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Impact assessment of global and national biofuels developments on agriculture in Pakistan

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HIGHLIGHTS

- ▶ Three scenarios of increased biofuels use are modeled using GTAP model.
- ▶ Impact on prices, production, and trade of agricultural commodities for Pakistan are presented.
- ▶ Expansion in biofuels will increase prices of most of agricultural commodities in Pakistan.
- ▶ Production of feedstock crops (especially sugarcane) will increase considerably.
- ▶ Overall trade balance for agricultural commodities will worsen due to Pakistan's biofuels program.

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ABSTRACT

This research uses GTAP model to assess the expected future effects of national and global biofuels policies on agriculture markets and food prices in Pakistan. Our results show that by 2020, global mandates on biofuels will significantly affect the prices, production and trade of major feedstock crops such as sugarcane, maize, soybean and rapeseed, especially in the USA, Brazil and EU. Global biofuels developments are projected to increase the prices of maize, rapeseed, soybean, and sugarcane in Pakistan. Pakistan will benefit from improved trade balance in agriculture under the global-only scenario. Under Pakistan plus three-producer's biofuels scenario, the price and production of sugarcane in Pakistan will increase substantially. Under this scenario, the country will face considerable loss in agricultural trade. Consequently, food-security of net-buyers may be threatened. The income of feedstock farmers will increase. Higher crude oil prices will strongly influence commodity markets via increased production of biofuels and agricultural production costs.

1. Introduction

Biofuel is a type of fuel whose energy is derived from biological carbon fixation. Biofuels include fuels derived from biomass conversion, as well as solid biomass, liquid fuels and various biogases [1]. Production of liquid biofuels has increased five-fold over the last two decades due to policy interventions and changing relative energy prices [2]. The increasing production of biofuels is triggered mainly to gain energy security by decreasing dependence on import of fast-depleting fossil fuels and saving considerable amounts of foreign exchange; to mitigate the global warming emissions by reducing the use of fossil fuels; and to improve the agricultural development by offering better prices and new jobs [3].

While many developed and few developing countries are setting up ambitious targets to achieve their national biofuels mandates, the effectiveness of biofuels to produce the desired results is strongly debated in recent literature. There are studies suggesting that rather than decreasing carbon dioxide and other greenhouse gas emissions, biofuels actually increase them [4,5]. More important are the spillover negative effects on food security of millions of poor in developing countries, who depend on cereals as their major food intake. Many researchers have found a positive relationship between the increased food cost and the recent surge in demand to use crops as fuel [6–9].

Other factors have also impinged on food supplies and prices, however, most experts see the biofuels demand as a substantial contributor, and one that exacerbates any other factor on food costs. With 800 million people at risk for hunger and malnutrition, the consequences are far more severe in developing nations than they are in developed nations. [10] World Bank President Robert Zoellick has acknowledged that "biofuels is no doubt a significant contributor" to high food costs, adding that "it is clearly the case that programs in Europe and the United States that have increased

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biofuel production have contributed to the added demand for food". Moreover, this is occurring only when a small fraction of biofuels mandates have been realised. The US is only one-quarter of the way toward the 36 billion gallon requirement by 2022 included in latest big energy bill. The European Union also has plans to increase its biodiesel use, though it is now reconsidering this policy.

On the other hand, surplus-subsidised production has been creating unbalances in global agricultural markets, depressing international prices and dislocating agricultural production in low-income countries [11]. The incomes of farm households, frequently one of the poorest groups in low-income countries, may be increased by higher commodity prices [12]. This makes the trade-off between fuel and food a complex policy issue that needs very careful research encompassing all the related factors and stakeholders. Only a comprehensive study would provide a guideline on how the world (and individual countries) should proceed with their biofuel plans.

We hypothesise that Pakistan' agriculture-based economy can also experience ripple effects of increased demand of agriculture products by biofuels from national and international markets. It should be noted that Pakistan's economy has been growing at a steady rate during last 20 years. This growth has resulted in remarkable increase in energy demand, thus putting huge pressure on country's limited energy resources [13]. To cope with increasing energy demand, Pakistan is also starting a biofuels blending program. The government has approved a policy to achieve a minimum of 5% by volume share of biodiesel in the total petroleum diesel consumption by 2015. And gradually take it to 10% by 2025 [14]. Whether Pakistan can achieve the targeted objectives of the biofuels policy, i.e. reducing dependence on imported fossil fuels and environmental improvements is open to question. There are even more crucial issues related to the expansion of biofuels like: what would be the choice of feedstock (oilseeds crops for biodiesel or sugarcane for ethanol)? How would the increased demand affect production and prices of feedstock crops and other related agricultural commodities? To answer above questions a serious economic analysis is needed.

Many studies have analysed the impacts of biofuels developments on emerging and transition economies, e.g. [15,16]. Yet no such effort has been made for Pakistan. This is the first quantitative study to understand the effects of national and global biofuels developments on agriculture and the rest of economy in Pakistan. We aim to assess the direction and magnitude of impact of expected growth in biofuels-related demand for agricultural products on agricultural production, trade and food prices. In relation to Pakistan this is carried out through quantitative assessment of different market scenarios based on the use of GTAP model. The results would help to shape future policies on choosing the best available options, which ensure economical and socially sustainable development of biofuels in the country.

The paper is divided into five sections. Following the introduction, Section 2 outlines the model, data and methods used in the study. Section 3 elaborates the scenarios used to assess the impacts of biofuels development on Pakistan. Section 4 presents the effects of these scenarios. In Section 5 the paper concludes with some brief remarks.

2. Data, model and scenarios

This study covers only first generation ethanol produced from maize (ethanol1), sugarcane, and sugar beet (ethanol2); and biodiesel produced from oilseeds crops like soybean, rapeseed, and sunflower (biodiesel). Our model is based on the data in 2004, so we would focus on the biofuels production and trade trends in that year. Here, the US is the largest producer of ethanol (in terms of value) valuing at US$ 5974.2 million (Table 1). Brazil, with US$ 3669.9 million, is the second biggest producer of ethanol in the world. Brazil is also the single largest producer of ethanol from sugarcane. Other major producers of ethanol are China, India, Russia, EU27, South Africa, and Canada. European Union (EU27) is the world's top biodiesel producer at US$ 992 million, mostly from rapeseed. In 2004, USA is the only other biodiesel producers with sizable production at US$ 46 million.

Pakistan, the focus of this study, produced about 33 million gallons of ethanol worth over US$ 55 million in 2004. Almost all of this ethanol was produced from molasses, which in turn is a by-product of sugar production from sugarcane and is synthesised in the distilleries attached with sugar mills.

In 2004, Pakistan exported US$ 37 million worth of ethanol, mostly to EU countries. Notice that in our model we assumed no international trade in biodiesel, given that there are only few countries producing biodiesel, which is assumed to be domestically consumed.

Moreover, we have used GTAP model to perform recursive-dynamic simulations. In these simulations, the total time, 2006–2020, is divided into three parts. The multi-period simulation results are computed one-period-at-a-time, using the data from the previous period as base data for the next period. This in turn is done by dividing the shocks into appropriate sub-shocks for each period. Such a method has been popularly adopted by many other studies, e.g. [17,18].

Production structure of biofuels is very important for the forecasting model. For each type of biofuel, specific plant-level cost-of-production-models were used. Our analysis for ethanol1 is based on the work by Tiffany and Eidman [19]. Information from [20–22] was used for ethanol2. For biodiesel, information from [23] was used.

We used GTAP, a multi-region, multi-sector, computable general equilibrium model, with perfect competition and constant returns to scale, to capture the implications of expected biofuels developments both on national and international levels. The GTAP model is a comparative static model providing powerful insights into the underlying data and mechanisms of economic change resulting from the development of biofuels and other trade policy changes. For this study, we extended the latest GTAP model and database (version 7) to include biofuels sector for Pakistan,

Table 1
Biofuels production by type in 2004 (US$ millions).[a]

	Countries	Ethanol1[b]	Ethanol2[c]	Biodiesel	Total
1	Australia	0	55.8	2.6	58.4
2	China	1629.2	0	2.6	1631.8
3	Japan	1.5	0	0	1.5
4	Korea	1.5	0	2.6	4.1
5	Indonesia	0	74.4	0	74.4
6	Malaysia	1.0	0	0	1.0
7	Philippines	0	37.2	0	37.2
8	India	0	780.8	0	780.8
9	Pakistan	0	55.8	0	55.8
10	Canada	103.1	0	5.2	108.3
11	USA	5974.2	0	46.6	6020.8
12	Argentina	0	71.0	5.2	76.2
13	Brazil	0	3669.9	0	6741.4
14	EU27	305.9	0	992.0	1297.9
15	South Africa	0	185.9	0	185.9
16	Russia	334.6	0	0	334.6
17	ROW	655.7	682.8	53.3	1675.7
	Total	9004.6	5613.4	1110.1	19225.8

Source: assimilated by author from various sources such as: IEA, RFA outlook reports, and GAIN reports by USDA.
[a] Using 2004 price US$ 1.69/gallon.
[b] Produced from maize as feedstock.
[c] Sugarcane feedstock.

covering major biofuels producers with special focus on Pakistan. We refer to the extended version of the model as GTAP-PBIO (GTAP model incorporating Pakistan's biofuels sector).

For developing a reliable database for GTAP-PBIO, the key players in the field of global biofuels developments were carefully examined in the light of existing data and literature. Then the original 113 countries/region of GTAP were aggregated down to 17 regions of strategic importance to the research objectives. These countries/regions are selected because one/more of the following reasons. They are either; major producers/consumers of biofuels; major exporters/importers of biofuels; and/or major trade partners with Pakistan in 2004. As mentioned earlier, version 7 of GTAP database contains 57 sectors, however not all of these sectors are important to this study. Therefore, to develop the starting point for incorporating biofuels sector into the database, these sectors were aggregated into 28 sectors. To be used as the feedstock, two original GTAP sectors were split into four new sectors. Specifically, using FAO, production, price and trade data, other coarse grain (ogr) was split into maize and othgro, while other oilseeds (osd) were split into soybean and othosd.[1]

We also introduced some structural changes into the standard GTAP model for a better representation of the emergence of biofuels production. Particularly, we introduced energy-capital substitution relationships that are described in the GTAP-E model [24]. We based most of the changes to GTAP model on Yang et al. [16], for instance assumption on substitution between biofuels and petroleum products, elasticity of substitution between crude oil and biofuels, allocation of agricultural land in post biofuels era.

3. Development of scenarios

After identifying the critical factors relating to development of biofuels in Pakistan and around the world, we formulated various scenarios to capture the possible effects during 2006–2020. Here, we first ran a simulation based on 2004 data to produce the database which outlines world economy in 2006. Notice that these scenarios should not be taken as market forecasts, rather as plausible projections of expansion in biofuels. The projected implications of biofuels developments, especially at national level in Pakistan, will offer useful insight into developing new policy suggestions.

A total of four types of scenarios were developed to understand the possible effects of biofuels on Pakistan. This included a reference scenario, two policy scenarios and a market scenario. The reference scenario presents the world markets in 2020, where biofuels production is set to remain at 2006 level. The other three scenarios were formulated for simulating the impacts of future developments in biofuels on Pakistan in terms of agricultural production, prices and trade. These scenarios would reflect the usage of food and feed crops as feedstock for ethanol and biodiesel production to displace liquid fuels in transport during the study period. In the light of mandates and related policies of USA, Brazil, EU and Pakistan; one market-scenario and two policy scenarios were developed, which are referred to as "alternative scenarios." For each of these alternative scenarios there is a respective reference scenario, holding all the biofuels production at 2006 level, while projecting other macro level changes in the model. Market scenario is designed to see how much of biofuels are produced under very conducive market conditions, i.e. without any policy bindings. The policy scenarios are designed to achieve the minimum level of targets of biofuel production in each country, by providing subsidies to biofuel sectors. The following sections explain each scenario in more details.

[1] Details on these aggregations can be obtained from authors, upon request.

3.1. Reference scenario (P0)

The biofuels production is set to remain at 2006 level in reference scenarios. The idea is to forecast the developments in global economy in the absence of biofuels and then compare it with the alternative scenarios. In practice, this is achieved by swapping the output ethanol *(qo)* in all regions (*r*) with the output tax/subsidy in respective region, i.e. *to* (*i*, *r*). In developing corresponding reference scenario for the market (M1) scenario, the supply price of crude oil is set to increase to US$ 142/barrel in 2020, which is a level achieved in 2008. Although the price can literally be set at any other level, but we chose this price level as a maximum possible price of crude oil in 2020, which was achieved in the recent past.

3.2. Policy scenario (P1)

Policy scenario (P1) is designed to reflect the effects of biofuel production according to country-specific targets of USA, Brazil and EU. Here the model is designed to produce at least the amount of biofuels required to meet targets of each of these countries. It should be noted that the targets are the minimum levels of biofuel to be produced for each country, making it a policy-binding scenario. The government subsidy to biofuels sector is set to increase to a level where it can support the production of targeted values of biofuels. This subsidy is assumed to be paid to producers in the model and is greatly affected by petroleum price and the substitutability between biofuels and petroleum. More specifically, the higher the petroleum price and the value of substitution elasticity between biofuels and fossil fuels the lower the amount of subsidy needed to support the mandated biofuels production in each country.

After reviewing current biofuel production levels and future mandates of USA, Brazil, and the EU, separate targets were set for ethanol and biodiesel for each of these countries (see Table 2). In particular, for a period between 2006 and 2020, ethanol production for Brazil is set to increase by 220.7%, 210.4% for USA and 1354.7% for the EU. Only the EU and USA policies have set requirements for considerable future production of biodiesel as transport fuel. Therefore the biodiesel production for the EU is set to increase by about 825%, coming mostly from rapeseed. The US biodiesel is formulated to increase by 725%, compared to the 2006 level.

In addition, crude oil price is exogenously specified only in the baseline scenario – where it is kept to increase by 5% by 2020,

Table 2
Biofuels production used for development of scenarios.

Biofuel type/ country	Base year	Under various scenarios in 2020		
	2006[a]	P0 scenario[b]	P1 scenario[c]	P2 scenario[d]
Ethanol (million tons)				
Brazil	13.5	13.5	43.2	43.2
EU27	1.4	1.4	21.0	21.0
USA	15.8	15.8	117.8	117.8
Pakistan	0.2	0.2	0.2	4.3
Diesel (million tons)				
EU27	5.0	5.0	46.4	46.4
USA	0.8	0.8	6.9	6.9

Source: own calculations based on production data and future mandates of each country/region.
[a] Simulations start from the base year.
[b] No country increases biofuels beyond its 2006 level.
[c] Only three producers (USA + EU + Brazil) produce biofuels to meet their policy requirements.
[d] Three producers + Pakistan produce biofuels to meet their policy requirements.

according to the projection by IEA [25]. In the policy scenarios, the technology calibrated from P0 scenario is used to reflect crude oil price trend in 2020. The value of substitution elasticity between fossil fuels and biofuels is a very critical factor that will link the food prices to underlying crude oil prices. This value is set to 3.0 in this scenario.[2]

3.3. Policy scenario-II (P2)

This scenario is essentially same as P1, except that it includes ethanol blending mandate of Pakistan as well. This study assumes a 10% blending requirement by 2020 to capture the effects of maximum developments of biofuels production and use in transport industry. Pakistan does not have the infrastructure and policy environment necessary for implementing blending requirements for biofuels. Therefore, the 10% target, set by Pakistan's biofuel sector, may seem very ambitious if it is to be achieved within 14 years. As shown in Table 2, in order to meet this requirement, Pakistan needs to increase its ethanol production from 0.2 million tons to 4.3 million tons, which in itself is a huge change.

3.4. Market scenario (M1)

In our simulations, we have also considered the possibility of biofuels production under most favourable market conditions. The industry works under pure-profit motives rather than obligated by mandatory policy targets. In this scenario both crude oil price and substitution elasticity are set to high values, so that the three-producers and Pakistan can produce as much biofuels as are possible under these conditions, without any policy bindings.

Higher value of substitution parameter means it is easier for the motorists to switch between traditional fuels and biofuels. There is no empirical research (that we know of) that estimates the substitutability between biofuels and fossil fuels. The lower estimate of the elasticity of substitution is based on a historical simulation between 2001 and 2006 that is reported in Hertel et al. [24]. In their study, the calibrated elasticities of substitution between biofuels and fossil fuels in the USA, EU and Brazil are between 1.0 and 3.0. Intuitively, these levels of elasticities imply that there is little substitutability between biofuels and fossil fuel. However, since these estimates are based on data from a period of time when biofuels were in their infancy. Also, the infrastructure to allow cars to use either type of fuels was underdeveloped. We, therefore, believe that the substitution of biofuels and fossil fuels in 2020 would not be the same as in 2000. In Brazil today, for example, drivers act in a way in which the substitutability of biofuels and fossil fuels is very high. When drivers pull into a gas station to add fuel to their vehicles, they calculate the price of gasoline relative to ethanol. If the price of ethanol is less than three quarters of gasoline price, many drivers fill up with ethanol. It is believed that if efforts are made by governments to expand infrastructures and encourage the adoption of flex fuel vehicles (in the same way Brazil did during the 1980s), the same high degree of substitutability could characterise the rest of the world in the future. Due to this possibility in the future, we set 20 as the value for the elasticity of substitution in this scenario.

Moreover, in this scenario, the petroleum price is set to increase to US$ 142/barrel, the level achieved in 2008. Hertel et al. [24] have discussed that at a high petroleum price, the biofuels targets would become non-binding and the industry would rather develop based on profitable nature of biofuels production.

[2] Hertel et al. [24] have set this parameter at 3.0 for the USA. Assuming that the technology will improve so much as to make fossil fuels and biofuels more easily substitutable in coming year, we have assumed the default value of 3.0 for all the regions.

4. Results and discussion

Before moving to the main analysis of simulation results, it is imperative to briefly describe the level and share of GDP at factor costs, which will help the reader to have a clearer idea of direction and depth of impacts of biofuels on Pakistan. In 2004, agriculture, manufacturing and services sectors contributed 22.4%, 18.3% and 51.3%, respectively, to the gross domestic product of Pakistan (at constant factor price). This shows that agriculture, the focus of this study, is the second major contributor to national GDP.[3] The resources are expected to move towards the sectors of the economy which become more attractive due to higher prices.

In P1 scenario, we have major biofuels producers implementing biofuels mandates. These are also the major producers of agricultural products. This would drive up agricultural prices globally. In response to this price change, we should see shifting of resources towards agriculture in Pakistan, as well. Particularly, it is highly likely that unskilled labour and capital will shift from industry and services towards agriculture. Under P2, in addition to P1 countries Pakistan is also imposing its own mandate. This should divert even more resources into agriculture sector as a whole. There would be some major reallocations within agriculture, of course. We expect further increase in resource shift towards production of feedstock crops. Finally, we have the market scenario where global crude oil prices increase rapidly and the substitution elasticity between traditional fuels and biofuels is set to a very high value. We expect that agriculture, especially feedstock crops would attract huge resources from other sectors.

In the following, we present the detailed impacts of the three scenarios on Pakistan in terms of changes in prices, production and trade of agricultural commodities.

4.1. Impacts on prices of agricultural commodities in Pakistan

Increase in biofuels production will result in higher feedstock prices. The price hike will, in turn, translate into; (a) increased net returns for the feedstock producers and (b) additional burden on the net buyers of these commodities. The food CPI will increase especially under P2 and M1 scenarios. This effect will be different in different regions of the country due to variations in the share of food expenditures in total household income. Higher crop prices will also affect the household labour income (skilled and unskilled) in agriculture. Regional income disparities will also be affected due to differential increase in farmers' incomes, who cultivate different crops.

Under P1 scenario, the prices of several agricultural commodities will have strong impacts in Pakistan. Here, Pakistan will not expand its biofuels production beyond 2006-level. Expansion in biofuels production in USA, EU, and Brazil, however, will increase demand for maize, rapeseed and sugarcane in these countries, respectively. This increase in demand will translate into higher prices of maize, rapeseed and sugarcane in USA, EU and Brazil. These changes in prices are also transmitted to Pakistan via international markets. The prices of agricultural commodities in Pakistan will increase in the range of 0.9–19.0% (Table 3, column 1). Apart from rapeseed, the prices of most of the other agricultural commodities exhibit minimal changes in Pakistan.

On the other hand, domestic prices go up much more under P2 and price rises are no longer confined to a few sectors (Table 3, column 2). Naturally, the prices of feedstock crops and related commodities will show the sharpest increase. Strong demand for sugarcane by ethanol industry will result in tremendous increase

[3] Pakistan, Government of Economic survey of Pakistan 2004–2005. Economic Adviser's Wing, Finance Division, Islamabad; 2005.

Table 3
Effects of global scenarios on prices of agricultural commodities and related industries in Pakistan; compared with the reference scenario (%) in 2020.

Commodity	P1 scenario[a]	P2 scenario[b]	M1 scenario[c]
Rice	1.5	32.1	17.9
Wheat	1.5	10.5	24.9
Maize	9.2	13.5	42.2
Other grains	0.9	13.8	30.9
Vegetable and fruits	1.0	41.0	55.0
Soybean	5.6	10.7	31.3
Other oilseeds crops	19.0	4.7	94.7
Other crops nec.	1.8	6.3	8.5
Milk and dairy products	0.5	20.3	38.1
Meat products	0.2	8.2	15.8
Livestock	0.7	28.1	66.9
Sugarcane	3.8	146.6	426.8
Sugar	1.5	75.2	175.7
processed food	1.9	5.9	27.4

Source: simulation results of the study.
[a] Only three producers (USA + EU + Brazil) produce biofuels to meet their policy requirements.
[b] Three producers + Pakistan produce biofuels to meet their policy requirements.
[c] Three producers + Pakistan produce biofuels under high oil price and high substitution elasticity between fossil fuels and biofuels.

(146.6%) in sugarcane price as compared to reference scenario. As a direct result of high sugarcane price, the sugar price will increase by staggering 75%. At the same time, prices of those commodities that have high mobility of land use by sugarcane will also increase significantly. When compared with P1 scenario, the prices of other (non-feedstock) commodities undergo much higher increase due to shifting of more resources towards sugarcane.

Interestingly, when compared to P1, the biofuels developments in Pakistan-only scenario will have a much higher impact on agricultural prices. For example, the prices of rice, vegetable and fruits, milk and dairy products and livestock increase by a net of 30.6%, 40%, 19.8% and 27.4%, respectively in 2020 (the difference between columns 2 and 1). The effects in terms of relative changes, the change in price under P2 divided by the corresponding change under P1, are also quite large under P2. Moreover, the price of rapeseeds (other oilseeds crops) rise comparatively less (4.7%) under P2 scenario than under P1 scenario (19%), mainly because this is a minor crop in Pakistan and is not much affected by resource shifting towards sugarcane production. Under P2 scenario, increased fodder and feed costs also cause the prices of milk and livestock to increase significantly.

In contrast to P1, the market (M1) scenario will have a huge impact on all the agricultural commodity prices in Pakistan, in 2020. The supply price of sugarcane, the feedstock crop for ethanol in Pakistan, will increase by staggering 426.8% compared to reference case (Table 3, column 3). Again, the price of sugar is directly affected by increased sugarcane price and goes up by almost 176%. The increase in price of sugarcane will attract more resources from other competing crops, thus causing their prices to rise as well. The prices of rapeseed (other oilseeds crops) and maize will rise by 94.7% and 42.2%, mainly because of their increased international demand in EU and USA.

4.2. Impacts on production of agricultural commodities in Pakistan

Expansion in biofuels production will bring major sectoral changes in Pakistan. The production of most demanded (feedstock) crops will rise sharply. In particular, the biofuels developments in three major producers (US, EU and Brazil) will significantly change the production structure of agricultural commodities in Pakistan. Mostly the effect would be concentrated on the feedstock crops via price changes. As a result of biofuels developments in the three major producing countries in 2020, the production of maize, rapeseed (other oilseeds crops), soybean and sugarcane will rise by 5.2%, 9%, 2.7% and 1.6%, respectively. The case of other oilseeds crops is of particular interest. Pakistan imports large quantities of edible oils for its domestic use as food. However, due to increased use in EU as feedstock, Pakistan will see a shift towards more domestic production of oilseeds crops. Production of all other agricultural commodities will change slightly under P1 scenario.

The expansion of biofuels in Pakistan, under P2, will have even more significant impacts on domestic production of agricultural commodities. Obviously, the production of sugarcane will rise by the greatest margin (27.6%) due to its direct use as feedstock for ethanol production. According to our simulations, rice and sugar are the two major agriculture based commodities that will be negatively affected by diversion of resources towards sugarcane for ethanol production. Here, the production of rice decreases by 19.75%, mainly because rice in Pakistan is a major crop and has very high mobility of land usage with sugarcane. The production of sugar will decrease by 20.9%, mainly due to diversion of sugarcane from sugar production towards ethanol production. Output of most of the other agricultural commodities will decrease in P2 scenario compared with P1 scenario (Table 4, columns 1 and 2).

The impact of biofuels boom under market (M1) scenario will be very striking on production of agricultural commodities in Pakistan. The strong expansion in ethanol production in Pakistan will increase the share of sugarcane used for ethanol from around 2% (of the total production) in reference scenario to 51% in M1 scenario. The increased share comes primarily at the expense of lower supply to sugar production, which declines from 76% to 39% (not given in tables). In response to higher prices caused by fast growing biofuels industry, the farmers in Pakistan are expected to grow more of the high-priced crops, especially the feedstock crops. Therefore, the production of sugarcane will go up by 62.8%, while the production of processed sugar will go down by 17.5% (Table 4, column 3). The expansion in sugarcane production will put huge pressure on arable land and other agricultural resources, thus reducing the production of most of the other agricultural commodities. For example, production of rice, wheat, other crops (cotton), and soybean will drop by 10.7%, 5.3%, 7.8% and 15.5%, respectively. In particular, the heavy drop in cotton production is due to the high resource-competition with sugarcane crop in eastern regions of the

Table 4
Effect of biofuels scenarios on production of agricultural commodities and related industries in Pakistan; compared with the reference scenario (%) in 2020.

Commodity	P1 scenario[a]	P2 scenario[b]	M1 scenario[c]
Rice	0.7	−19.7	−10.7
Wheat	0.5	−5.2	−5.3
Maize	5.2	1.7	2.1
Other grains	0.2	−5.5	−2.5
Vegetable and fruits	0	−5.2	−0.3
Soybean	2.7	4.6	−7.8
Other oilseeds crops	9.0	10.7	9.0
Other crops nec.	0.6	−3.7	−15.5
Milk and dairy products	−0.1	−1.6	8.1
Meat products	0.4	−1.8	5.4
Livestock	−0.2	−3.3	1.7
Sugarcane	1.6	27.6	62.8
Sugar	2.3	−20.9	−17.3
Processed food	−1.0	−3.7	−5.7

Source: simulation results of the study.
[a] Only three producers (USA + EU + Brazil) produce biofuels to meet their policy requirements.
[b] Three producers + Pakistan produce biofuels to meet their policy requirements.
[c] Three producers + Pakistan produce biofuels under high oil price and high substitution elasticity between fossil fuels and biofuels.

Table 5
Effects of global scenarios on trade of agricultural commodities and related industries in Pakistan; compared with the reference scenario (million US$) in 2020.

Commodity	P1 scenario[a]			P2 scenario[b]			M1 scenario[c]		
	Exports	Imports	Net exports	Exports	Imports	Net exports	Exports	Imports	Net exports
Rice	41.6	0.3	41.3	−173.9	4.5	−178.4	−208.8	1.9	−210.7
Wheat	0.0	−21.6	21.6	0.0	50.8	−50.8	−0.3	140.0	−140.3
Maize	0.1	−12.8	12.9	0.0	−9.6	9.7	4.0	−4.1	8.1
Other grains	0.0	0.0	0.0	0.0	0.2	−0.2	0.0	0.6	−0.6
Vegetable and fruits	8.1	−1.2	9.4	−17.1	335.1	−352.2	−33.8	300.6	−334.4
Soybean	0.0	1.0	−1.0	0.0	−1.3	1.3	0.3	3.2	−2.9
Other oilseeds crops	6.6	−4.8	1.8	19.7	35.0	−15.3	73.5	197.1	−123.6
Other crops nec	14.6	−72.8	87.4	24.5	−82.6	107.0	74.9	−677.1	752.0
Milk & dairy products	0.1	−3.9	4.0	−2.6	129.7	−132.3	−17.1	68.3	−85.4
Meat products	5.2	−1.8	7.0	−18.5	9.1	−27.6	−36.6	17.7	−54.4
Livestock	0.1	−1.3	1.4	−9.2	91.4	−100.6	−19.9	95.3	−115.2
Sugarcane	0.0	0.0	0.0	0.0	1.5	−1.5	0.0	6.7	−6.7
Sugar	0.5	−74.1	74.6	−147.1	931.1	−1078.3	−102.4	799.0	−901.4
Processed food	−6.5	40.3	−46.8	−87.6	217.4	−305.0	−245.2	543.6	−788.8
Total	70.5	−152.6	213.5	−411.8	1712.2	−2124.0	−511.3	1492.8	−2004.2

Source: simulation results of the study.
[a] Only three producers (USA + EU + Brazil) produce biofuels to meet their policy requirements.
[b] Three producers + Pakistan produce biofuels to meet their policy requirements.
[c] Three producers + Pakistan produce biofuels under high oil price and high substitution elasticity between fossil fuels and biofuels.

country. While the production of rice and wheat will decrease due to their high land-mobility with sugarcane in southern regions. It is also worth mentioning that the movement of recourses towards agriculture will also be evident from the change in real value added to agriculture in Pakistan. Notice that in 2020, the real agricultural value added will increase by 2.6%, 33.4% and 54.4% under P1, P2 and M1 scenarios, respectively.

4.3. Impacts on trade of agricultural commodities in Pakistan

The expansion in biofuels will affect agricultural trade from Pakistan to varying extents. The biofuels developments in the USA, Brazil and the EU under P1 scenario will have an overall positive impact on net exports of agricultural commodities from Pakistan, except for soybeans and processed food (Table 5, column 3). While exports of all but processed food rise, their respective imports will decline. The higher world market prices and the relative lower domestic prices are the main causes behind this shift in commodity trade. The magnitude of the increase in exports of one commodity depends on both its trade status and opportunity created by biofuel development in the rest of the world. For instance, the net-exports of both rice (mostly basmati rice) and other crops (mostly cotton) will increase by US$ 41.3 million and US$ 87.4 million due to Pakistan's comparative advantage in these crops and the higher world prices induced under P1 scenario in 2020.

As noted in Table 4, the prices of maize and soybean will rise more than those of rice and cotton crops, under P1 scenario. There will, however, virtually be no increase in the exports of maize and soybean. This is mainly because of the little comparative advantage for maize and soybean in Pakistan. As a whole, the net exports of agricultural commodities will improve by US$ 213.5 million in P1 compared with reference scenario in 2020. We observe that the gains in net-exports of cotton crop (other crops) are due to a drop in world supply. Pakistan will import more processed food in 2020 as compared to reference scenario, mainly because of the increased cost of production in domestic market due to higher prices of inputs, i.e. sugarcane, sugar, maize wheat, and edible oils.

If the mandated targets of biofuels production in Pakistan and the other three producers are met (under P2 scenario), the net-exports of most of the agricultural commodities will decrease from Pakistan. Pakistan's trade in processed sugar will decrease by the highest margin, i.e. US$ 1078.3 million. In contrast, due to strong comparative advantage and higher international prices, Pakistan's net-exports of cotton (other crops) will increase by US$ 107 million. Under P2 scenario the total net-export (trade-balance) of agricultural commodities will deteriorate by US$ 2124 million under P2 scenario.

Our results show that Pakistan's biofuels mandate, under P2 scenario, will increase country's dependence on imported food, especially on sugar. It is particularly striking when we note that Pakistan has a predominantly agricultural economy and that it has been self-sufficient in most food items. Notice that under P2 scenario, Pakistan effectively imports sugar to be used as feedstock for ethanol production. Although, the extra spending on imported sugar (US$ 940.3 million) can be largely offset by extra exports earnings (US$ 549.8 million) from ethanol. However, this would also expose Pakistan to risks associated with sugar imports from volatile world markets.

Changes in real exchange rate also have profound impact on trade performance of agricultural commodities of Pakistan. In GTAP, the real exchange rate is presented by the combined change in prices of all primary endowments (land, labour and capital). An appreciation of real exchange rate will dampen the competitiveness of an economy leading to fewer exports and more imports. As a result, the overall trade balance will be exacerbated. Noticeably, there are significant differences in the prices of primary endowments between P1 and P2 scenarios for Pakistan (given in Table A2 of the Appendix). A rise in real exchange rate (prices of primary endowments), under P2 scenario, will translate into lower exports of agricultural commodities originating from Pakistan.

Pakistan's agricultural trade will suffer some serious decline under M1 scenario (Table 5, columns 7–9). With the exception of cotton (other crops) and maize, the trade balance of all of agricultural commodities will deteriorate. Pakistan's superior quality cotton is highly demanded in international markets. There will be extra opportunities for Pakistan's cotton exports, mainly due to shrinking of cotton exports from USA. However, the losses in other agricultural commodities are so huge that even an extra US$ 752 million in cotton trade will be no match for a combined drop

Table 6
Effects of global scenarios on overall trade and fuel trade in Pakistan; compared with the reference scenario (million US$) in 2020.

Commodity	P1 scenario[a]			P2 scenario[b]			M1 scenario[c]		
	Exports	Imports	Net exports	Exports	Imports	Net exports	Exports	Imports	Net exports
Energy[d]	−4.7	−166.0	161.2 (1.8)[e]	−92.8	−2631.7	2538.9 (26)	−72.4	−1433.9	1361.5 (7.3)
Food	55.9	−79.8	126.1	−436.3	1794.8	−2231.1	−586.2	2169.9	−2756.2
Total trade	−301.4	−483.7	182.3 (0.9)	−2986.4	−1296.2	−1690.2 (8.2)	−2577.5	3476.4	−6053.8 (38.2)

Source: simulation results of the study.
[a] Only three producers (USA + EU + Brazil) produce biofuels to meet their policy requirements.
[b] Three producers + Pakistan produce biofuels to meet their policy requirements.
[c] Three producers + Pakistan produce biofuels under high oil price and high substitution elasticity between fossil fuels and biofuels.
[d] Oil + p_c sectors from GTAP.
[e] Figures in parenthesis are the increase/decrease in net exports as percentage of total exports under each scenario.

of US$ 2756[4] million in net-exports of all the other agricultural commodities. Most of the domestic sugarcane will be diverted to ethanol production at the expense of sugar and processed food production. The latter two commodities will exhibit a combined drop of US$ 1690 million in their net-exports. This shows that biofuels production and, consequently, agricultural markets will be highly influenced by changes in oil price, both globally and in Pakistan.

We noted that the biofuels developments under three-producer scenario will marginally improve the total trade situation of Pakistan by less than 1% of the total net exports, under P1 scenario (see Table 6, column 3). The situation reverses under both P2 and M1 scenarios, where Pakistan spends 8.2% and 38.2% more on net exports, respectively. Note that decline in textile exports is the major source of decrease in net exports under both scenarios.[5] This indicates that even if Pakistan succeeds in ensuring security of supply and reducing greenhouse gas (GHG) emissions, the country's agricultural net export will decline due to increased production of biofuels.

We have seen that sugar is a major agricultural and food import item, especially under P2 and M1 scenarios. There are some other possible scenarios that can affect Pakistan's economy. Take for example, if all the major sugar producing countries instead of only four countries in the world would engage in ethanol production in the future. Under this situation, Pakistan's need and capacity to import more sugar from the world market will be affected differently. There would be far less sugar available in the world market, at relatively higher price, for Pakistan to import. This would further hurt the country's bid to achieve and maintain a sustained level of food self-sufficiency in future.

One major reason for adopting a biofuels program is to ensure energy security by decreasing dependence on imported fuel sources. Our analysis shows that in terms of total fuel import bill, Pakistan will spend 26% and 7.3% less under P2 and M1 scenarios (Table 6, columns 6 and 9). When we combine the savings from decreased fuel imports and extra earning from ethanol exports, Pakistan will earn (save) US$ 1.83 billion and US$ 12.1 billion under P2 and M1 scenarios, respectively. Energy security is an idea which depends on many factors and needs further studies to see if saving crude oil imports will actually benefit Pakistan to achieve energy security. Meanwhile, it is worthwhile to notice that the supporting policy to biofuel development in Pakistan should be carefully evaluated as any distortion caused by subsidies will lead to the inefficiency of the overall economy.

[4] This figure is derived by subtracting net-exports from cotton (US$ 752 million) from the total next-exports (US$-2004.2 million) under M1 (Table 5, column 9).

[5] The textile sector, production or exports, has not been shown in table because it does not directly pertain to the agriculture sector, which main theme of the study. Mentioning of textiles is suitable here, because the sector is the major agro-based industry and makes up a major share in total exports earnings for Pakistan.

5. Conclusion

Many countries have set targets for the expansion of biofuels. Increased size and importance of biofuels industry is expected to alter the world agriculture markets. While there are ample studies on projected changes in the global and individual agriculture markets of other countries, we estimate the effects on Pakistan's agriculture. Agricultural, especially food, supplies and prices will be under huge press due to raw materials used for expanding biofuels production. This study uses a global computable general equilibrium model to analyse the impacts of large-scale expansions in biofuels on agricultural prices, production and trade in Pakistan.

The results show that the global biofuels developments, particularly those in USA, EU and Brazil, will affect the prices, supply and trade of agricultural commodities in the respective national and world markets. The spillover effects of these changes will also reach Pakistan in terms of increased prices, higher production, and improved trade of feedstock used in the three major producers. These results indicate that Pakistan's foreign exchange spending on its traditional agricultural imports, i.e. edible oils, sugar, and processed food will increase. In the long run, however, due to rising global food prices, Pakistan's domestic production and self-sufficiency of these commodities will also grow.

While the impacts of Pakistan's biofuels developments on world agriculture are less significant, they are very much evident from changes in domestic agriculture market of Pakistan. The rapid expansion of domestic ethanol production will substantially increase sugarcane production and reduce production of most of other crops and livestock. Changes in prices and production of agricultural commodities in Pakistan due to its own domestic biofuel program will also induce significant changes in its agricultural trade. Overall, the agricultural trade deficit of Pakistan will increase significantly. While reducing crude oil imports through Pakistan's national biofuel program can improve its national energy security, it may have adverse effects on the national food self-sufficiency as the imports (or exports) of food and feed will rise (or fall).

International oil prices and the substitutability between biofuels and fossil fuels will, to a large part, determine the degree of the impacts of biofuels developments on the prices, production, and trade of agricultural and food products. This study shows that if energy prices are going to maintain at a high level in 2020, and if ethanol becomes increasingly substitutable for gasoline. It will be very critical to develop and adopt biofuel technology that uses less food crops in order to ensure food self-sufficiency (a key component of food-security) in Pakistan (and most net-food-importing countries). Otherwise, in order to ensure national food self-sufficiency, the national biofuels program will have to be abandoned.

It is expected that the Pakistani farmers who produce marketable quantities of feedstock crops (sugarcane, maize and rapeseed) will benefit from expansion in biofuels industry. Their incomes are expected to rise due to higher agricultural prices. Therefore, biofuels may improve the household food security of such farmers due to their improved ability to buy food. For subsistence farmers, incomes of most of them may improve only slightly. While they cannot gain from increase in agricultural price as they are only self-sufficient in food. They could gain from rise in unskilled labour wage if some of their family labour is engaged in off-farm employment. However, for urban consumers, particularly the urban poor, biofuels will adversely affect their food consumption and living costs. Therefore, it is essential to develop social security system to provide the necessary support for vulnerable groups in urban areas. We expect that in the long run investment in agriculture will increase from both government and the private sectors. Increasing investment in agriculture induced by higher food prices will raise agricultural productivity, which will partly offset the rise in agricultural prices from the expansion of the biofuels industry. Government should also consider the options to promote feedstock crops which are less input-intensive, (sugarcane is highly water intensive crop), in order to ease the pressure on competing crops and reduce environmental externalities.

In conclusion, there will be some major effects of national biofuels mandate on Pakistan's economy. Therefore, the policy for mandatory target of biofuels blending with fossil fuels in motor vehicles is open to questions. The government has set out a policy to blend 10% of biodiesel with conventional diesel in motor vehicle fuel. Our analysis suggests that this is not a realistic target due to two major reasons. One, we expect that the targeted energy security would not be achieved. Because, in order to produce the required volumes of biodiesel, Pakistan will have to import more of oilseeds crops, in addition to palm oil, which is used for culinary purposes. Thus increasing its dependence on imported (feedstock) fuels, rather than reducing it. There are some serious food-security issues at stake too. Two, the country already has an emerging industry for ethanol production, which uses domestic supply of sugarcane (molasses) as feedstock. Although an ethanol blending policy will not be totally free of risks such as, food-security of the net-buyers, food self-sufficiency of the country, increased price risks associated with volatile international markets in agriculture and environmental consequences, among others. Adopting a policy for ethanol blending, however, would be more beneficial due to economic efficiency, enhanced energy security and higher employment opportunities created by expanding ethanol industry.

In the end, it is worth pointing out that this study is not designed to assess the environmental consequences of expansion in biofuels markets. We expect that expansion of feedstock crops will also result in mono-crop systems that could have negative consequences on the environment. We believe that the future research in this field will also cover the environmental and energy-balance impacts of biofuels. An analysis of environmental effects of Pakistan's biofuels program will provide very valuable guide to assess the sustainability of the program. The assessment of economic impacts on Pakistan can also be improved if some kind of national model is used to assess the impact on producers and consumers of agricultural commodities. Before implementing a full-scale biofuels program, detailed studies should be conducted on biofuel, in terms of their production technology, use and impacts on environment and agriculture.

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Appendix A. Pakistan's trade data in GTAP

Pakistan is gradually improving its international trade performance. In GTAP data, the share of total trade (exports plus imports) in GDP is 30% [26]. Pakistan's exports are composed of 58% of textile and related products, 14.4% of miscellaneous manufacturing articles and 9.7% of food, live animals and beverages. The three largest markets for exported goods are EU, USA and China. Machinery and transport equipment account for 33% of total imports in 2004. Other major commodity groups include chemicals and related products, petroleum (products plus crude) and food items respectively with 15.1%, 13.7% and 10.7% of total imports. Pakistan, though agriculture based economy, is not self-sufficient in most of the agricultural commodities, especially food crops. The data on production, import, export, total consumption and self-sufficiency of GTAP commodities for Pakistan is given in Appendix (Table A1).

The main data used to prepare a Pakistan database for GTAP 7 was a 34-sector 2001–2002 Pakistan SAM prepared by Dorosh, Niazi and Nazli [27]. Their data was based on various national sources. The data representing Pakistan's economy in version 7 of GTAP Data Base is largely consistent with the trade statistics provided by the government of Pakistan in its economic survey.

Table A1
Overview of Pakistan's economy in 2004, million US$.

Commodity	Production	Import	Export	Consumption	Self-sufficiency
Rice	2720.3	4.6	671.7	2053.3	1.32
Wheat	1697.3	247.3	0.4	1944.2	0.87
Maize	94.2	17.8	0	112	0.84
Cereal grains, other	15.1	1.8	0.2	16.7	0.90
Vegetable & fruits	4860.4	215.9	164.8	4911.7	0.99
Soybean	13.3	16.6	0.2	29.7	0.45
Other oilseeds	251.7	213.8	17.8	447.7	0.56
Other crops	5045.5	1051.7	122.7	5974.5	0.84
Milk	14587.8	46	11	14623	1.00
Meat	1230.8	56.4	31.8	1255.4	0.98
Livestock, other products	5694.6	45.1	43.6	5696.1	1.00
Forestry	197.4	46.6	16.9	227.1	0.87
Coal	131.6	197.5	0	329.1	0.40
Oil	721.3	2262.9	3.1	2981.3	0.24
Gas	309.9	0.1	0	310	1.00
Mining & extraction	3083.5	398.8	126.1	3386.3	0.91
Sugarcane	1421.9	0.1	0	1422	1.00
Sugar	3755	24.4	135.2	3644.2	1.03
Processed food	5859.8	1336.8	392.6	6804.5	0.86
Textile & clothing	22939.5	1040.7	9560.3	14551.1	1.58
Manufacturing, light	3345.5	862.2	891.8	3324.7	1.01
Petroleum, products	3709.2	1947.2	162.9	5493.7	0.68
Chemicals, rubber	3206.9	4627.5	379	7491.3	0.43
Manufacturing, heavy	4786.6	10120.2	901.3	14029.2	0.34
Electricity	6629.8	0.1	0	6629.9	1.00
Utilities & construction	12494.5	25.6	24.9	12495.8	1.00
Services, other	53420.3	2796.6	1804.3	54413.1	0.98
Ethanol	56.1	0.4	40.6	16.3	3.44
Transport, road	11145.5	339.5	127.4	11353.4	0.98
Sea transport	336.6	143	106.8	322.4	1.04
Air transport	1968.6	2576.9	751.9	3689.7	0.53
Total	175731.3	30665.3	16489.9	189980.6	–

Source: GTAP Data Base version 7.

Table A2
Impacts of biofuels scenarios on real price change of endowments of Pakistan; compared with the reference scenario (%) in 2020.

Endowments	P1 scenario[a]	P2 scenario[b]	M1 scenario[c]
Land	3	39.8	118.9
Unskilled labour	0.5	35.2	37.7
Skilled labour	0.3	32.3	34.1
Capital	0.1	39.5	36
Natural resources	10	15.5	406.4

Source: simulation results of the study.
[a] Only three producers (USA + EU + Brazil) produce biofuels to meet their policy requirements.
[b] Three producers + Pakistan produce biofuels to meet their policy requirements.
[c] Three producers + Pakistan produce biofuels under high oil price and high substitution elasticity between fossil fuels and biofuels.

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