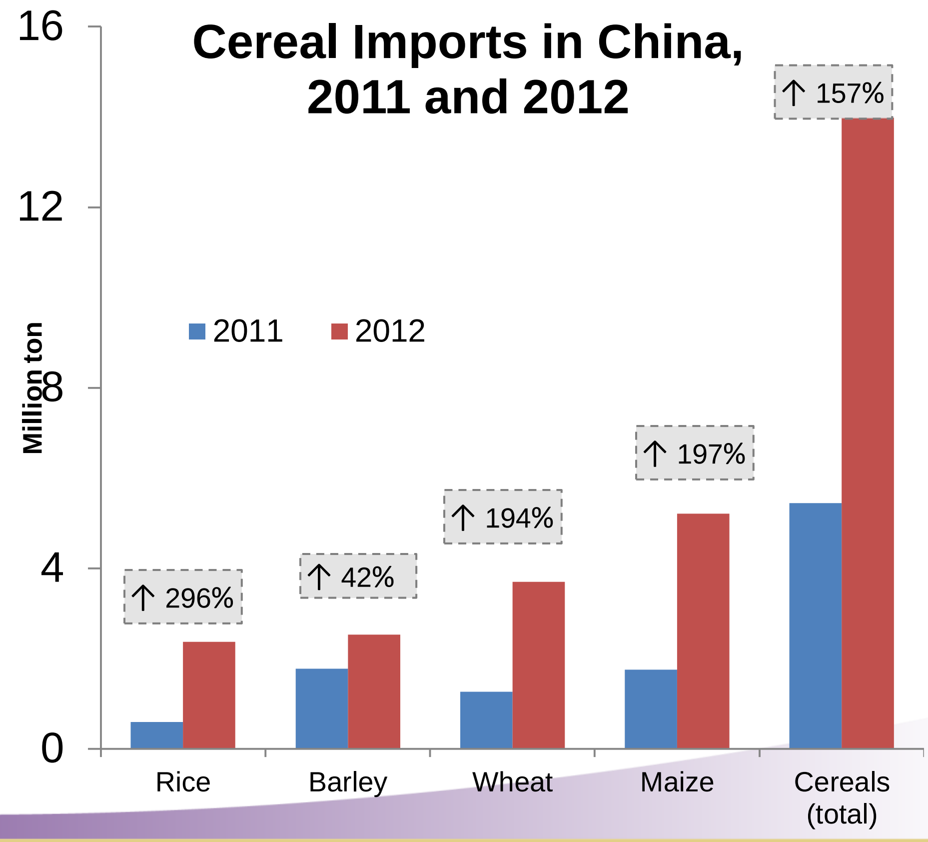
Source: FAOSTAT (2013)

China's Agricultural Imports

- 3rd largest food importer in the world
- Food imports grew 21% per year 2000-11 **(UNCTAD 2012)**



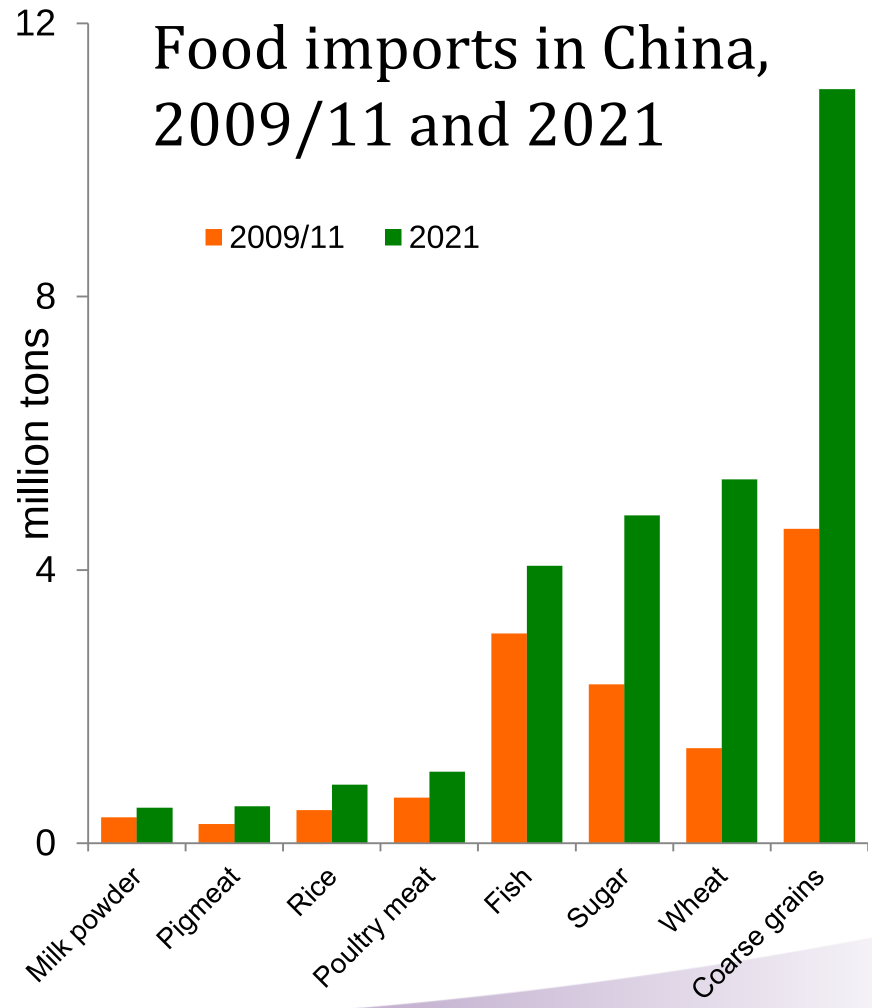
Source: FAOSTAT (2013)



Source: Chinese MOA

Implications for Agricultural Trade

- Stagnant TFP lead to increased import of other cereal crops
- Price fluctuations in international market



Source: OECD-FAO (2012)

Questions?

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