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**Article**

## Food for fuel: The effect of the US biofuel mandate on poverty in India

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## Supplement to “Food for fuel: The effect of the US biofuel mandate on poverty in India”

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### APPENDIX: TABLES

TABLE A1. Parameters for crop production cost.

	Rice		Wheat		Sugar		Corn		Other Crops	
	$\eta_1^r$	$\eta_2^r$	$\eta_1^r$	$\eta_2^r$	$\eta_1^r$	$\eta_2^r$	$\eta_1^r$	$\eta_2^r$	$\eta_1^r$	$\eta_2^r$
US	1.15	1.50	1.15	1.50	1.20	1.55	1.15	1.50	1.20	1.55
India	1.55	1.80	1.55	1.80	1.45	1.70	1.55	1.80	1.45	1.70
ROW	1.50	1.75	1.50	1.75	1.35	1.65	1.50	1.75	1.35	1.65

*Note:* Source: GTAP 5 (1997).

TABLE A2. Parameters for the cost of land conversion.

	$\psi_1^r$	$\psi_2^r$
US	430	431
India	200	200
ROW	56	106

*Note:* Source: Gouel and Hertel (2006).

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TABLE A3. Cost and yield data for corn ethanol.

	US	India	ROW
Representative crop	Corn	Sugarcane	Sugarcane
Share	(93%)	(82%)	(63%)
Unit cost (\$/gallon)	0.73	1.06	0.63
<i>Energy yield by land quality (gallons/ha)</i>			
High	876	1200	1463
Medium	681	912	1254
Low	487	790	1115

*Note:* Share denotes production of representative crop in regional biofuel production. The representative crop for ROW is sugarcane since Brazil is the dominant producer with 47% of ROW production in 2012. Unit costs of production are taken from IEA-ETSAP (2013), OECD/IEA (2011), and Ravindranath, Sita Lakshmi, Manuvie, and Balachandra (2011).

TABLE A4. Parameters for supply of transport fuel.

	US	India	ROW
Transport fuel supply $q_e^r$ (MJ)	16,400	688	23,150
Gasoline supply $q_g^r$ (MJ)	15,840	540	22,000
Biofuels supply $q_{bf}^r$ (MJ)	800	40	1040
Share of gasoline $\mu_g^r$	0.90	0.95	0.95
Elasticity of substitution $\xi^r$	2	2	2
Constant $\lambda^r$	1.22	1.37	1.14

*Note:* MJ: MegaJoules; production of transport fuel ( $q_e^r$ ) equals consumption since transport fuel is not traded; supply of biofuels ( $q_{bf}^r$ ) and gasoline ( $q_g^r$ ) are from EIA (2014); the share of gasoline is calculated as the ratio of gasoline ( $q_g^r$ ) to transport fuel supply ( $q_e^r$ ); elasticities of substitution are from Hertel, Tyner, and Birur (2010).

TABLE A5. Parameters for extraction cost of crude oil.

	$\phi_1$	$\phi_2$	$\phi_3$
World Reserves (Billion Gallons)		\$/Gallon	
35,427	1.18	7.76	15

*Note:* Source: Oil reserves (British Petroleum (2013) and IEA (2014)); Cost parameters  $\phi_1$ ,  $\phi_2$ , and  $\phi_3$  are from Chakravorty, Magne, and Moreaux (2012).

TABLE A6. Demand parameters by region and commodity (base year 2012).

	US	India	ROW
Population (Billion)	0.31	1.22	5.36
GDP per capita (\$)	43,210	3295	10,714
		Rice	
Consumption per capita (kg)	8	70	53
Price (\$/ton)	450	450	450
Price elasticity	-0.15	-0.35	-0.20
Income elasticity	0.15	0.57	0.65
Constant $A_i^r$	0.004	0.005	0.0004
		Wheat	
Consumption per capita (kg)	80	60	65
Price (\$/ton)	250	250	250
Price elasticity	-0.15	-0.35	-0.20
Income elasticity	0.15	0.57	0.65
Constant $A_i^r$	0.036	0.004	0.0004
		Sugar	
Consumption per capita (kg)	60	23	22
Price (\$/ton)	450	450	450
Price elasticity	-0.23	-0.57	-0.25
Income elasticity	0.41	0.71	0.71
Constant $A_i^r$	0.003	0.0005	0.0002
		Meat	
Consumption per capita (kg)	375	75	70
Price (\$/ton)	1960	1960	1960
Price elasticity	-0.28	-0.37	-0.30
Income elasticity	0.43	0.97	0.77
Constant $A_i^r$	0.032	0.00048	0.00054
		Corn	
Consumption per capita (kg)	12	6	21
Price (\$/ton)	250	250	250
Price elasticity	-0.15	-0.35	-0.20
Income elasticity	0.15	0.57	0.65
Constant $A_i^r$	0.005	0.0004	0.00015
		Other food	
Consumption per capita (kg)	119	80	116
Price (\$/ton)	280	280	280
Price elasticity	-0.28	-0.53	-0.30
Income elasticity	0.41	0.71	0.71
Constant $A_i^r$	0.007	0.0067	0.0009
		Transport fuel	
Consumption per capita (VMT)	9250	69	752
Price (\$/VMT)	0.14	0.23	0.23
Price elasticity	-0.50	-0.21	-0.78
Income Elasticity	0.94	1.30	1.20
Constant $A_i^r$	0.003	0.001	0.003

Note: Sources: Consumption figures for food commodities are from FAO (2016); transport fuel: EIA (2014); prices: World Bank (2015); own-price and income elasticities for transport fuel: Parry and Small (2005), and Dimaranan, McDougall, and Hertel (2007); price and income elasticities for food commodities (US) are from Dimaranan, McDougall, and Hertel (2007), Regmi, Deepak, Seale, and Bernstein (2001), Regmi and Seale (2011), Muhammad et al. (2010); price elasticities for food commodities (ROW): Roberts and Schlenker (2013) and from Dimaranan, McDougall, and Hertel (2007); income elasticities for food commodities (ROW): Dimaranan, McDougall, and Hertel (2007); price and income elasticities for food commodities (India): Paul (2011), Dimaranan, McDougall, and Hertel (2007), Regmi et al. (2001), Regmi and Seale (2011); population figures: United Nations Population Division UNDP (2015); and per capita income: EIA (2015).

TABLE A7. Model validation: consumption of food and fuel in 2012.

	US			India			ROW		
	Observed	Predicted	% diff	Observed	Predicted	% diff	Observed	Predicted	% diff
Rice	8.00	8.21	2.63	70.00	74.40	6.29	53.00	54.87	3.53
Wheat	80.00	78.67	-1.66	60.00	57.69	-3.85	65.00	63.56	-2.22
Sugar	60.00	61.42	2.37	23.00	24.38	6.00	22.00	22.57	2.59
Meat	375.00	383.84	2.36	75.00	77.07	2.76	70.00	71.57	2.24
Corn	12.00	12.31	2.58	6.00	6.36	6.00	21.00	21.72	3.43
Other food	119.00	120.88	1.58	80.00	81.36	1.70	116.00	117.12	0.97
Fuel	9250	9810	6.05	69	73	5.80	752	763	1.46

Note: Consumption units for food in kg/capita and fuel in VMT/capita. Observed values are rounded off. % diff is the percent difference between observed values and model predictions. Sources: consumption of food commodities: FAO (2016), transport fuel: EIA (2014).

TABLE A8. Model validation: world commodity prices in year 2012.

	Observed	Predicted	% diff
Rice	450	462	2.66
Wheat	250	270	8.00
Sugar	450	471	4.66
Meat	1960	1820	-7.14
Corn	250	241	-3.60
Other food	280	271	-3.21

Note: % diff represents the percentage difference between observed values and model predictions. Prices are in 2005 dollars. Source: World Bank (2015).

TABLE A9. Model validation: average growth rate of food prices, 2005–2012.

	Observed	Predicted
Rice	7%	7%
Wheat	9%	8%
Sugar	7%	6%
Meat	5%	3%
Corn	11%	14%
Other food	7%	9%

Note: Average growth rates of observed prices are calculated from annual real food prices in 2005 dollars. Source: World Bank (2015).

TABLE A10. Parameters used in the sensitivity analysis and Monte Carlo simulations.

	US			India			ROW		
	Mean	Std. Dev.	Shock (%)	Mean	Std. Dev.	Shock (%)	Mean	Std. Dev.	Shock (%)
<i>Price elasticity</i>									
Cereals	-0.15	0.022	15	-0.35	0.105	30	-0.20	0.060	30
Sugar	-0.23	0.038	17	-0.34	0.085	25	-0.25	0.065	26
Meat	-0.28	0.039	14	-0.37	0.063	17	-0.30	0.096	32
Other food	-0.28	0.038	14	-0.58	0.116	20	-0.30	0.096	32
Fuel	-0.50	0.074	15	-0.21	0.063	30	-0.78	0.026	3
<i>Income elasticity</i>									
Cereals	0.15	0.021	14	0.57	0.037	6	0.65	0.12	18
Sugar	0.41	0.049	12	0.71	0.001	0.1	0.65	0.05	7.6
Meat	0.43	0.120	28	0.97	0.038	4	0.77	0.07	9
Other food	0.41	0.042	10	0.71	0.009	1	0.71	0.06	8
Fuel	1.30	0.016	1.2	1.30	0.020	2	1.20	0.12	10
<i>Crop yield (tons/hectare)</i>									
Rice-H	7.1		12	3.2		13	4.0		3
Rice-M	5.1	0.936	16	2.8	0.482	15	3.0	0.122	4
Rice-L	3.5		24	1.8		22	2.0		6
Wheat-H	6.8		3.5	4.0		9	2.9		16
Wheat-M	5.0	0.273	5	1.8	0.439	21	1.8	0.472	26
Wheat-L	2.9		8	1.5		26	0.8		50
Sugar-H	86		5.5	79		7	70		6.5
Sugar-M	72	4.706	7.5	60	5.598	9	60	4.563	7.5
Sugar-L	65		8.5	52		11	50		8
Corn-H	9.3		12	3.9		10	4.7		13
Corn-M	7.1	1.329	16	3.3	0.430	21	4.3	0.681	14
Corn-L	4.7		25	1.9		20	2.6		23
Other crops-H	4.5		11	2.0		10	2.2		9
Other crops-M	3.5	0.49	14	1.5	0.30	12	1.8	0.308	10
Other crops-L	2.5		20	1.0		20	0.9		19
<i>Unit extraction cost of oil (\$/barrel)</i>									
Unit Cost	50	7.500	15	50	7.50	15	50	7.500	15
<i>Unit cost of biofuel (\$/gallon)</i>									
Ethanol	0.73	0.025	3.5	0.63	0.02	3	0.63	0.02	3
Cellulosic ethanol	0.99	0.150	15	na	na	na	na	na	na
<i>Demand parameters in base year</i>									
GDP/capita (\$)	43,210	1022	2.4	3295	105	3.2	10,714	284	2.5
Population (Billion)	0.31	0.0070	2.3	1.22	0.020	1.6	5.36	0.120	2.4

*Note:* Sources: The magnitude of the shock equals the ratio of standard deviation to mean, as shown. Price elasticities: Regmi et al. (2001), Parry and Small (2005), Dimaranan, McDougall, and Hertel (2007), Muhammad et al. (2010), Regmi and Seale (2011), Roberts and Schlenker (2013) and Bento, Klotz, and Landry (2015); Income elasticities: Parry and Small (2005), Dimaranan, McDougall, and Hertel (2007), Muhammad et al. (2010), Bento, Klotz, and Landry (2015); Crop yields: FAO (2016); Oil cost: World Bank (2015); Ethanol cost: OECD/IEA (2011) and IEA-ETSAP (2013); Cellulosic ethanol cost: Carriquiry, Du, and Timilsina (2011), OECD/IEA (2010), OECD/IEA (2011) and IEA-ETSAP (2013); GDP per capita: EIA (2014); Population: UNDP (2015). Notes: Cereals include rice, wheat, and corn. Rice-H, Rice-M and Rice-L should be respectively read as: yield of rice on high, medium, and low land qualities. The same notation applies for wheat, corn, sugar, and other food. The standard deviation is uniform across the different land classes since it is calculated from historical data. Cellulosic ethanol is not produced in India and ROW. Due to a lack on data on land conversion cost, we could not calculate the standard deviation. We assume a shock of 15%.

TABLE A11. Matching between commodities, expenditure categories, and industries.

Products (1)	NSS Codes (2)	NSS Description (3)		NIC Codes (4)	NIC Description (5)
Rice	101–102	Rice		1111	Growing of food grain crops
	103	Chira		1403	Activities establishing a crop, promoting its growth or protecting it from disease and insects.
	104	Khoi, lava		1404	Harvesting and activities related to harvesting, such as preparation of crop cleaning, trimming, grading, drying.
Wheat	105–106	Muri and Other Rice Products		1111	Growing of food grain crops
	107–108	Wheat, atta		1403	Activities establishing a crop, promoting its growth or protecting it from disease and insects. Transplantation of rice in rice fields.
	110	Maida			Harvesting and activities related to harvesting, such as preparation of crop cleaning, trimming, grading, drying.
Sugarcane	111	Suji, rawa		1404	
	112–114	Bread, bakery, sewai, noodles, other wheat products			
	269	Sugar (subtotal)		1115	Growing of sugarcane or sugar beet
Meat/Dairy	160	Milk: liquid (liter)		1407	Activities to promote propagation, growth and output of animals and to obtain
	161	Baby food		1409	Other agricultural and animal service activities, n.e.c.
	162	Milk: condensed/powder		1211	Farming of cattle, sheep, goats, horses, asses, mules and hinnies; dairy farming
	163	Curd		1212	Rearing of goats, production of milk
	164	Ghee		1213	Rearing of sheep; production of shorn wool
	165	Butter		1214	Rearing of horses, camels, mules, and other.
	166	Ice cream		1221	Raising of pigs and swine
	167	Other milk products		1222	Raising of poultry (including broiler) and other domesticated birds; production of eggs and operation of poultry hatcheries

(Continues)

TABLE A11. *Continued.*

Products (1)	NSS Codes (2)	NSS Description (3)		NIC Codes (4)	NIC Description (5)
180	Eggs (no.)	1223	Raising of bees; production of honey		
181	Fish, prawn	1224	Raising of silk worms; production of silk worm cocoons		
182	Goat meat/mutton	1225	Farming of rabbits including angora rabbits		
183	Beef/buffalo meat	1229	Other animal farming; production of animal products n.e.c.		
184	Pork	1500	Hunting, trapping, and game propagation including related service activities		
185	Chicken	5011–5012	Fishing on commercial basis in ocean, sea, and coastal areas		
186	Others: birds, crab, oyster, tortoise, etc.	5021–5023	Fishing, fish farming, gathering of marine materials, other fishing activities		
Other food	115–122	Jowar, bajra, maize, barley, small millets other cereal Cereal substitutes: tapioca, jackfruit, etc.	1112	Growing of oilseeds including peanuts or soya beans	
	139	Cereal substitutes: tapioca, jackfruit, etc.	1119	Growing of other crops, n.e.c.	
	159	Pulses and pulse products	1121	Growing of vegetables	
	179	Edible oil (subtotal)	1122	Growing of horticultural specialties including: seeds for flowers, fruit or	
	229	Vegetables (subtotal)	1131	Growing of coffee or cocoa beans	
	249	Fruits (fresh, subtotal)	1132	Growing of tea or mate leaves including the activities of tea factories associated	
	259	Fruits (dry, subtotal)	1133	Growing of edible nuts including coconuts	
	289	Spices (subtotal)	1134	Growing of fruit: citrus, tropical pome or stone fruit; small fruit such as berries;	
	290–293	Tea and coffee	1135	Growing of spice crops including: spice leaves	

## REFERENCES

- Bento, A. M., R. Klotz, and J. Landry (2015), "Are there carbon savings from US biofuel policies? The critical importance of accounting for leakage in land and fuel markets." *Energy Journal*, 36 (3), 1276–1289. [5]
- British Petroleum (2013), "BP Statistical Review of World Energy". British Petroleum, London. [2]
- Carriquiry, M. A., X. Du, and G. R. Timilsina (2011), "Second-generation biofuels: Economics and policies." *Energy Policy*, 39 (7), 4222–4234. [5]
- Chakravorty, U., B. Magne, and M. Moreaux (2012), "Resource use under climate stabilization: Can nuclear power provide clean energy?" *Journal of Public Economic Theory*, 14 (2), 349–389. [2]
- Dimaranan, B., R. McDougall, and T. Hertel (2007), "Behavioral parameters. GTAP data base documentation." Available at <https://www.gtap.agecon.purdue.edu/resources/download/861.pdf>. [3, 5]
- EIA (2014), "International Energy Statistics, 2013". U.S. Energy Information Administration, Washington DC, USA. [2, 3, 4, 5]
- EIA (2015), "International Energy Outlook, 2014". U.S. Energy Information Administration, Washington DC, USA. [3]
- FAO (2016), "Statistical databases." Food and Agriculture Organization of the United Nations. [3, 4, 5]
- Gouel, C. and T. Hertel (2006), "Introducing Forest Access Cost Functions into a General Equilibrium Model." GTAP Working Research Memorandum, no. 8, Available at <https://www.gtap.agecon.purdue.edu/resources/download/2899.pdf>. [1]
- GTAP 5 (1997), "Global trade analysis project database documentation." Purdue University. [1]
- Hertel, T., W. Tyner, and D. Birur (2010), "The global impacts of biofuel mandates." *Energy Journal*, 31 (1), 75–100. [2]
- IEA (2014), "Key world energy statistics." International Energy Agency. [2]
- IEA-ETSAP, I. (2013), "Production of liquid biofuels, technology brief." IEA-ETSAP and IRENA. [2, 5]
- Muhammad, A., J. L. Seale, B. Meade, and A. Regmi (2010), "International evidence on food consumption patterns: An update using 2005 international comparison program data." Technical Bulletin 125. [3, 5]
- OECD/IEA (2010), "Sustainable production of second generation biofuels: Potential and perspectives in major economies and developing countries." OECD/IEA. [5]
- OECD/IEA (2011), "Technology roadmap, biofuels for transport." OECD/IEA. [2, 5]

Parry, I. W. and K. A. Small (2005), "Does Britain or the United States have the right gasoline tax?" *The American Economic Review*, 95 (4), 1276–1289. [3, 5]

Paul, S. (2011), "Food Preference and Nutrition in India." Available at SSRN <https://ssrn.com/abstract=1960295> or <http://dx.doi.org/10.2139/ssrn.1960295>. [3]

Ravindranath, N., C. Sita Lakshmi, R. Manuvie, and P. Balachandra (2011), "Biofuel production and implications for land use, food production and environment in India." *Energy Policy*, 39 (10), 5737–5745. [2]

Regmi, A., M. Deepak, J. Jr. Seale, and J. Bernstein (2001), "Cross-country analysis of food consumption patterns." In *Changing Structure of Global Food Consumption and Trade*, 14–22. [3, 5]

Regmi, A. and J. L. Seale (2011), "Cross-price elasticities of demand across 114 countries." Technical Bulletin 1929. [3, 5]

Roberts, M. J. and W. Schlenker (2013), "Identifying Supply and Demand Elasticities of Agricultural Commodities: Implications for the US Ethanol Mandate." *American Economic Review*, 103 (6), 2268–2295. [3, 5]

UNDP (2015), "Population Prospects: The 2015 Revision". The Population Division of the Department of Economic and Social Affairs of the UN Secretariat. [3, 5]

World Bank (2015), "Commodity Markets Outlook, Prices (Pink Sheet)." World Bank. [3, 4, 5]

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