Analyzing Drivers of World Food Prices: Weather, Growth, and Biofuels

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Abstract

The recent rise of food cost in world markets has accelerated the research examining the underlying factors for this rise. The present research investigated the separate and combined impacts of three factors thought to contribute to the price rise: adverse weather events, strong and sustained growth in high populated countries, and increased biofuels production. The research further analysed the effects of these price rises on consumption expenditures in Brazil, China and India. Analyses were carried out using a partial equilibrium trade model with a focus on the 2004 to 2007 period. The modelling suggests that the most important factor behind the price rise depends on the commodity, with maize/corn, oilseeds, and sugar most affected by biofuels, while some meats and dairy products are more affected by income growth.

Keywords: Food prices, partial equilibrium model, biofuel.

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1. Introduction

The recent increases in international prices of basic food products has attracted the attention of farmers, consumers, policy makers and governments, international institutions, the media and people in low-income countries with low food security. Farmers' interest in the subject has two dimensions. Rising food prices may create the incentive to increase production; however, at the same time rising feed prices may increase the cost of producing livestock. Consumers and particularly poor people in lower-income countries are concerned about rising food expenditures. They are also concerned about food security, that is, long-term availability of enough. Policy makers and international institutions are trying to take policy actions to maintain food security of the poor people while trying to understand the factors driving the price increases.

A recent report by FAO (2008b) grouped factors behind food price rises into supply and demand side developments. On the supply side, one major factor has been the weather-related production shortfalls that affected production of cereals and oilseeds during 2005 and 2006 (IFPRI, 2007). Another supply side factor is the decreasing stock levels, particularly in cereals, since the high prices in the mid 1990s (FAO, 2008b). Increasing energy costs, especially fuel, has raised the cost of production of all commodities. Finally, the trade-off and/or competition between oilseeds and grains areas is another consideration on the supply side (European Bank, 2008).

On the demand side, the structure of food demand is trending toward higher-value food items with the growth in populous, lower-income countries such as India and China. This income growth is putting pressure on demand for animal feed. Demand for energy and the increasing prices of fossil fuel have increased demand for biofuels, adding to demand for commodities to use as feedstock. Similarly, changing worldwide rural-urban distribution of population in favour of urban areas creates changes in food preferences and contributes to the food price rise (Cohen, 2006).

In addition to these factors, developments in the international financial markets may contribute to raising spot price volatility, by offering an expanding range of financial instruments for traders to increase portfolio diversification (FAO, 2008b). Moreover, policy measures taken by countries to attain food security and to decrease domestic prices, such as export bans and import liberalization, may have created excess demand in international markets and pushed prices upward.

The present research focused on two issues. First, the individual impacts of three drivers of world food prices were analyzed. The three drivers were adverse weather events, economic growth in populous countries, and increased biofuels production. The second issue explored was the effect of rising food prices on food consumption expenditures in Brazil, China and India. The analysis employed a partial equilibrium model of trade in agricultural commodities, simulating the impacts of shocks from 2004 to 2007.

2. Previous Applied Work

Agricultural production is linked to the energy sector and to the environment, and interacts with other industries, with factor markets, and with the macro-economy. These linkages and interactions can be captured in different modelling frameworks and techniques, each with advantages and limitations, so a full review of prior literature is unrealistic. However, there are a number of recent review papers and articles that bear highlighting.

Rajogapal and Zilberman (2007) extensively reviewed the applied literature relating to biofuels. They grouped methodologies and related work under the following headings: cost accounting models, micro-models of resource allocation and decision making, sector models, and general equilibrium models. They classified sector models into models that analyze outcomes of biofuel mandates at a global level, models that analyze outcomes of biofuel mandates at a national level and models that analyze outcomes of policies to sequester carbon through agriculture. They classified general equilibrium models into models that analyze impact of bio-fuel and carbon targets on the national economy and models that emphasize international trade.

The review in Rajogapal and Zilberman (2007) can be extended to research related to the drivers of world food prices and impacts of increases on lower-income countries. Mitchell (2008), focused on the USA markets, provided an analysis of the factors behind food price rise. Collins (2008) investigated the same issue in world markets. Neither Mitchell (2008) nor Collins (2008) used a full partial or general equilibrium framework but followed the dynamics behind the actual food price data rather than price forecast. Therefore, both studies provided useful information for economic agents and policy makers.

On the relationship between food prices and poverty in low-income countries, Ivanic and Martin (2008) and Son and Kakwani (2006) have provided interesting analyses. While the first one employs both partial and general equilibrium models to derive the impacts, the second one measures poverty and estimates money metric utility function.

3. Empirical Model[1]

A multi-country, multi-commodity partial equilibrium modelling framework was employed for this analysis. The non-spatial, synthetic[2] model quantified the price, supply, demand and net trade effects of shocks to the agricultural sector. The model was updated to the base year 2004 and short-term sequential simulations were carried out for 2004 to 2007. The model solution is found by simulating the effects of excess domestic supply/demand in each commodity/country on the world market to determine world market clearing prices. World market clearing prices are then used to derive the domestic prices, supply, demand, stock and net trade for the countries in the model, including the Rest of the World.

Uniform country/commodity-level directly estimated partial supply and demand response[3] equations are used to reflect the behavioural relationships. Supply and demand are specified as functions of various prices and shift factors (equations 1 and 2). Per capita income is included in demand and feed prices are included in livestock supply as well. Feed and processing demand (equations 3 and 4) are modelled, with the former specified as the conditional input demand.

$$qs_{it} = \alpha_0 shf_{qs}^{\ 1} pp_{it}^{\alpha_1} \prod_j pp_{jt}^{\ \alpha_j} \ ; \qquad \alpha_1 > 0,\ \alpha_j < 0 \qquad 1$$

$$qd_{i,fot} = \beta_0 shf_{qd}^{\ 1} pc_{it}^{\beta_1} pinc_t^{\beta_2} \prod_j pc_{jt}^{\ \beta_j} \ ; \qquad \beta_1 < 0, \beta_2 > 0,\ \beta_j > 0 \qquad 2$$

$$qd_{i,fet} = \chi_0 shf_{qd}^{\ 1} pc_{it}^{\chi_1} \prod_j \prod_q pc_{jt}^{\ \chi_j} qs_{qt}^{\ \chi_q} \ ; \qquad \chi_1 < 0, \chi_j > 0, \chi_q > 0 \qquad 3$$

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[1] See Cagatay and Saunders (2003a) and (2003b) for specifics.
[2] Elasticity measures used in the behavioral equations of this particular study are available from the authors.
[3] See Colman (1983) and Moschini (1989) for specifics.

$$qd_{OS,prt} = \delta_0 shf_{qd}{}^{1} pc_{OSt}{}^{\delta_{OS}} \prod_r pp_{rt}{}^{\delta_r}; \qquad \delta_{OS} < 0, \delta_r > 0 \qquad 4$$

$$shf_{qs} = shf_{qd} = 1 \text{ initially}$$

Variables and Parameters:

i: own commodity

j: substitutes

pc: consumer price

pinc: per capita income

pp: producer price

pp_r: producer price of oilmeals and oil

qd_{fe}: domestic feed demand

qd_{fo}: domestic food demand

qd_{OS}: domestic processing demand for oilseeds

qs: domestic supply

qs_q: domestic supply of meat, poultry products and raw milk

Stocks are allowed in the model and are accumulated with the transaction motive, which responds to quantity of production or consumption (equation 5). Finally, net trade is determined as an identity that accounts for the difference between domestic supply and demand (equation 6).

$$qe_{it} = \varphi_0 qs_{it}{}^{\varphi_1}; \qquad \varphi_1 > 0 \qquad 5$$

$$qt_{it} = qs_{it} - (qd_{i,fot} + qd_{i,fet} + qd_{i,prt}) - (\Delta qe_{it}) \qquad 6$$

Domestic prices are specified as a function of world prices (reflected by price transmission elasticity), domestic and border policies (reflected as price wedge) and transportation costs (assumed to be 0 in the present analysis) (equation 7).

$$pp_{it} = \left(\frac{WDp_{it}}{ex} \right)^{\varepsilon_{\tau}} + tp_{it} + sd_{it} + si_{it} + sg_{it} + sm_{it} \qquad 7$$

Variables and Parameters:

ex: exchange rate

pp: producer price

sd: direct payments

sg: general services expenditure

si: input subsidy

sm: other producer market subsidy

tp_i: border policy

WDp: world price

ε_m: price transmission elasticity

4. Empirical Analysis

The model included 18 countries and 22 products and provided outputs regarding supply; food, feed and processing demand; stocks; and net trade at the country and commodity level. For the present research, the outputs of interest are world prices for each commodity as well as consumption expenditures in Brazil, China and India. The other countries and commodities in the model contributed the equilibrium solutions found, although they are not specifically discussed.

4.1. Scenarios

The research first aimed to assess the individual impact of supply and demand factors on world food prices. One major supply-side factor considered was the occurrence of adverse weather events, such as drought, on production in Australia, Canada, USA and the EU. Scenario 1 simulated this shock by shifting production from its base trend to the actual production achieved in these countries. Table 1 provides the data by commodity and by country or region. These changes were assumed to be entirely weather-related for modelling purposes. Care should be taken in interpreting the annual rates of change in the table. For example, wheat production increased in USA and Australia from 2006 to 2007, but production in 2007 was below 2004. The change in supply was included in the model by using the shift variable in equation 1. For example, the 9.35 percent decrease in wheat supply in the EU was modelled by changing the shift variable from 1.00 to 0.9065 (1 - 0.0935), creating exogenous pivotal leftward shift of the supply curve.

Table 1: Scenario 1 – Weather Impacts (annual change in supply)

	Australia	Canada	USA	EU
		Wheat		
2004-05	14.54	3.54	0.004	-9.35
2005-06	-57.59	1.87	-16.04	-6.77
2006-07	23.11	-26.49	14.20	-5.13
		Maize		
2004-05	6.25	7.07	-5.87	-12.00
2005-06	-40.43	-4.98	-5.21	-13.37
2006-07	40.00	29.59	24.10	-13.33
		Grains (other)		
2004-05	20.49	-5.87	-8.06	-15.73
2005-06	-59.63	-14.53	-30.21	0.08
2006-07	63.16	14.54	51.59	1.68
		Oilseeds		
2004-05	-4.08	20.00	0.56	-2.51
2005-06	-52.41	-1.47	1.95	4.55
2006-07	84.90	-7.40	-16.48	-7.98

Source: Index mundi database.

One demand factor putting upward pressure on world food prices is the recent growth in populous countries such as Brazil, India and China. This growth is expected to increase the demand for high-value foods by increasing income in these countries. Table 2 provides data regarding per capita income growth in these countries and income elasticity of demand for livestock commodities (generally higher value and relatively elastic). These data were used to calculate annual increases in total demand due to income growth, shown in table 3. The demand changes were modelled by using the demand shifters in equations 2 and 3. For example, the rise of 3.2 percent in beef demand in Brazil was incorporated by changing the shift variable from 1 to 1.032 in beef demand equation.

Table 2: Income Growth and Income Elasticity of Demand

	Brazil	China	India
Annual Per Capita Income Growth (%)			
2004-05	4.50	12.90	10.60
2005-06	5.50	14.00	11.60
2006-07	6.80	13.80	10.50
Income Elasticity of Demand			
Beef and veal	0.70	0.70	0.50
Sheepmeat		0.26	0.63
Liquid milk	0.30	0.30	0.71
Butter	0.47	0.47	0.74
Cheese	0.55	0.55	
Milk powder (whole)	0.49	0.49	
Milk powder (skim)	0.49	0.49	

Source: IMF World Economic Outlook Database.

Table 3: Scenario 2 – Economic Growth (annual change in demand)

	Beef and veal	Sheepmeat	Liquid milk	Butter	Cheese	Milk powder (whole)	Milk powder (skim)
				<u>**Brazil**</u>			
2004-05	3.20	0.00	1.40	2.10	2.50	2.20	2.20
2005-06	3.90	0.00	1.70	2.60	3.10	2.70	2.70
2006-07	4.70	0.00	2.00	3.20	3.70	3.30	3.30
				<u>**China**</u>			
2004-05	9.00	3.30	3.90	6.00	7.10	6.30	6.30
2005-06	9.80	3.60	4.20	6.60	7.70	6.90	6.90
2006-07	9.70	3.60	4.10	6.50	7.60	6.80	6.80
				<u>**India**</u>			
2004-05	5.30	6.70	7.50	7.80	0.00	0.00	0.00
2005-06	5.80	7.30	8.20	8.50	0.00	0.00	0.00
2006-07	5.30	6.60	7.50	7.80	0.00	0.00	0.00

Another demand factor putting pressure on food prices is rising biofuels production in the EU, USA, Canada, Brazil, China and India. The rise in biofuels, presented in Table 4, requires more sugar, grains and feed stock. In scenario three, the rise in crop demand was simulated based on the increase in biofuels production. Conversion factors were used to determine the required tonnes of crops by type for producing one thousand litres of bio-ethanol (based on Pimentel (2003) and Rajogapal and Zilberman (2007)) and bio-diesel (based on Pimentel and Patzek (2005)). Crop tonnage (e.g., sugarcane) was converted to commodity equivalents (e.g., raw sugar)

(FAO, 2000). As before the demand shifts were modelled with the shift parameters in relevant commodities and countries.

Table 4: Scenario 3-Rise in Bio-energy Production (change in demand)

	Brazil	USA	Canada	EU	China	India
Bio-ethanol production-change in crop demand						
	sugar	*maize*	*wheat*	*wheat & sugar*	*sugar*	*sugar*
2004-05	8.60	35.10	111.00	8.90	-16.50	-25.70
2005-06	7.90	26.00	52.60	15.20	-19.80	-34.60
2006-07	7.30	20.60	34.50	-28.00	-24.70	-52.90
Bio-diesel production-change in crop demand						
	Brazil	**USA**	**Canada**	**EU**	**China**	**India**
	soya-oilseeds	*soya-oilseeds*	*rapeseed-oilseeds*	*rapeseed-oilseeds*	*soya-oilseeds*	*soya-oilseeds*
2004-05	74.80	131.70	290.00	73.00	22.50	266.70
2005-06	42.80	56.80	74.40	42.20	18.40	72.70
2006-07	30.00	36.20	42.60	29.70	15.50	42.10

Source: Ledebur et al. (2008) for the EU; OECD (2008) and Dufey (2006) for the others.

Finally, a fourth scenario modelled simultaneous simulation of the first three to derive the total impact of individual supply and demand shocks.

4.2. Scenario outcomes

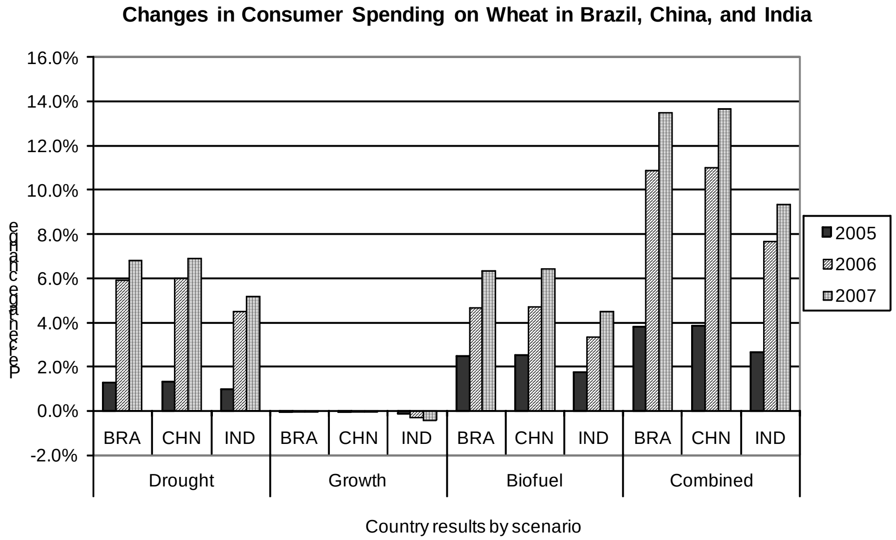
Annual changes in world prices for 12 commodities are presented for the four scenarios in Table 5. Time series results are graphed in Figure 1. When overall effects are considered (scenario 4), the largest impacts were on maize/corn prices, which more than double from 2004 to 2007. That commodity aside, world prices rose in the range of 10 to 20 percent over that period. Wheat and oilseed had the largest increases, with meat and dairy prices rising less.

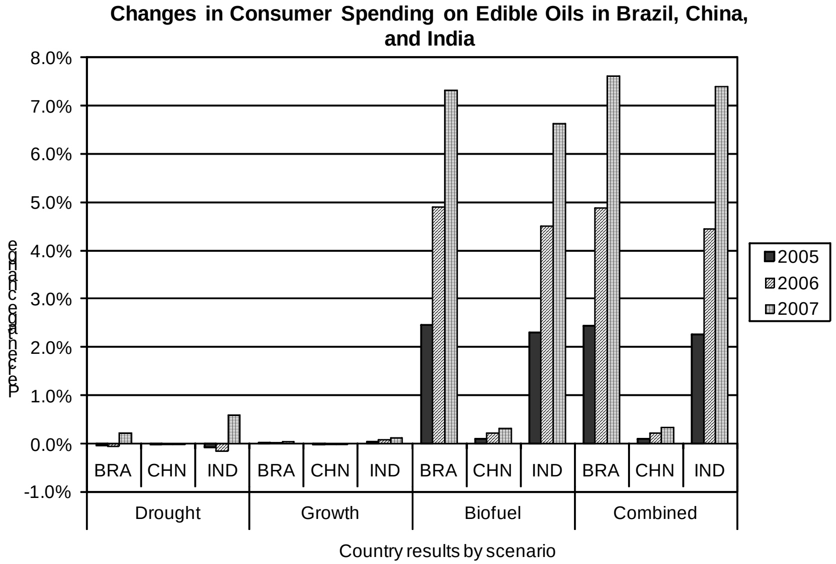
Comparing the combined results with the outcomes from the separate scenarios, the relative impacts of different factors can be assessed. The factor with the largest impact on prices varied by crop. Weather was the most impact factor for wheat prices, and contributed to rice and oilseed price changes. Income growth was most responsible for the price rises in beef and veal and sheepmeat as well as some dairy products. For maize/corn, sugar, and oilseeds, the main biofuels crops, the increased production of biofuels had the largest impact. The changes in those markets also flowed through to poultry and some dairy products. These results suggest that it may be simplistic to attribute the rise in food prices to a single cause; several factors are simultaneously affecting prices, and have different impacts on different commodities.

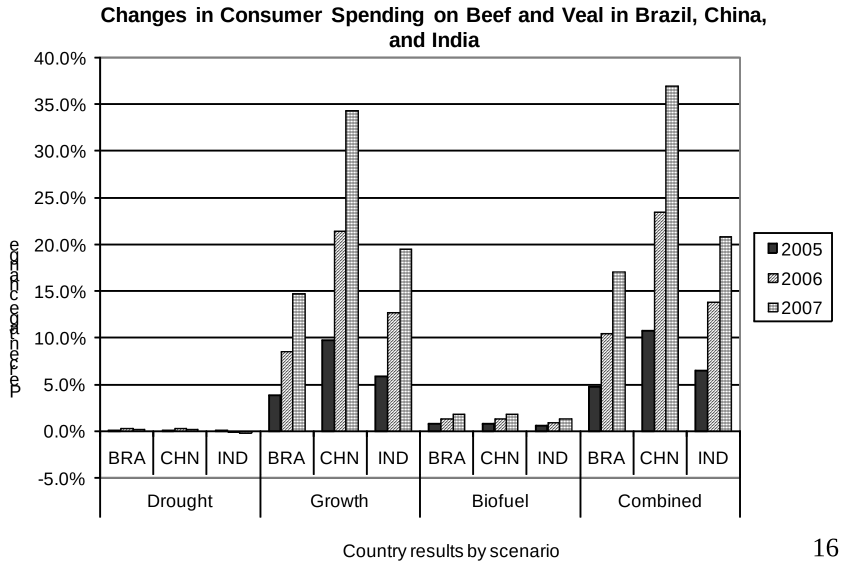
Table 5: Change in World Price (%)

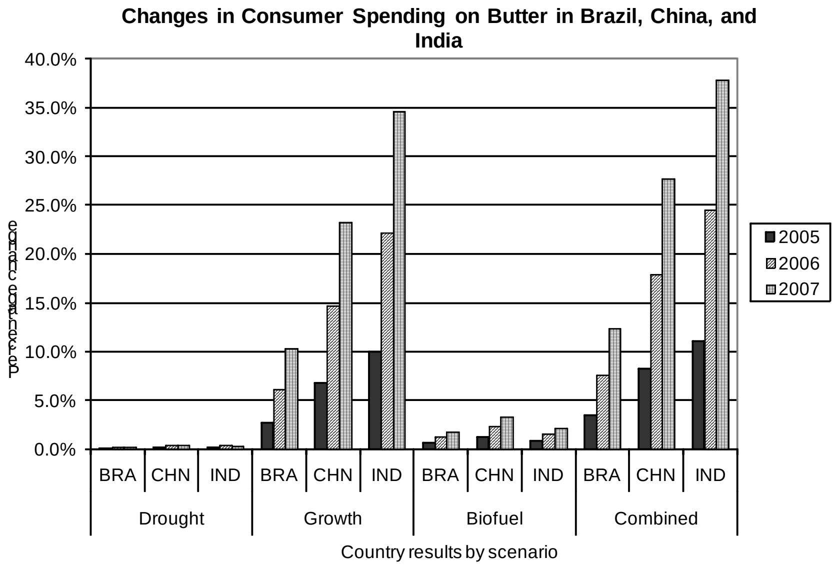
Year	Wheat	Maize/ corn	Rice	Sugar	Oil-seeds	Beef and veal	Sheep-meat	Poultry	Butter	Cheese	Milk powder, whole	Milk powder, skim
Scenario 1 – Weather impacts												
2005	1.7	4.5	0.1	0.0	-0.7	0.3	0.2	0.3	0.2	0.3	0.2	0.3
2006	7.6	10.0	0.5	0.1	-1.0	0.7	0.5	0.8	0.5	0.8	0.6	0.9
2007	8.8	-1.5	0.5	0.2	5.5	0.4	0.3	0.4	0.5	0.5	0.4	0.7
Scenario 2 – Growth												
2005	0.0	0.0	0.0	0.0	0.0	1.5	2.0	0.1	2.1	0.1	1.1	-0.2
2006	0.0	0.0	0.0	0.0	0.0	3.4	4.2	0.3	4.6	0.2	2.3	-0.6
2007	0.0	0.1	0.0	0.0	0.0	5.6	6.4	0.5	7.3	0.3	3.7	-1.1
Scenario 3 – Biofuels												
2005	3.2	39.8	-0.3	1.0	3.0	1.7	0.9	2.0	1.2	1.8	1.0	1.4
2006	6.0	75.7	-0.5	2.0	5.8	3.1	1.7	3.6	2.2	3.4	1.8	2.9
2007	8.1	108.1	-0.8	2.7	8.3	4.2	2.3	4.9	2.9	4.6	2.4	4.1
Scenario 4 – Combined												
2005	4.9	46.1	-0.2	1.0	2.3	3.6	3.1	2.5	3.5	2.2	2.3	1.5
2006	14.0	93.0	-0.1	2.1	4.8	7.4	6.4	4.8	7.4	4.4	4.7	3.2
2007	17.5	104.8	-0.4	2.8	14.2	10.5	9.1	5.8	10.8	5.4	6.5	3.6

Figure 1. Consumer Expenditure on Four Commodities by Scenario and Country









One should take care in interpreting these results. The modelling in this research examined three factors affecting world price, but others have also been discussed. There has been interest in the impacts of international financial markets on price volatility (FAO, 2008b), and short-term policy measures enacted as food prices have increased may have achieved domestic price support at the cost of international price rises or increased volatility. The second reason for caution is that the results did not replicate the actual price changes in this period. For example, the modelled increase in maize/corn prices was over twice the actual price rise of 47.0 percent (FAO, 2008a), while the 2.8 percent modelled price rise in sugar was much smaller that the observed 40.6 percent rise over the period. The difficulty then become determining whether the difference between the modelled and actual price changes are due to the model itself or changes in the markets that were not modelled.

In Table 6, the findings regarding consumption expenditures on four commodities in Brazil, China, and India are presented. Consumption expenditures generally rose for all commodities and countries in the 2004 to 2007 period. However, this rise was the result of changes in both price and quantity. By comparing Table 6 with Table 5, the relative price and quantity impacts are apparent. Consumption expenditure for scenario 1 (weather impacts) and scenario 3 (biofuel) increased less than the rise in price, so quantity consumed must have fallen. The same was true for wheat and oil in scenario 2 (growth). However, the expenditure on beef and veal and butter increased at a higher rate than prices did in scenario 2, which explicitly modelled changes in food expenditure from income growth. These increases were maintained in scenario 4, which examined all three factors, so that the total impact of weather, growth, and biofuels production was to increase beef and veal and butter consumption in Brazil, China, and India.

Table 6. Changes in Consumption Expenditure by Country and Commodity (percent)

		-- Wheat --			-- Beef and veal --		
Scenario	Country	2005	2006	2007	2005	2006	2007
Weather impacts	Brazil	1.3	5.9	6.8	0.1	0.3	0.2
	China	1.3	6.0	6.9	0.1	0.3	0.2
	India	1.0	4.5	5.2	0.0	-0.1	-0.2
Growth	Brazil	0.0	0.0	0.0	3.8	8.6	14.8
	China	0.0	0.0	0.0	9.7	21.4	34.3
	India	-0.1	-0.3	-0.4	5.9	12.8	19.5
Biofuel	Brazil	2.5	4.7	6.3	0.8	1.4	1.9
	China	2.5	4.7	6.4	0.8	1.4	1.8
	India	1.8	3.3	4.5	0.5	1.0	1.3
Combined	Brazil	3.8	10.9	13.5	4.7	10.5	17.1
	China	3.9	11.0	13.7	10.7	23.5	37.0
	India	2.6	7.7	9.4	6.5	13.8	20.9
		-- Oil --			-- Butter --		
Scenario	Country	2005	2006	2007	2005	2006	2007
Weather impacts	Brazil	0.0	-0.1	0.2	0.1	0.2	0.2
	China	0.0	0.0	0.0	0.1	0.4	0.4
	India	-0.1	-0.1	0.6	0.1	0.4	0.3
Growth	Brazil	0.0	0.0	0.0	2.7	6.1	10.3
	China	0.0	0.0	0.0	6.8	14.7	23.2
	India	0.0	0.1	0.1	10.0	22.2	34.6
Biofuel	Brazil	2.5	4.9	7.3	0.7	1.2	1.7
	China	0.1	0.2	0.3	1.3	2.3	3.3
	India	2.3	4.5	6.6	0.9	1.6	2.1
Combined	Brazil	2.4	4.9	7.6	3.5	7.6	12.4
	China	0.1	0.2	0.3	8.3	17.8	27.7
	India	2.3	4.4	7.4	11.1	24.5	37.9

As before, one should consider these results with caution. Several factors that might have influenced prices were not including in these model, with unknown effect. More importantly, the differences between the scenarios and commodities that explicitly accounted for the income elasticity of demand (livestock products in scenarios 2 and 4) and the other scenarios and commodities indicate the importance of this elasticity on model results and actual consumption. While weather events and biofuel production may increase prices, the net impact on highly populated and lower-income countries will depend on their own income growth and the income elasticity of demand for food.

5. Conclusion

This research firstly aimed at assessing the specific impacts of underlying factors behind the rise in world food prices. The research further aimed at investigating the impacts on consumption expenditures particularly in highly populated and lower-income countries such as China and India. Sequential simulations were performed for 2004 to 2007 using a partial equilibrium agricultural trade model. The simulations emphasized three factors affecting markets. On the supply side, the adverse impact of extreme weather events was investigated. On the demand side, the effects of rising biofuel production and per capita income growth were examined.

The factor with the largest impact on prices varied by crop. Wheat prices were most susceptible to the impacts of weather, while maize/corn, sugar, oilseeds, and poultry were most affected by the increased production of biofuels. The increased demand for higher-valued food products as a result of income growth created that largest price rises in beef and veal and sheepmeat as well as some dairy products. These results suggest that it may be simplistic to attribute the rise in food prices to a single cause, such as increased demand for biofuels; several factors are simultaneously affecting prices, and have different impacts on different commodities.

The results obtained and the caveats discussed above point to several possible directions for further modelling work to understand commodity prices. Two factors that could be examined are the impacts of international trading in agricultural commodities on price volatility, and the impact of governmental domestic food-security policies on international markets. The modelled results did not mimic the observed changes in international commodity prices over the period examined; accounting for these additional factors may improve the results. Another area that seems important in light of the findings is the impact of the elasticity of demand. The present research accounted for the income elasticity of demand as an exogenous shock to the model. Further model development may be able to make these changes endogenous.

The implication is that those concerned about food prices should avoid simplifying a complex situation. Food price rises in lower-income countries may be a short-run threat to food security, but the appropriate solution will depend on the commodity and the drivers of the price rise. Income growth, some of which will arise through higher agricultural revenues, may help improve food security, but it is also contributing to the observed price increases.

The results do suggest useful strategies for coping with environmental uncertainty. If nothing can be done in practice to avoid the production impacts of droughts or floods, which were modelled as exogenous shocks in this research, international trade appears to dampen the effects of those events on world commodity prices. Similarly, although not explicitly included in this modelling, the building of commodity stocks may provide a buffer again large price swings. More of both of these activities can be fostered through general economic growth.

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