Empirical Studies of Energy and Productivity Trends in Developing Countries

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19 March 2001

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Technology, Energy and Productivity Research at LBNL: An Overview

- Estimation of productivity trends and elasticities initiated for India in 1996
  - Aggregate manufacturing and energy intensive industry
    - » Steel, cement, aluminum, fertilizers, glass, pulp and paper
  - Growth accounting, and time series and panel data econometric analysis
- Extended to Brazil, Indonesia, Mexico and S. Korea in 1998
  - Brazil -- paper, chemicals, metals, minerals, agg. manuf.
  - S. Korea --- cement, fertilizer, steel, paper, agg. manuf.
  - Mexico -- cement, paper, steel, agg. manuf.
  - Indonesia -- cement, fertilizer, steel, paper, agg. manuf.
- Web site address: www.eetd.lbl.gov/ea/ccm/ccPubs.html

Brazil: Data

- Data on output, inputs (labor, energy, materials), and investment from the Annual Survey of Mining and Manufacturing (Pesquisa Industrial Annual) and Censo Industrial (5-yearly industrial census).
- Some aggregation necessary to get consistent time series data - minerals (includes cement), chemicals (includes fertilizer), metals (includes iron and steel).
- Wholesale price data for inputs and outputs from Conjuntura Economica.
- Capital series problematic - approximated from investment data with assumptions on depreciation and growth rates.

Brazil Growth Accounting:

- Sectors:
  - Aggregate manufacturing
  - Energy intensive industry
    - » Chemicals, metals, minerals, paper

- Decomposition of output growth into growth in inputs and productivity growth

- Partial (input specific) productivity growth

Brazil Growth Accounting - Results

Sources of Growth in Sectoral Output, 1970-93 - Brazil

Sector	Growth Rate of						Total
	Output	Capital	Labor	Energy	Material	Total Input	Productivity
Minerals	1.11%	-0.22%	-0.70%	-0.13%	2.27%	1.22%	-0.11%
Chemicals	5.31%	0.41%	0.26%	0.11%	7.51%	8.29%	-2.98%
Metals	8.79%	0.22%	-0.01%	0.04%	3.95%	4.21%	4.59%
Aggregate Manuf.	5.07%	0.06%	-0.02%	0.02%	4.81%	4.88%	0.19%

India, S. Korea, and Brazil
Time Series Econometric Analysis

- Sectors:
  - Aggregate manufacturing
  - Energy intensive industry
    - » Steel, cement, aluminum, fertilizers, glass, pulp and paper
- Patterns of substitution
- Energy price elasticities
- Input biases of technological change
- Decomposition of output growth into growth in inputs and productivity growth
- Partial (input specific) productivity growth
- Translog functional form

Brazil Econometrics - Results

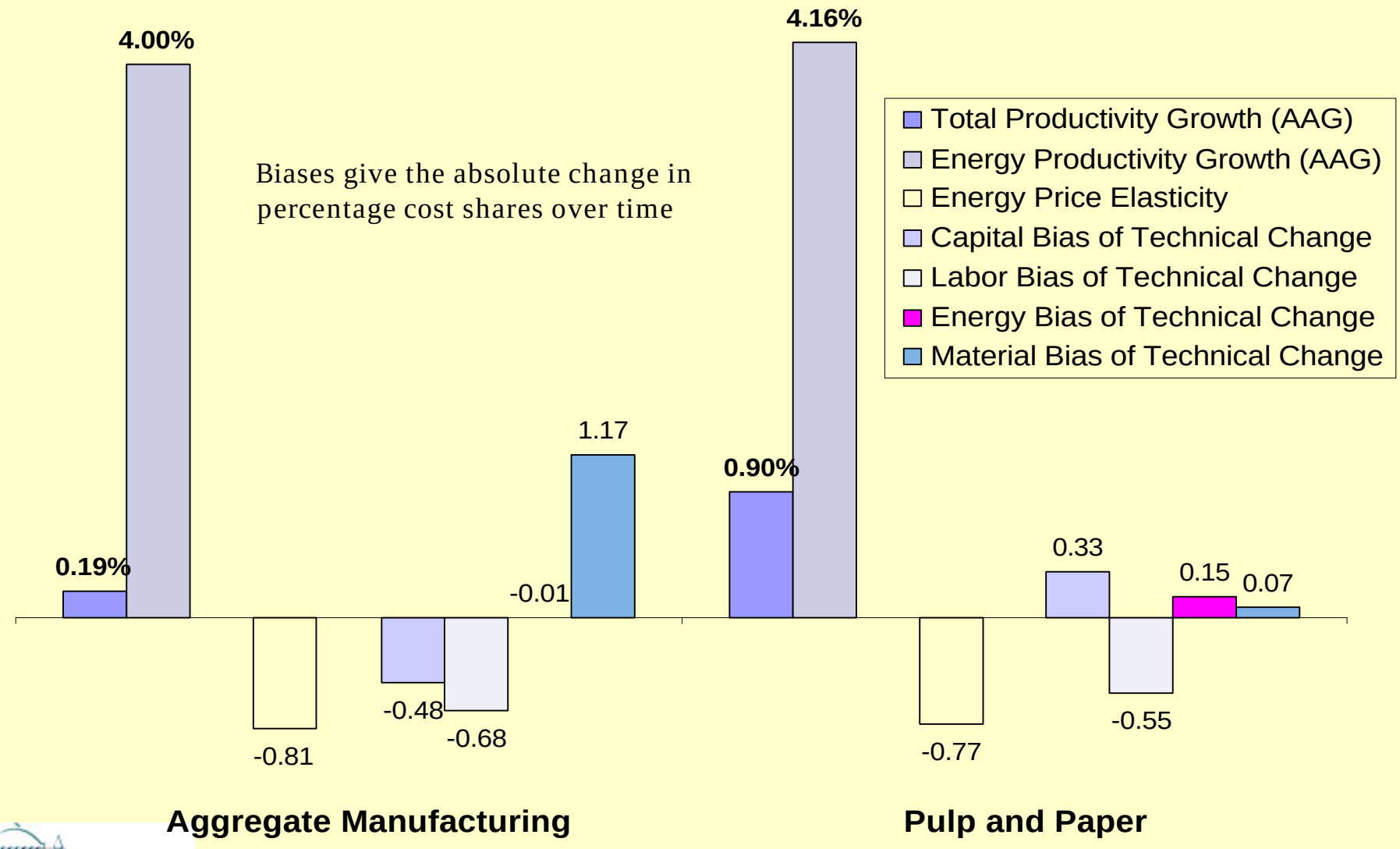
- **Cost Shares - average for the years 1970-1993 - BRAZIL**

Inputs	*Minerals*	*Chemicals*	*Metals*	*Paper*	*Agg. Manuf.*
Capital	10%	7%	6%	7%	5%
Labor	28%	11%	19%	20%	20%
Energy	14%	3%	5%	5%	3%
Materials	48%	79%	70%	67%	72%

- **Energy Price Elasticities – BRAZIL**

	Mineral	*Chemicals*	*Metals*	*Paper*	*Agg. Manuf.*
E_{ee}	**-0.39**	-0.15	**-0.66**	**-0.77**	-0.81

Brazil (1970-93)



Input Biases of Technological Change
Brazil Time Series Analysis

Technical Change Biases - BRAZIL

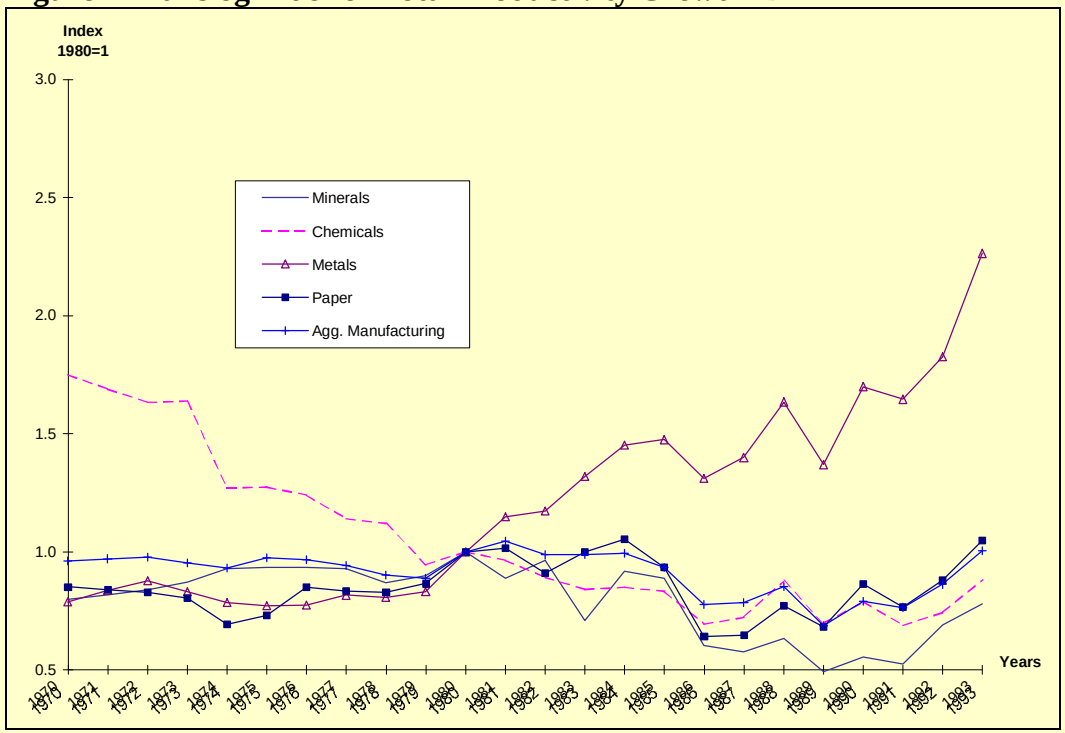
	Minerals	Chemicals	Metals	Paper	Agg. Manuf.
Capital	saving	saving	saving	using	saving
Labor	saving	saving	using	saving	saving
Energy	saving	using	using	using	saving
Materials	using	using	saving	using	using

Patterns of Substitutability and Complementarity

Interfactor Relationships - BRAZIL

	Minerals	Chemicals	Metals	Paper	Aggregate Manuf.
Capital-Labor	S	C	S	S	S
Capital-Energy	S	C	S	S	S
Capital-Material	C	C	S	S	C
Labor-Energy	C	S	C	S	C
Labor-Material	C	C	C	C	C
Energy-Material	S	S	S	S	S

Figure 1 Translog Index of Total Productivity Growth BRAZIL



Second Generation Model (SGM) Features

- Computable general equilibrium (CGE) model
  - 12 world regions, including India, S. Korea, China and Mexico
  - 18 producing sectors per region, including pulp and paper, iron and steel, chemicals, cement, non-ferrous metals
- Key parameters
  - Labor productivity influences GDP growth
  - Energy efficiency influences energy consumption by fuel
- Model structure
  - Non-nested CES functional form with one elasticity of substitution parameter
  - Long-run elasticity applies to new capital vintages; and short-run elasticity to old vintages
  - Substitution elasticity determines energy demand response

LBNL Estimates and SGM Requirements

- LBNL analysis using a translog function yields for energy-intensive industry and aggregate manufacturing:
  - Allen elasticities of substitution (KL, KE, KM, LE, LM and EM)
  - Total productivity estimates and partial ones for K, L, E, and M
  - Autonomous technological change estimates

- SGM using a non-nested CES function requires:
  - Substitution elasticity (KL=KE=KM=LE=LM=EM) which is used to determine own price elasticity for factor inputs
  - Autonomous technological change estimates

Estimates for Elasticity of Substitution - Brazil Non-Nested CES KLEM Model

Sector	**Elasticity of Substitution**
Chemical	0.52116
Metal	0.57372
Minerals	0.5944
Aggregate Manufacturing	0.9999

Elasticity of Substitution used in SGM-BRAZIL

	– Default values:	Estimated values*
Chemicals	0.276	0.52116
Cement, etc.	0.276	0.5944
Iron and Steel	0.276	0.57372
NF Metals	0.276	0.57372
Other Industry	0.276	0.9999

- * Econometrically derived values

SGM Brazil Carbon Scenarios Using Alternative Elasticity Estimates for the Industrial Sector

Brazil Carbon Emission (Mt C)

	Elasticity = 0.276			**Elasticity = derived**		
	Reference	With C Tax	% change	Reference	With C Tax	% change
		103R$(1999) / t C			103R$(1999) / t C	
1990	76.9	76.9	0.00%	76.9	76.9	0.00%
1995	91.6	91.6	0.00%	91.8	91.8	0.00%
2000	109.8	109.8	0.00%	111.6	111.6	0.00%
2005	130.4	130.4	0.00%	134.9	134.9	0.00%
2010	156	148.9	-4.77%	165.4	156.6	-5.62%
2015	188.1	174.3	-7.92%	204.6	186	-10.00%
2020	224.8	204	-10.20%	250.9	220.9	-13.58%
2025	267.3	240.1	-11.33%	307	265	-15.85%
2030	313.2	282	-11.06%	370.6	319.3	-16.07%
2035	364.2	328.1	-11.00%	443	381.9	-16.00%
2040	421.1	378.3	-11.31%	525.1	452	-16.17%
2045	483.9	432.8	-11.81%	617.5	529.5	-16.62%
2050	552.6	493.1	-12.07%	720.7	615.7	-17.05%

N.B. The elasticity of substitution for the aggregate manufacturing sector was set equal to 0.97

Observations

- Higher emissions relative to the reference case:
  - In SGM, capital, materials and energy substitute for labor
  - Higher elasticity implies more energy substitution
  - Energy consumption and hence carbon emissions rise more
- Increase in GDP value between the two cases
- Policy implication:
  - For the same carbon tax, Brazil could substitute away from carbon with less impact on GDP compared to earlier SGM runs.

Issues to be Resolved

- Do econometric estimates represent elasticity values that are short-run, long-run or something in between?
- How should we judge relevance of historical estimates for long-run future projections?
- Does assumption of perfect competition really make sense?
- CES production structures contain limited number of independent elasticity parameters compared to translog functions; how to resolve this problem?

Future Work

- Research on agriculture and electric power initiated for India and South Korea - aim to begin work on China in 2001.
- Estimation of nested CES functional forms.
- Application of LBNL technical change results to SGM.
- Continued interaction with SGM and other IA modelers
- Cross-sectional analysis of industrialized and developing country data

Publications

- J. Roy, J. Sathaye, A. Sanstad, P. Mongia, and K. Schumacher, 1999: "Productivity Trends in India's Energy Intensive Industries", The Energy Journal 20(3).
- J. Roy, K. Schumacher, J. Sathaye, and A. Sanstad, 2000: "Patterns of Fuel Input Use and Technological Change in India's Energy-Intensive Industries", LBNL-45498
- K. Schumacher, J. Roy, and J. Sathaye, 2000: "Productivity Trends and Technological Change in Energy Intensive Industries in Brazil, India and South Korea". Draft-LBNL-45499
- P. Mongia, K. Schumacher and J. Sathaye, 1998: "Policy Reforms and Productivity Growth in India's Energy Intensive Industries", LBNL 41841.
- P. Mongia, K. Schumacher and J. Sathaye, 1998: "Productivity Growth and Technical Change in India's Energy Intensive Industries - A Survey", LBNL 41840.
- K. Schumacher and J. Sathaye, 1999: "Energy and Productivity Growth in Indian Industries", LBNL-46187.

Publications (contd.)

- Schumacher, K., and J. Sathaye: “India's Aluminum Industry: Productivity, Energy Efficiency and Carbon Emissions”, LBNL-41845, Lawrence Berkeley National Laboratory, 1999.
- Schumacher, K., and J. Sathaye: “India's Cement Industry: Productivity, Energy Efficiency and Carbon Emissions”, LBNL-41842, Lawrence Berkeley National Laboratory, 1999.
- Schumacher, K., and J. Sathaye: “India's Fertilizer Industry: Productivity and Energy Efficiency”, LBNL-41846, Lawrence Berkeley National Laboratory, 1999.
- Schumacher, K., and J. Sathaye: “India's Pulp and Paper Industry: Productivity and Energy Efficiency”, LBNL-41843, Lawrence Berkeley National Laboratory, 1999.
- Schumacher, K., and J. Sathaye: “India's Iron and Steel Industry: Productivity, Energy Efficiency and Carbon Emissions”, LBNL-41844, Lawrence Berkeley National Laboratory, 1998.