Measuring competition between non food and food demand on world grain markets : Is biofuel production compatible with pressure for food production ?

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Abstract

The flow of agricultural products between countries is conditioned by several factors including domestic and trade policy tools for the main competing exporters countries, and macroeconomic variables (such as real income per capita, rate of population growth,etc). Important structural changes are occurring on world agricultural markets that will have an impact on the long term competitiveness of countries and regions. These changes include developments in biofuels production linked to policy incentives, and the rapid growth in income and population numbers in some developing countries (such as India and China). An important issue is to identify the factors that are going to modify the balance between the supply and demand for agricultural products in the long term. In this paper, we look the example of arable crops. These markets allow an interesting analysis since they are directly concerned with the evolution of biofuels. One important question is to measure the competition between food demand and non food demand. We use a partial equilibrium model that focuses on world arable crop markets, the World Econometric Modeling of Arable Crops. The aim of the model is to produce annual market projections over a medium-term perspective and to simulate the impact of alternative national and international agricultural policy reforms for the main arable crops.

The results of the simulations performed show that even if incentives to produce of biofuels have strong impacts on world markets, other factors such as changes in the assumptions of concerning the growth of emerging countries are also of great importance since the world cereal and oilseed markets as much are just by them.

Keywords - Modeling- Econometric - Partial equilibrium- - Land uses - biofuels

Introduction

The flow of agricultural products between countries is conditioned by several factors including domestic and trade policy tools for the main competing exporters countries, and macroeconomic variables (such as real income per capita, rate of population growth, etc). Important structural changes are occurring on world agricultural markets that will have an impact on the long term competitiveness of countries and regions. These changes include developments in biofuels production linked to policy incentives, and rapid growth in income and population numbers in some developing countries (such as India and China).

An important issue is to identify the factors that are going to modify the balance between the supply and demand for agricultural products in the long term. In this paper, we will take the example of arable crops. These markets allow an interesting analysis since they are directly concerned with the evolution of biofuels. One important question is thus to measure the competition between food demand and non food demand.

The recent launch of public schemes in favor of the production of biofuels in many countries (for instance in the United States, in the European Union and in China) is likely to have a profound impact on policy on the equilibriums of agricultural markets for commodities linked to biofuels. It is an acknowledged fact that biofuels have a positive effect in helping to reduce emissions of greenhouse gases. These plant-derived fuels represent new outlets for certain agricultural commodities. Although they are more expensive to produce than traditional fuels, there is considerable support from the authorities for the production of biofuels. However, the achievement of these goals, which represent a real breakthrough, will be no easy matter, and will require trade-offs to be made. On the basis of the sectors in place today, one vital requirement if this policy is to be effectively implemented, will be the management of competition in the food sector for the use of farmland.

The objective of this study is to evaluate the effect of these policies on the world markets. Furthermore, we will study the impacts of these policies and the consequences of changes in some developing countries. The contribution made by this research is that it takes into account not only the price effects caused by the impact of these policies promoting biofuels but also the effects on areas created by the farmland resource constraint (limited areas of farmland are available). To achieve these aims, we use a multi-market partial equilibrium model representing the main countries operating on arable crop markets. From a

methodological viewpoint, the challenge is to explicitly introduce into the modeling the constraint of land availability, so as to measure competition in the food sector.

We use a partial equilibrium model that focuses on world arable crop markets, the World Econometric Modeling of Arable Crops. The aim of the model is to produce annual market projections over a medium-term perspective and to simulate the impact of alternative national and international agricultural policy reforms for the main arable crops. The structure of the paper is as follows. In the next section, we introduce and briefly analyze the main features of the World Econometric Modeling of Arable Crops. Section three presents the simulation results. The final section concludes with a discussion of future extensions to this work.

The modeling structure

This section outlines the general structure and modeling approach used in the World Econometric Modeling of Arable Crop (WEMAC). Before presenting the behavioral equations of each regional sub-models[1], we first describe the general features of the model, the current country and commodity coverage.

Characteristics of the WEMAC model

The WEMAC model, or World Econometric Modelling of Arable Crops, is an econometric, partial equilibrium, multi-market model focusing on world cereal and oilseed markets[2]. The prospects for likely developments in world agricultural commodity markets are for the most part modelled on the basis of results provided by a limited number of international organisations such as the OECD (Organisation for Economic Co-operation and Development), the FAO (Food and Agricrop Organisation of the United Nations) and by American universities (FAPRI, Food and Agricultural Policy Research Institute). The use of these models by States and non-governmental organisations has an impact on multilateral bargaining in the agricultural sector. Given this high-stake context, the French government and professionals in the arable sector wished to strengthen France's own ability to make projections, and so lent its support to the INRA-run project to build the WEMAC model. This model has a double purpose: forecasting and simulation. The WEMAC model is a forecasting

[1] In the modeling, a country represents a state and a region refers to an aggregate of different countries.

[2] This project has been under development since 2001. It was commissioned jointly by the French Ministry of Agriculture and Pluriagri (a partnership created by French producers of arable crops and the Crédit Agricole bank), and is being run by INRA, Rennes (France).

tool which generates medium-term annual projections for world cereal and oilseed markets, assuming that agricultural policies remain unchanged. It can also be used to assess the respective roles of traditional operators and emerging countries on world agricultural markets.

The WEMAC model is also a simulation tool that can be used to simulate the effects of alternative policy scenarios on cereal and oilseed markets. These scenarios include alternative agricultural, domestic and trade policies, changes in agriculture and external conditions such macroeconomic shocks. The results of the simulation indicate the impact of these alternative scenarios on the equilibrium of world cereal and oilseed markets.

Specification details of the WEMAC model: The current country and commodity coverage

The whole model consists of a set of country or regional sub-models with linkages established across countries and commodities. The structure of each regional sub-model consists of the following behavioral equations: production (harvested area, yield), demand (food use, feed use, stocks), price linkages (prices transmission mechanism between domestic and world prices), trade flows (import and export equations). The behavioral equations are completed by a set of accounting identities to represent market balances. At the world level and for each commodity, a balanced situation between global imports and global exports is imposed; this constraint allows us to specify the world price. The country coverage includes all the major producing and consuming countries of arable crops: Argentina, Brazil, Canada, China, European Union (EU-25), India, United States, Ukraine, Russia and a 'North Africa and Middle East' block. Countries which are not explicitly modeled are included in an endogenous aggregated block, 'Rest of the world. The model is based on econometric estimates of behavioral equations. Most of the equations in the model are estimated using annual data from the period 1970-2001. The data comes from the USDA's PS&D database and EUROSTAT for the European Union. The structure of the WEMAC model and its characteristics are given in detail in the following text box.

Text box 1. Specification details of the WEMAC model

The WEMAC[3] model includes behavioural equations describing domestic supply, demand, stocks, prices linkages and trade flows, which define the general structure of the country sub-models.

Country coverage and commodities

The commodities studied are all arable crops (cereals and oilseeds). As regards cereals, we consider: soft wheat, durum wheat, maize, barley, rye, oats, millet, sorghum, triticale and rice. As regards oilseeds, we study: rapeseed, soybean and sunflower. "Commodity" coverage may be extended to other commodities such as high protein crops, so that specific national characteristics can be taken into account. The countries looked at in the model are the main producers or consumers of cereals and oilseeds. These are Argentina, Brazil, Canada, China, the United States, India, Russia, Ukraine, the European Union (25 member states), a "North Africa – Middle East" area and a "Rest of the World" area.

Data

The data used are annual historical data covering the years 1970-2001. Volume-related data come from the USDA's PS&D database and from EUROSTAT for the European Union. Price and agricultural policy data come from the Departments of Agriculture of the countries in question, from the USDA and the OECD. The macro-economic variables come from the FMI.

Domestic supply

The crop acreage depends on the different competing crops, the total crop acreage allocated to arable crops and vector of exogenous variables which could have an impact (these variables depend on the country and include such things as domestic policy variables). By and large, the traditional factors behind yield changes are weather conditions, technological innovation (generally introduced as a linear trend with a positive effect), and commodity price. Dummy variables[4] measure gain or loss of yield for a specific crop in specific years, owing in particular to exceptional weather conditions. They are used for years when there are peaks and troughs in yield indicating climate events. The area and yield equations are jointly estimated using the iterative Seemingly Unrelated Regression Method. Production in a country/region is determined as the product of estimated area harvested times yield equations.

Domestic demand

For cereals, feed and non-feed demands are estimated, while industrial demand is treated as exogenous. For oilseeds, we estimate the demand for oilseed crushing and feed demand for oilseed meal, while other types of demand are treated as exogenous. Non-feed demand depends on the market price for the crop and income. Feed demand depends on the production of different livestock species, on the price of the crop under consideration, and on the price of the other raw materials used in animal feed (cereal substitutes, other protein matters). Finally, the last component of demand is related to the stock level. The stock level generally depends on the market price and on the beginning stock (lagged value of the stock variable). This structure is modified to accommodate policy intervention, especially in the EU, United States and China. The intervention system in the EU is modelled in stocks equations with the intervention price of the considered commodity. In the United States, adjustments are included for cereals to account for government loan programs and stockholding policies. In China, various schemes to promote self-sufficiency in cereals have been implemented over the last two decades. Hence, we take these programs into account in the changes in Chinese stocks.

Price transmission

A single world price is assumed to exist for each of the commodities. Since producer and market domestic prices are different we have two types of transmission price equations to estimate. Except where these are set by government, domestic prices are linked to world prices via linkage equations including exchange rates.

Import and export equations

The WEMAC model distinguishes between imports and exports. Many barriers to trade remain in place and there has been an expansion in the relative importance of non-tariff barriers to trade e.g. tariff-rate quotas and preferential access agreements. The nature and operation of such measures varies between countries and in itself complicates the modelling of trade flows (Meilke, 1996). Imports mainly depend on the real income of the importing zone, on a price-competitiveness indicator (defined by the difference between the domestic and world prices), and on the customs duties applied to the crop. We distinguish imports by the import regime under which they enter. For countries applying tariff quotas, we do not estimate the total amount of imports, but the level of imports from which the tariff quota used has been subtracted. Hence, imports made under the Tariff Rate Quotas (TRQ) system are exogenous and equal to the scheduled TRQ. Exports depend on the foreign demand addressed to a country, on a price-competitiveness indicator, and on the unit amount of subsidies. A time trend is sometimes included in export equations to represent the entry of new competing countries. For the cereals exported as food aid, instead of considering total exports, we estimate total exports as the volume exported minus the level of food aid.

Closure of the model

For each country model, market clearing is obtained by selecting one behavioural variable as a residual variable. This means that one variable is not estimated but calculated as the residual to check the equilibrium on each regional market. The choice of the residual variable depends on policy and market characteristics relevant for the specific commodity. The market clearing condition that determines the world prices is implemented by forcing the sum of net trade across all countries in the model to zero. On the world market clearing is obtained by endogenous world price. Hence, after modelling each country, the net trade positions are summed across all countries. The clearing identity imposed is that the sum of all countries' net trade is equal to zero. This identity determines the world price of the corresponding commodity.

We use Newton's method to solve the world price[5].

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[3] http://www.rennes.inra.fr/wemac/

[4] A dummy variable attributes a value of 1 to a specific year or period, otherwise a value of 0.

[5] A main characteristic in the closure rule of the WEMAC model is that we do not make assumptions on a reference country as in other partial equilibrium models. For instance, in the FAPRI model, a large exporting

The model is characterized by a number of key features with respect to existing models, which should be highlighted from the start. First, the behavioral equations are estimated on the basis of historical data, rather than being calibrated. One key specificity is the econometric estimation of behavioural equations. One of the shortcomings linked to reference partial equilibrium models when forecasting changes in agricultural commodity markets is undoubtedly the "degree of subjectivity" involved in the adoption of behavioural equation parameters. These models are often called "empirical" models, meaning that the parameters either come from a review of available literature or are calibrated on what experts have said (van Tongeren and van Meijl, 2001). Secondly, as one aim of the WEMAC model is to provide quantitative evaluations of policy reforms, special attention is paid to modeling domestic and trade policy tools for the main producing countries, separating the effect of prices and that of other policy instruments. One of the major characteristics of current WEMAC modelling is that rather than being limited to an aggregate representation of the European Union as a whole, it actually provides information on each major European country, providing country-level estimates for France, Germany, Italy, Spain and the United-Kingdom.

Empirical analysis and Results of simulation

We have implemented two kinds of scenarios : the first one named “the non food demand scenario” and the second one called “the food demand scenario”. In the second scenario, we examine two points: the affect of a false appreciation of stocks in China and then the effect of a decrease of the economic growth in India.

Results of simulation are compared to the baseline. The baseline assumes a continuation of policies that are in place and policy changes that had been announced within existing programs in early 2005 (like the Farm Act of 2002 in the United States, and the 2003 CAP reform). Thus, the baseline projections assume trade policies as agreed in the Uruguay Round Agreement on Agriculture. The baseline offers an assessment of arable crop markets covering cereals and oilseeds over the period 2005 to 2015. The model generates projections over a ten year period with specific assumptions concerning key macro economic variables as well as agricultural and trade policies.

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country with minimal trade barriers is chosen as a residual supplier and in general, the residual supplier is the United States.

The baseline assumes a continuation of policies that are in place and policy changes that had been announced within existing programs in early 2005 (like the Farm Act of 2002 in the United States, and the 2003 CAP reform). Thus, the baseline projections assume trade policies as agreed in the Uruguay Round Agreement on Agriculture and exclude any possible modifications that may result from the current multilateral negotiations underway in the WTO under the Doha Development Agenda.

The baseline incorporates macroeconomic projections essentially obtained through FAPRI, or OECD or expert judgments. Concerning growth, Asian economies, the Latin America region and the CIS (Commonwealth of Independent States) are projected to grow at a high rate (7% annually for China). The growth rates of developed economies are presumed to be stable (between 2 and 3% annually for most of them). Most of the countries are expected to obtain price stability, with mild inflation and moderate inflation in the CIS. Inflation in Argentina and Brazil is presumed to stabilize at 7-8% annually. Currency movements against the U.S. dollar are expected to continue, including appreciation of OECD currencies and depreciation of most Latin American currencies. One key assumption is the change in the euro-dollar exchange rate; in WEMAC, the euro is presumed to be at a fixed rate of $1.28.

The baseline offers an assessment of arable crop markets covering cereals and oilseeds over the period 2005 to 2015.

Definition of the baseline: the example of the world maize market

The production of maize is expected to increase by an average annual growth rate of 1.3% between 2005 and 2015. For the United States, the world's main maize producer, the annual increase in maize production is expected to be relatively weak (+0.63%) especially compared to the growth in Argentine and Brazilian production (+2.65%).

The increase in the use of maize in livestock feed (the main outlet for maize) would explain the increase in total consumption. This increase is linked to changes in the structure of consumption: the high increase in consumption of meat and dairy products leads to a rapid rise in indirect demand for products used for animal feed, notably secondary cereals and especially oilseed meal (OECD, 2005). The annual growth in feed consumption is expected to be an average +1.6% over the period 2005-2015. This increase would mainly be due to the strong increase in the use of maize for feed in China (+2.3%).

As far as trading in maize is concerned, we can see two main changes. Firstly, China would become an importer from 2005. The second change would involve the United States; exports

from the United States, traditionally the world's leading maize exporter, would fall over the period 2005-2015, to the benefit of Argentina.

Maize exports from Argentina are expected to rise by more than 5.8 million tons between 2005 and 2015, to reach 19.5 million tons in 2015. Adjustments in market shares in favor of South American countries are linked to the assumption about the dollar-peso exchange rate. The Argentine currency should continue to weaken in relation to the dollar, leading to more competitive exports (OECD, 2005). The leveling off (and even decrease) of maize exports from the United States would be due to two points; firstly, the increase in the utilization of cereals for livestock feed and secondly, the development of non-feed/food demand.

The world maize price is expected to rise between 2005 and 2015, as a result of the strong increase in consumption in relation to production. Year on year variations would be relatively low. The world maize price is expected to reach $121.95/t in 2015.

- *Non food scenario*

The non food scenario corresponds to the implementation of the mandate of incorporation in the United States (284 million hectolitres of biofuels in 2012). Two alternatives are studied: in the first case (variant A), we suppose constant arable crops area and in the second (variant B), we suppose an increase in arable crops area of 3 million hectares.

(insert table 1)

On the American market, the support for the biofuels would increase the production of corn of about 3% in the first case and about 5% in the case of an increase in arable crops area. The increase in corn production arises from the rise in the harvested area: +2.7% in the variant A and +5.45% in the variant B. The corn consumption would increase of more than 8%: 8.13% in the variant A and 9.59% in the variant B. The corn consumption would increase more in the variant B than in the variant A because of the effect on domestic prices. In fact, the growth of corn price would be lower in the variant B (see below). Impacts on corn supply and demand would send back directly on trade. Corn exports would strongly decrease -21.65% in the first alternative and -13.62% in the second alternative.

(insert table 2)

The effects on domestic prices are the same than those on world prices. The increase in corn consumption would lead to a rise in corn price (+15.92% in the variant A and +9.15% in the variant B). Soft wheat and soybean domestic prices would increase in the first case due to the

competition between crops in the supply side. These impacts would be temperate in the second case.

(insert table 3)

The effects on the world markets would be a raising of prices of the corn (+16.87% in the first case and +9.70% in the second), a raising of prices of wheat of 4.60% in the first case and a reduction in this one of 1.18% in the second case. Indeed, in the first case, the increase in the production of corn would come from a rise of the corn area, this increase in area would be done with the detriment of the other products. In the second case, arable crops area increases, the increase in the corn area thus does not make with the detriment wheat area. Soybean world price would increase of 1.65% in the variant A and 0.88% in the variant B. As for the wheat, the rise in corn area in the first case would be done with the detriment of the other products. Furthermore effect on soybean meal world price would be strong: -7.78% in the variant A and -8.46% in the variant B. The reduction of this world price comes from the increase in the production of corn by-product. In fact, the increase in ethanol production would imply a rise in the production of corn by-products (corn gluten feed, corn gluten meal). The increase in the supply of these by-products would cause their prices to drop. As they are substitutes for oil meal, the fall in their prices would increase demand for them, and decrease the demand for oil meal. The result of the lower demand for oil meal would be a decrease in soybean meal and other protein meal prices.

- *Food scenario*

In the food scenario, we analyse two points: the effect of a decrease of the economic growth in India and then the effect of a false appreciation of stocks in China.

In the first point, we suppose that the growth in India would be lower than in the baseline (2.25 per annum instead of 5.5% in the baseline). We study the impacts of the food scenario on wheat market.

(insert table 4)

On the Indian market, wheat production would decrease of -0.69% in 2015, consumption would decline by -6.45% and the net import would be reduced by -62%. The net import would reach 3.5 million tons instead of 9 million tons forecast in the baseline.

(Insert table 5)

The deceleration of the growth would strongly decrease the Indian corn imports, thus involving a considerable effect on the world price. The food scenario shows that a deceleration of the growth in India would involve a fall in the world price of common wheat of 11%.

In addition, this scenario also shows the impact of an error of measure in China. We analyse results on corn market. We suppose an appreciation of the supply of corn in China: increase of 5%.

(Insert table 6)

(Insert table 7)

The appreciation of the offer of corn in China, translated here by an increase in the offer of corn of 5%, would involve a reduction in the corn imports of China. Corn net imports would reach 1.6 million tons in 2015 instead of 9 million tons in the baseline. Impacts on Chinese market would decrease corn world price of 5.15%.

Results of these different scenarios on the cereals world prices are summed up in this table.

(Insert table 8)

In the non food scenario, cereals world prices would increase of about +5% for wheat and +17% for corn. In the food scenario, soft wheat world price would decrease of -11% and corn world price would decline of -5%. Effects of food scenario could be as strong as those of non food scenario.

These results of simulations show that even if the incentives to the production of biofuels have strong impacts on the world markets, changes on the assumptions of growth of emergent countries, for example, are also of great importance since the world markets of the field crops are affected as much.

Table 1. U.S. maize market, comparison EPA scenario to the baseline (results in 2015).

(Thousand metric ton)	Baseline	EPA scenario Variant A	EPA scenario Variant B
Harvested area	26029	26738 (+2.72%)	27449 (+5.45%)
Production	260720	268542	275375

		(+3.00%)	(+5.62%)
Domestic use	215536	233066	236208
		(+8.13%)	(+9.59%)
Net export	44870	35155	38760
		(-21.65%)	(-13.62%)

Table 2. Effects on domestic prices (results in 2015).

(U.S.$/t)	Baseline	EPA scenario Variant A	EPA scenario Variant B
Corn	102.47	118.78	111.84
		(+15.92%)	(+9.15%)
Soft Wheat	143.44	150.02	141.76
		(+4.59%)	(-1.17%)
Soybean	256.51	260.49	258.63
		(+1.55%)	(+0.85%)

Table 3. Effects on cereals and oilseed world prices (results in 2015).

(U.S.$/t)	Baseline	EPA scenario Variant A	EPA scenario Variant B
Corn	121.95	142.53	133.78
		(+16.87%)	(+9.70%)
Soft Wheat	151.95	158.94	150.16
		(+4.60%)	(-1.18%)
Soybean	249.94	254.07	252.12
		(+1.65%)	(+0.88%)
Soybean meal	273.17	251.93	250.07
		(-7.78%)	(-8.46%)

Table 4. Food scenario in India: effects on wheat market in India (results in 2015).

(Thousand metric ton)	Baseline	Food scenario India
Production	89266	88647 (-0.69%)
Domestic use	98410	92063 (-6.45%)
Net import	9142	3479 (-61.94%)

Table 5. Food scenario in India: effects on cereals world price (results in 2015).

(U.S.$/t)	Baseline	Food scenario India
Soft Wheat	151.95	134.69 (-11.36%)
Corn	121.95	120.94 (-0.83%)
Soybean	249.94	249.84 (-0.04%)

Table 6. Food scenario in China: effects on corn market in China (results in 2015).

(Thousand metric ton)	Baseline	Food scenario China
Production	152866	160509 (+5.00%)
Domestic use	161491	161748 (+0.16%)
Net import	9035	1650 (-81.74%)

Table 7. Food scenario in China: effects on cereals world price (results in 2015).

(U.S.$/t)	Baseline	Food scenario China
Soft Wheat	151.95	149.69 (-1.48%)
Corn	121.95	115.67 (-5.15%)
Soybean	249.94	249.74 (-0.08%)

Table 8. Summary of effects on cereals world prices (results in 2015).

% from baseline	Soft wheat	Corn
Non food scenario in the United States (variant A)	+4.60%	+16.87%
Food scenario in India	-11.36%	--
Food scenario in China	--	-5.15%

Summary and Conclusions

An important issue is to identify the factors that are going to modify the balance between the supply and demand for agricultural products in the long term. In this paper, we look the example of arable crops. These markets allow an interesting analysis since they are directly concerned with the evolution of biofuels. One important question is to measure the competition between food demand and non food demand. We use a partial equilibrium model that focuses on world arable crop markets, the World Econometric Modeling of Arable Crops.

The results of the simulations performed show that even if incentives to produce of biofuels have strong impacts on world markets, other factors such as changes in the assumptions of concerning the growth of emerging countries are also of great importance since the world cereal and oilseed markets as much are just by them.

We implement two kinds of scenarios : the first one named “the non food demand scenario” and the second one called “the food demand scenario”. In the second scenario, we examine

two points : the effect of an erroneous assessment of stocks in China and then the impact of an fall in economic growth in India.

We compare the results of the simulation to the baseline. The baseline assumes a continuation of policies that are in place and policy changes that had been announced within existing programs in early 2005 (like the Farm Act of 2002 in the United States, and the 2003 CAP reform). Thus, the baseline projections assume trade policies as agreed in the Uruguay Round Agreement on Agriculture. The baseline offers an assessment of arable crop markets covering cereals and oilseeds over the period 2005 to 2015.

The nonfood scenario corresponds to the implementation of the mandate of incorporation in the United States (284 million hectolitres of biofuels in 2012). Two alternatives are studied: in the first case, we suppose a constant arable crop area and in the second, we suppose a 3 million hectare an increase in the arable crops area. On the American market, support for biofuels would increase the production of corn by about 3% in the first case and by about 5% in the case of an increase in the arable crop area. Corn consumption would increase by more than 8% (between 8 and 10% depending on the two alternatives). Corn exports would decrease sharply by-19% in the first alternative and by -11% in the second alternative. The effects on world markets would be a rise in the prices of corn (+16% in the first case and +10% in the second), a rise in the prices of corn of 3% in the first case and a decrease of 1% in the second case. In the first case, increase in corn production would be the result of the increase in the corn area which would be achieved at the expense of other crops. In the second case, the arable crop area increases and so the increase in the corn makes no difference to the wheat area.

The food scenario shows that a deceleration of the growth in India (2.25 per annum instead of 5.5%) would involve a fall in the world price of common wheat of 11%. Indeed the deceleration of the growth would strongly decrease the Indian corn imports, thus involving a considerable effect on the world price. In addition, this scenario also shows that an error of appreciation of the offer of corn in China, translated here by an increase in the offer of corn of 5%, would involve a reduction in the corn imports of China and a fall in the world price of corn of more than 5%.

These results of simulations show that even if the incentives to the production of biofuels have strong impacts on the world markets, changes on the assumptions of growth of emergent

countries, for example, are also of great importance since the world markets of the field crops are affected as much.

Extending the analysis, it would be worthwhile examining the possible consequences of the existence of a world ethanol market, due for example to the high export potential of Brazil, which is the world's leading producer and whose production costs are considerably lower than those of the United States. A natural extension would be to model the world market for ethanol by modeling the role of Brazil. Because of the land constraint in the United States, any increase in world production will come from Brazil. Brazil is the world's leading ethanol producer, distilling nearly 4 billion gallons in 2004 and its exports are increasing sharply. The Brazilian government launched its National Fuel Alcohol Program in the mid-1970s, and by 1980 ethanol use had overtaken gasoline. Since price liberalization in 1999, ethanol prices have remained a third lower than gasoline. Ethanol is produced from sugar cane in Brazil and the cost of transformation (per liter) is half the cost of transformation from maize. Hence ethanol exports from Brazil towards the United States would become more attractive than ethanol production in US industries. Brazil's future in the U.S. ethanol market would depend on infrastructure developments, petroleum prices, and the price of sugar versus maize.

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