

**China's Corn and Biofuel Policies and Agricultural Trade: Projections from an  
International Agricultural Commodity Market Model**

**Running title: CARD-IACM Projection of China Ag Imports**

Xi He, Postdoctoral Research Associate, Department of Economics and Center for Agricultural and Rural Development, Iowa State University, [xihe@iastate.edu](mailto:xihe@iastate.edu)

Miguel Carriquiry, Professor, Institute of Economics, Department of Economics of the University of the Republic, Uruguay, [miguel.carriquiry@gmail.com](mailto:miguel.carriquiry@gmail.com)

Amani Elobeid, Adjunct Associate Professor, Department of Economics and Center for Agricultural and Rural Development, Iowa State University, [amani@iastate.edu](mailto:amani@iastate.edu)

Dermot Hayes, Charles F. Curtiss Distinguished Professor, Department of Economics and Center for Agricultural and Rural Development, Iowa State University, [dhayes@iastate.edu](mailto:dhayes@iastate.edu)

Minghao Li, Assistant Professor, Department of Economics, Applied Statistics & International Business, New Mexico State University, [minghao@nmsu.edu](mailto:minghao@nmsu.edu)

Wendong Zhang, Assistant Professor, Department of Economics and Center for Agricultural and Rural Development, Iowa State University, [wdzhang@iastate.edu](mailto:wdzhang@iastate.edu)

**Acknowledgements:** This research was supported by the Center for Agricultural and Rural Development (CARD) at Iowa State University. The authors also gratefully acknowledge support from the USDA National Institute of Food and Agriculture Hatch Project 101,030 and grant 2019-67023-29414.

# **China's Corn and Biofuel Policies and Agricultural Trade: Projections from an International Agricultural Commodity Market Model**

**Running title: CARD-IACM Projection of China Ag Imports**

## **Abstract**

We calibrate the CARD International Agricultural Commodity Market model using 2019/20 marketing year crop data and 2020 calendar year livestock and biofuel data to project China's agricultural imports under six scenarios. We focus on ethanol, corn, and pork from 2021 to 2030. We establish baseline scenario projections, in which China does not implement its 7.2 million metric ton corn tariff rate quota (TRQ), imposes ethanol tariffs, and does not implement an ethanol mandate requiring a 10% ethanol blend in gasoline. The baseline is then compared with five other simulated policy scenarios differentiated by corn and ethanol policies. Baseline projections show that China's ethanol imports grow from 100 million liters in 2020 to 1.214 billion liters in 2030; however, they also show that China's corn and pork imports remain at high levels and peak in the 2022/23 marketing year. Compared with the baseline scenario, the ethanol mandate increases China's corn and pork imports, and the corn TRQ increases China's ethanol and pork imports. Both the ethanol mandate and corn import restrictions shift US and global exports from corn to ethanol and pork products. These projections can serve as benchmark estimates of China's imports of major agricultural commodities in the next decade.

**Keywords:** China agricultural imports; CARD International Agricultural Commodity Market Model (IACM); Ethanol mandate; Corn tariff rate quota (TRQ); Global agricultural trade

**JEL codes:** Q17; Q18; Q11

## 1. Introduction

In addition to soybeans, China has recently become a large importer of feed grains, including corn, barley, sorghum, and wheat, as well as of meat products, namely pork and beef. In 2020, China's corn imports reached a historical 17.4 million tons, far exceeding its tariff rate quota (TRQ) of 7.2 million tons (GACC, 2020). China's barley, sorghum, and wheat imports, respectively, reached record highs of 4.1, 4.2, and 8.0 million tons, a 188%, 300%, and 110% increase from their respective 2019 levels. Its pork imports surged from 1.21 million tons in 2017 to 4.39 million tons in 2020 (GACC, 2020). China has long been a major soybean importer and also imported a large amount of soybeans in 2020. While China's surging imports in 2020 caught many major agricultural exporters off guard and may have put upward pressure on world food prices (FAO, 2021),<sup>1</sup> it is unclear whether the dramatic increase in its feed grain and meat imports is a one-time event due to its phase one trade deal obligations with the United States (He, Hayes, and Zhang, 2020a), bad weather in the country's major food-producing provinces in June and July 2020,<sup>2</sup> and a need for feed grains as it rebuilds hog inventory after an African swine fever (ASF) outbreak,<sup>3</sup> or whether it is due to a long-term trend resulting from China's structural changes in food consumption patterns and constrained land and water resources (Huang, Wei, Qi, & Wei, 2017; Sheng & Song, 2019).

China's corn and ethanol policies add more uncertainty to its agricultural import prospects. In September 2017, in an effort to mitigate the air pollution problems and destock its record corn inventory, China announced a policy that expanded the mandatory use of 10% ethanol blend gasoline (E10) from 11 trial provinces to the entire country by 2020. Given China's constrained ethanol supply capacities, implementing the nationwide E10 mandate may require large imports of either ethanol or corn, the primary feedstock for ethanol production (Li et al., 2017).<sup>4</sup> However,

in 2017, China increased tariffs on ethanol from 5% to 30%, and further increased its tariffs on US denatured ethanol to 70% after two waves of retaliatory tariffs during the US-China trade war.<sup>5</sup> China then reduced its tariffs on US ethanol to 45% on February 18, 2020, after announcing a round of tariff exclusions for US agricultural commodities affected by the retaliatory tariffs (USDA GAIN, 2020). Not surprisingly, in early 2020, China suspended its plan to implement the E10 mandate due to insufficient ethanol production capacities. As corn is also an important feedstock for hog production, China's corn and ethanol policies will determine its imports of corn, pork, ethanol, and other major feed grains and meat products.

Given its growing role in international food markets, projecting China's agricultural imports under different corn and ethanol policies and the implications for global food trade is important for academics, policymakers, and agriculture-related stakeholders. In this article, we use the Center for Agricultural and Rural Development (CARD) International Agricultural Commodity Market (IACM) model, a deterministic partial equilibrium modeling system, to project China's agricultural imports from 2021 to 2030. A notable advantage of this model is that it accounts for a wide range of commodities and countries, extensive biological and agro-economic links between agricultural and biofuel commodities, and a comprehensive set of supply and demand factors, including arable land resources, population, and income level changes, that affect world food supply and demand.<sup>6</sup> The CARD IACM model is run to establish 10-year projections for supply, utilization, and prices for six scenarios including a baseline scenario. For the purpose of this paper, we focus on trade of the major agricultural commodities in China and major producing countries.

We first project China's agricultural imports in the baseline scenario where China does not implement the corn TRQ, imposes ethanol tariffs (30% on non-US countries and 45% on the

United States), and does not implement the nationwide E10 mandate. We then project China's agricultural imports under five other policy scenarios differentiated by whether China enforces its corn TRQ, removes ethanol tariffs, and/or implements the E10 mandate (see table 1 for details on the scenarios). The purpose of the policy simulations is twofold: (a) to compare China's imports of major feed grains and meat products, food self-sufficiency, and major countries' exports across scenarios; and (b) to investigate China's substitution between imports of corn, pork, and ethanol under the different policy scenarios.

We outline three sets of major findings. First, in the baseline scenario, international prices of ethanol, corn, and pork increase significantly over the projection period (2020 to 2030). Over the same period, China's corn and pork imports remain high. Comparisons of projections under different scenarios show that the E10 mandate and the corn TRQ increase prices and imports of ethanol, corn, and pork with varying degrees depending on the scenario. We project that China's ethanol and pork imports will be largest if China implements an E10 mandate with restricted corn imports.

The second set of results addresses the imports of other major feed grains including barley, sorghum, and wheat, as well as soybeans, and major meat products such as beef and broilers. Projections show that the E10 mandate increases the prices of both feed grain and meats while the corn TRQ increases international prices of meat. The price increases for feed grains and meats are larger when China imposes ethanol tariffs. In addition, China's imports of meat products, including pork, beef, and broilers, are much higher when it restricts corn imports than when it frees its corn imports, suggesting substitution between imports of corn and meat products.

The third set of findings focuses on the exports of feed grains and meat products of major exporting countries. We find that US ethanol exports are highest (a 103% increase from the baseline) when China implements the E10 mandate, restricts its corn imports, and removes ethanol tariffs. Both the E10 mandate and corn TRQ shift US exports from corn to ethanol and pork products. The bottom line in all scenarios is that if market forces are at work, China's resource constraints will prohibit it from returning to self-sufficiency in key commodities. Attempts to achieve self-sufficiency in one area will force it to import more in other areas.

Because the CARD IACM model uses pre-determined interactions between markets and commodities to project rather than to forecast production, consumption, prices, and trade, we do not account for many potential factors such as weather shocks, changes in border and domestic policies, and exchange rate fluctuations. However, these projections can serve as useful benchmark estimates of China's agricultural imports in the next decade. In addition, the comparisons of projected prices and imports under different scenarios also provide insights into China's substitution of imports between ethanol, feed grains, and meat products under different ethanol and corn policies and the impacts of China's agricultural and biofuel policies on global trade patterns. The model assumes that Chinese consumers and producers respond to market prices much as they have done in the past; however, it is always possible that Chinese central planners will overrule these forces to achieve a non-market outcome of their choice.

The rest of the paper is organized as follows. Section 2 describes the trend of China's agricultural imports and relevant corn and ethanol policies. Section 3 describes the CARD IACM model and presents the baseline and five policy scenarios. Section 4 presents our main findings, and Section 5 offers our conclusions.

## **2. Overview of China's Corn and Ethanol Policies and Agricultural Imports**

## *2.1 Corn and Ethanol Policies*

China's corn market has been turbulent in the past two decades (He, Hayes, and Zhang, 2020b). In 2008, to support farmers' incomes, China started a stockpiling program in which the government purchased corn from farmers at a higher price than the market level. China's corn harvested area gradually increased from 23 million hectares in 2000 to a record 44.9 million hectares in 2015, and corn inventory increased from 35 million metric tons (MMT) in 2005 to 223 MMT in 2016. To destock its corn inventory and reduce corn production, in 2016 China ended the stockpiling program, reduced corn subsidies, and promoted ethanol fuel. As a result, corn consumption exceeded production for the first time in 2016, and its corn inventory declined to 16 MMT in 2019. In 2020, for the first time since China agreed to an optional corn TRQ of 7.2 MMT in 1996, China's imports exceeded the TRQ, reaching 17.4 MMT. China has already agreed to purchase half that amount in the 2022/23 marketing year. Therefore, in our baseline scenario we assume that China will continue to ignore the TRQ.

To mitigate air pollution problems, China started an E10 mandate in several provinces/cities and planned to implement a nationwide E10 mandate by the end of 2020 (Li et al., 2017). However, China also increased its tariffs on ethanol from 5% to 30% in 2017 and imposed retaliatory tariffs on US ethanol. Due to a lack of corn supplies and limited ethanol production/import availability, China later suspended this mandate.

## *2.2 China's Growing Agricultural Imports*

China's agricultural imports have increased significantly since joining the World Trade Organization (WTO) in 2001. Figure 1 shows China's import value of soybeans, corn, wheat, sorghum, barley, pork, beef, and broilers from 2000 to 2020. To ensure self-sufficiency of food staples, China maintained its quota system for wheat, rice, and corn imports when it opened its

soybean market in the mid-1990s. Soybeans have accounted for the lion's share of China's agricultural imports since the opening of the market in 2000. China's imports of corn and wheat were quite limited prior to 2020.

### **3. CARD IACM Model and Policy Scenarios**

#### *3.1 CARD IACM Model*

Baseline and scenario projections are determined using the CARD IACM model. This model is a deterministic agricultural modeling system that can quantify the impact of market changes and policies on global land allocation. This model is a modified version of the CARD-FAPRI model, which has been widely used in agricultural and biofuel policy evaluations (Meyers, Westhoff, Fabiosa, and Hayes, 2010; Elobeid, Carriquiry, and Fabiosa, 2012; Carriquiry, Elobeid, Dumortier, and Goodrich, 2020).<sup>7</sup> Unlike the CARD-FAPRI model, the CARD IACM model allows for longer-term projections (longer than 10 years) and includes a land allocation mechanism on the supply side and nutritional restrictions on the demand side (to set reasonable limits on caloric intake under a longer time horizon). The modified model has been used by Dumortier, Carriquiry, and Elobeid (2021) to analyze the effect of vehicle fuel efficiency on biofuel demand and, consequently, on global agricultural markets.

The model is comprised of 22 countries/regions with all agricultural sectors (commodities) contained within each country or region.<sup>8</sup> The countries/regions are selected according to their significance in the agricultural commodity marketplace. Within each country or region, each sector's land use is placed within a hierarchical land-use structure. The first tier determines the total land allocated to agriculture and is driven by net returns to agriculture. The second tier determines the share of land allocated to crops, forestry, and pasture, depending on whether crop production becomes more profitable. The third tier is competition among crops. On the demand



side, the model assumes that per capita demand for food increases with income at a decreasing rate. This model uses a partial equilibrium framework to solve a set of successive annual commodity prices to equate global supply and demand for agricultural products.

To generate yearly projections from 2021 to 2030, we calibrate the model using the 2019/20 marketing year data for crops and 2020 calendar year data for livestock and biofuels. Production, consumption, stock, and trade data for crops and livestock products are from USDA's Production, Supply, and Distribution dataset (USDA, 2020a). Production, consumption, stock, and trade data for biofuels are from USDA's biofuels annual report (USDA, 2020b). Historical and projected macroeconomic variables, including GDP per capita, GDP deflator, and population are from USDA Economic Research Service international macroeconomic database (USDA, 2020b). Elasticities for supply and demand are estimated using relevant prices and quantities similar to the CARD-FAPRI model (FAPRI, 1996).<sup>9</sup>

To determine the market equilibria for each year from 2021 to 2030, the model solves for international prices for ten major commodities of interest—barley, corn, rice, sorghum, soybeans, wheat, pork, beef, broilers, and ethanol. Considering that China's corn market will be isolated from the international market when China limits its corn imports, we can also solve for China's domestic corn price by equating corn domestic supply and TRQ with demand, given that a 65% out-of-quota tariff would be prohibitively high. For other commodities, international prices transmit to China based on price transmission equations.

### *3.2 Policy Scenarios*

Table 1 lists the baseline scenario and the five other simulated policy scenarios. In the baseline model, China does not implement its corn TRQ, imposes a 45% tariff on US ethanol and a 30% tariff on ethanol from non-US countries, and does not implement the E10 mandate. The second

scenario assumes China maintains the corn and ethanol tariff policies in the baseline but implements the nationwide E10 mandate. The third scenario assumes China removes tariffs on ethanol on top of the E10 mandate in the second scenario. The fourth, fifth, and sixth scenarios assume the same E10 mandate and ethanol tariff policy as in the first, second, and third scenarios, except that China implements the corn TRQ rather than removes it. Comparisons of agricultural import projections under the six scenarios provide insights into the impact of corn and ethanol policies on China's agricultural imports.<sup>10</sup>

Based on China's historical gasoline consumption from 2010 to 2020, we project China's gasoline consumption from 2021 to 2031 using a linear trend and then assume China gradually ramps up the E10 mandate (from a 2% blend rate in 2021 to a 10% blend rate in 2030). Figure 2 shows China's ethanol fuel production, consumption, and imports from 2010 to 2020, and the projected consumption from 2021 to 2030 if China implements the E10 mandate. China's ethanol fuel consumption will increase from 3.3 billion liters in 2020 to 22.5 billion liters if it gradually implements the E10 mandate from 2021 to 2030.

### *3.3 Expected Impacts of Restricted Corn Imports and E10 Mandate*

China's implementation of the nationwide E10 mandate and the associated ethanol import demand would impact the domestic and global ethanol and agricultural markets in several ways. First, in addition to an ethanol price increase, international corn and pork prices would also increase, given that corn is the major feedstock for ethanol and pork production in major ethanol and pork exporting countries such as the United States (Wright, 2014; Hochman & Zilberman, 2018). Second, the impact of the E10 mandate on China's corn imports depends on two opposing forces. On the one hand, the E10 mandate would require China to produce more ethanol, which requires large amounts of corn as feedstock. On the other hand, the higher international corn

price would lower China's corn import demand. The results suggest that first force will dominate, and that China's corn imports would increase under the E10 mandate. While the E10 mandate would also increase China's ethanol imports, whether China would import ethanol or corn is ambiguous and depends on the relative costs of imported ethanol and domestically produced ethanol that are solved for in the model. Third, the E10 mandate's impact on China's pork imports is also unpredictable without the model. A higher corn price would increase pork production costs and lower the domestic supply of pork. However, a higher pork price would decrease pork consumption. Therefore, whether the E10 mandate increases or decreases China's pork imports depends on the various pork production and consumption price elasticities that are embedded in the model.

The enforcement of the corn TRQ would also affect the agricultural and biofuel markets in several ways, depending on whether the E10 mandate is implemented. First, the corn TRQ would reduce China's corn supply and increase its domestic corn price, which would lead to higher hog production costs and more pork imports. Similarly, the corn TRQ would also increase domestic ethanol production costs and, therefore, increase ethanol imports. In addition, the increase in pork and ethanol imports would be much higher if China implements the E10 mandate and enforces the corn TRQ at the same time. Given that the corn TRQ would reduce corn imports, the expected increase in ethanol and pork imports indicate there would be substitution between corn and pork/ethanol imports.

China's corn and ethanol policies would also affect its production of major crops that compete for land with corn, including soybeans, wheat, rice, sorghum, and consequently, the production of other major meat products substitutable for pork products, including beef and broilers.

The impacts across agricultural commodities and countries are complex, and the explicit and comprehensive modeling of these linkages in the CARD IACM model captures these interactions and provides projections and comparisons of prices, production, consumption, and trade across policy scenarios.

## **4. Results**

We first show projected prices, production, consumption, and imports of ethanol, corn, and pork in section 4.1. We then present China's projected imports of other major feed grains and meat products in section 4.2, followed by comparisons of the self-sufficiency rate of commodities in section 4.3. Finally, in section 4.4, we compare the projected exports of the major agricultural commodities for the major exporting countries.

### *4.1 Projected Prices, Production, Consumption, and Imports of Ethanol, Corn, and Pork*

Figures 3–5 show the projected prices, production, consumption, and imports of ethanol, corn, and pork in the six scenarios. There are several major findings.

First, in the baseline scenario, the international ethanol price increases by 24% from \$0.78/liter in 2020 to \$0.97/liter in 2030. Over the same period, the international corn price increases 29% from \$210/metric ton to \$270/metric ton, and the international pork price increases 35% from \$2,560/metric ton to \$3,458/metric ton. China's ethanol imports will grow from 100 million liters in 2020 to 1.213 billion liters in 2030. China's corn imports grow from 17.4 MMT in 2020 to 27.56 MMT in the 2022/23 marketing year, then gradually decline to 21.25 MMT in the 2029/30 marketing year. China's pork imports increase from 4.5 MMT in 2020 to 4.95 MMT in the 2022/23 marketing year, then gradually decline to 2.73 MMT in 2029/30.

On the production side, the increase in China's corn production results from both higher harvested area (from 41.3 million hectares in 2020 to 41.7 million hectares in 2030) and increased yield (from 6.32 metric tons per hectare in 2020 to 6.67 metric tons per hectare in 2030). The increase in corn harvested area partially comes from the reduced harvested area of soybeans, barley, and sorghum. On the consumption side, corn feed consumption is projected to remain flat as high corn prices cause hog producers to shift feed from corn to other alternatives, such as sorghum and barley. As a result, while we project that both China's corn production and consumption will increase, production increases slightly faster than consumption and the consumption-production gap peaks in 2022/23 and then gradually declines. Similarly, China's pork imports peak in 2022/23 and then gradually decline because China's pork production is projected to grow faster than consumption as the industry recovers from ASF. In the model, pork production is driven by behavioral equations that capture cost as well as technical and biological relations. On the demand side, pork consumption is determined primarily by income and prices of pork and of competing meats. However, as income increases, consumption does not continue to increase indefinitely over the longer time horizon. With the rise in per capita income, food accounts for smaller shares of the additional income and the increase in consumption of pork begins to wane. These baseline results are richer and more complex than the trend line growth typically seen in baselines. This is true because our initial year is a disequilibrium year with low pork production and consumption due to ASF and high corn and soybean prices and a depletion of stocks due to the trade war.

Figures 3–5 show an abrupt change in 2021 when China implements the E10 mandate with restricted corn imports. Specifically, in figures 3a–3d, the E10 mandate with corn TRQ leads to a significant increase in the international ethanol price in 2021, a sharp decrease in China's ethanol

production, and a sharp increase in ethanol imports. In figures 4a–4d, the E10 mandate with limited corn imports leads to higher corn production and lower corn consumption—limited corn imports lead to a higher domestic corn price, incentivizing production and discouraging consumption. In figures 5a–5d, the E10 mandate with the corn TRQ in place leads to a decline in pork production in the early 2020s due to high domestic feed prices, though the international corn price actually declines with the corn TRQ due to decreased demand from China. These sudden initial changes in prices gradually disappear as China’s ethanol production capacity catches up.

To compare projections in different scenarios, table 2 panel A presents the actual and projected prices, production, consumption, and net imports of ethanol, corn, and pork in 2020 and from 2021 to 2030 in the six scenarios. Table 2 panel B presents the percent changes in projections in 2030 using the five simulated policy scenarios as compared to the baseline projections. There are several findings. First, columns (2) and (3) in panel B show that implementing the E10 mandate increases international corn and pork prices and imports. Specifically, compared with the baseline projections, corn (pork) price increases by 1.34%–1.29% (0.32%–0.33%), and corn (pork) imports increase by 2.54%–4.51% (1.17%–1.28%). In addition, with the E10 mandate, free ethanol imports increase ethanol imports and decrease corn and pork imports relative to restricted ethanol imports, which suggests substitutions between ethanol and corn/pork imports. Second, column (4) in panel B shows that restricting corn imports reduces the international price and China’s imports of corn relative to the baseline but increases China’s imports of ethanol and pork relative to the baseline. The restricted corn imports increase China’s ethanol and pork imports due to limited corn purchased from other countries and high domestic corn prices, thus reducing ethanol and pork production. Moreover, China’s ethanol

imports are projected to increase the most in scenario 6 where China implements an E10 mandate with restricted corn imports and free ethanol imports (a 2,518% increase compared to the baseline); China's pork imports are projected to increase the most in scenario 5 when China implements an E10 mandate with restricted corn and ethanol imports (a 31.63% increase compared to the baseline); and, China's corn imports are projected to increase the most in scenario 2 when China implements an E10 mandate without free ethanol imports (a 4.51% increase from the baseline). Finally, an interesting finding in table 2 is that China would import more ethanol rather than more corn if it implements the E10 mandate, which could be caused by the difficulty of expanding ethanol production capacities within a limited time horizon.

#### *4.2 Projected Prices and Net Imports of Other Major Feed Grains and Meat Products*

Figures 6a and 6b present the relative percentage changes in average prices and net imports of barley, corn, sorghum, soybeans, wheat, beef, broilers, and pork from 2021 to 2030 in the five policy scenarios compared with the baseline projections. Figure 6a shows that the prices of these commodities are higher in scenarios 2 and 3 in which China implements an E10 mandate, with higher prices in scenario 2 than in scenario 3 when China does not impose ethanol tariffs. In addition, prices of meat products are always higher in the five policy scenarios relative to the baseline. Another important finding in figure 6b is that China's beef and broiler imports are much higher when it restricts corn imports than when it does not impose the corn TRQ, suggesting substitutions between imports of corn and meat products.

Overall, the projections for other major feed grains and meat products show that: (a) the E10 mandate leads to higher prices of feed grains and meat products; (b) restricting corn imports leads to higher prices of meat products; (c) impacts of E10 on prices are smaller when China implements the E10 mandate with free ethanol imports than when China implements the E10

mandate with ethanol tariffs; and, (d) China's meat product imports see a large increase when the country restricts corn imports.

#### *4.3 Self-sufficiency of Major Feed Grains and Meat Products*

Table 3 presents China's self-sufficiency rate of major feed grains and meat products in 2017, 2020, and 2021–2030 under different scenarios. The projections in the baseline show that China's self-sufficiency rate of feed grains and ethanol decrease from their 2020 levels. However, China's pork and beef self-sufficiency rates slightly increase from their 2020 levels but remain significantly lower than their 2017 levels. China's ethanol self-sufficiency rate is the lowest, 20.69%, when it implements an E10 mandate with free ethanol and corn imports. China's corn self-sufficiency rate is the lowest, 91.17%, when it implements an E10 mandate with free corn imports and restricted ethanol imports. China's meat product self-sufficiency rate is lowest (89.17% for pork, 72.26% for beef, and 93.97% for broilers) when it implements the E10 mandate with restricted corn and ethanol imports.

#### *4.4 Major Exporting Countries' Agricultural Exports*

Table 4 panel A presents projected exports of the major commodities for major exporting countries from 2021 to 2030 and panel B presents the relative changes to the projections in the baseline. There are several interesting findings. First, the E10 mandate increases US ethanol and pork exports and reduces US corn exports relative to the baseline because the mandate will require large amounts of US corn for US ethanol production. In addition, China's corn imports when it implements the mandate increase by around 2.5%–4.5%, and other corn exporters, such as Ukraine, meet China's higher corn import demand. Second, US ethanol exports are highest when China implements the mandate with restricted corn imports and free ethanol exports (scenario 6). Finally, the mandate shifts US exports from corn to ethanol and pork, and corn



import restrictions also shift US exports from corn to ethanol and pork products. These findings suggest that China's large ethanol imports will be associated with more US ethanol and pork exports and less US corn exports.

Table 5 presents global trade of corn, ethanol, and pork. The baseline projections show that global trade in corn and pork remain at high levels, 169 million metric tons and 9 million metric tons, respectively, and global ethanol trade increases by 41% in the next 10 years. In addition, panel B shows that depending on whether China enforces a corn TRQ and removes ethanol tariffs, China's E10 mandate would increase world ethanol trade by 173%–232% and increase world pork trade by 0.21%–13.53% relative to the baseline. Finally, both China's E10 mandate and corn TRQ would shift world trade from corn to pork/ethanol.

## **5. Conclusions**

As China continues to be an important player in the world agricultural market, its food and biofuel policies have significant implications for international food prices and trade. China's record imports of feed grains and meat products in 2020 were quite unexpected, and better projections of China's agricultural imports are critical for global agricultural production and stable world food prices. We use the CARD IACM model, which contains extensive linkages between all major commodities in 22 countries/regions, to project China's feedstock and meat imports under policy scenarios differentiated by corn and ethanol policies. In the baseline scenario, China does not implement the corn TRQ, imposes ethanol tariffs, and does not implement the nationwide E10 mandate.

In the baseline scenario, we project international prices of ethanol, corn, and pork to increase by 24%, 29%, and 35%, respectively. In addition, we project China's ethanol imports will

gradually grow from 100 million liters to 1.213 billion liters, while China's corn and pork imports will peak in 2022/23 and then gradually decline.

Comparisons of projections under different scenarios show that the E10 mandate increases prices and imports of corn and meat products, and the corn TRQ increases the prices and imports of meat products. In addition, the corn TRQ will increase China's corn self-sufficiency and decrease its self-sufficiency for pork products due to higher feed production costs in meat production. Finally, both the E10 mandate and corn import restriction would shift US and world exports from corn to ethanol and pork.

There are caveats in our projections. For example, the projections do not fully capture all potential factors that impact food prices, production, consumption, and trade, such as temporary tariff and non-tariff trade measures, weather shocks, exchange rate fluctuations, and formation of regional trade agreements in the projection period. However, our projections under different policy scenarios and comparisons of projections under different policy scenarios provide useful benchmarks and insights for predicting China's agricultural trade prospects.

## Endnotes

1. In April 2021, the Food and Agriculture Organization food price index was around 30.8% higher than during the same period the previous year, which marked the eleventh consecutive monthly rise to its highest level since May 2014 (FAO, 2021).
2. In June and July 2020, severe floods wreaked havoc in many provinces in southern China.
3. The African swine fever outbreak that started in August 2018 wiped out 40% of China's sow inventory, and China imported large quantities of pork to meet its demand in 2019 and 2020.
4. In 2020, corn accounted for 89% of the feedstock used in ethanol production in China, wheat accounted for 5%, and other commodities, including sweet cassava, accounted for the remaining 6% (USDA GAIN, 2020).
5. On April 2, 2018, China imposed an additional 15% tariff on US denatured ethanol in response to the US 232 Action, raising the tariffs from 30% to 45%. On July 6, 2018, China imposed an additional 25% tariff on US denatured ethanol, raising the tariff to 70%.
6. A number of studies emphasize the importance of considering China's income-induced changes in food consumption patterns when predicting China's future food demand (e.g., Hansen & Gale, 2014; Gale, Hansen, & Jewison, 2015).
7. FAPRI is the Food and Agricultural Policy Research Institute, formerly a division of the Center for Agricultural and Rural Development.
8. The 22 countries/regions included in the updated CARD model are Argentina, Australia, Brazil, Canada, Chile, China, Egypt, the European Union, India, Indonesia, Japan, Malaysia, Mexico, New Zealand, Nigeria, Peru, Russia, South Africa, Ukraine, the United States, Vietnam, and the aggregate rest of the world (ROW) region required to close the model.

9. Where estimation was not feasible, model parameters were derived from the literature as well as information based on economic theory and technical relationships.

10. While the three policies (implementation of E10 mandate, enforcement of corn TRQ, and elimination of ethanol tariffs) would generate eight possible policy scenarios, we exclude two scenarios—No TRQ/No E10/Free ethanol and TRQ/No E10/Free ethanol—from the analysis because these two scenarios assume China would free ethanol imports without the E10 mandate, which is less likely than the scenario in which China frees its ethanol imports when it implements the E10 mandate.

## References

- Carriquiry, M., Elobeid, A., Dumortier, J., & Goodrich, R. (2020). Incorporating sub-national Brazilian agricultural production and land-use into US biofuel policy evaluation. *Applied Economic Perspectives and Policy*, 42(3), 497–523.
- Dumortier, Jerome, Miguel Carriquiry, and Amani Elobeid. (2021). Where does all the biofuel go? Fuel efficiency gains and its effects on global agricultural production. *Energy Policy*, 148, 1-11, <https://doi.org/10.1016/j.enpol.2020.111909>.
- Elobeid, A., Carriquiry, M., Fabiosa, J. F. (2012). Implications of global ethanol expansion on Brazilian regional land use. In *Socioeconomic and environmental impacts of biofuels: Evidence from developing nations* (pp. 171–190). Cambridge: Cambridge University Press.
- Food and Agricultural Policy Research Institute (FAPRI) (1996). World agricultural outlook. Staff paper No. 2–96. Iowa State University and University of Missouri, Columbia.
- Food and Agricultural Organization (FAO) (2021). FAO food price index. Available at <http://www.fao.org/worldfoodsituation/foodpricesindex/en/>.
- Gale, H. F., Hansen, J., & Jewison, M. (2015). *China's growing demand for agricultural imports* (USDA-ERS Publication No. EIB-136). Available at <https://www.ers.usda.gov/publications/pub-details/?pubid=43940>.
- General Administration of Customs of China (GACC). 2020. *Monthly statistics of main imported products*. Data retrieved from <http://www.customs.gov.cn/customs/302249/302274/302277/index.html>.
- Hansen, J., & Gale, F. (2014). China in the next decade: Rising meat demand and growing imports of feed. *Amber Waves*, April 7, 2014.

- He, X., Hayes, D. J., & Zhang, W. (2020a). China's agricultural imports under the Phase One deal: Is success possible? (2020). *CARD Policy Briefs*, 29.
- He, X., Hayes, D. J., & Zhang, W. (2020b). Upheaval in China's corn market: Will China expand its Tariff Rate Quota for corn?. *Agricultural Policy Review*, 2020(3), 2.
- Hochman, G., & Zilberman, D. (2018). Corn ethanol and US biofuel policy 10 years later: A quantitative assessment. *American Journal of Agricultural Economics*, 100(2), 570–584.
- Huang, J. K., Wei, W. E. I., Qi, C. U. I., & Wei, X. I. E. (2017). The prospects for China's food security and imports: Will China starve the world via imports? *Journal of Integrative Agriculture*, 16(12), 2933–2944.
- Li, M., Zhang, W., Hayes, D., Arthur, R., Yang, Y., & Wang, X. (2017). China's new nationwide E10 ethanol mandate and its global implications. *CARD Agricultural Policy Review*, (Fall 2017), 3-13.
- Meyers, W. H., Westhoff, P., Fabiosa, J. F., & Hayes, D. J. (2010). The FAPRI global modeling system and outlook process. *Journal of International Agricultural Trade and Development*, 6(1), 1–20.
- Sheng, Y., & Song, L. (2019). Agricultural production and food consumption in China: A long-term projection. *China Economic Review*, 53, 15–29.
- United States Department of Agriculture Global Agricultural Information Network (USDA GAIN). (2020). Data accessed from <https://gain.fas.usda.gov/#/>.
- United States Department of Agriculture Foreign Agricultural Service (USDA). (2020a). *Production, consumption, and distribution online*. Available at <https://apps.fas.usda.gov/psdonline/app/index.html#/app/advQuery>

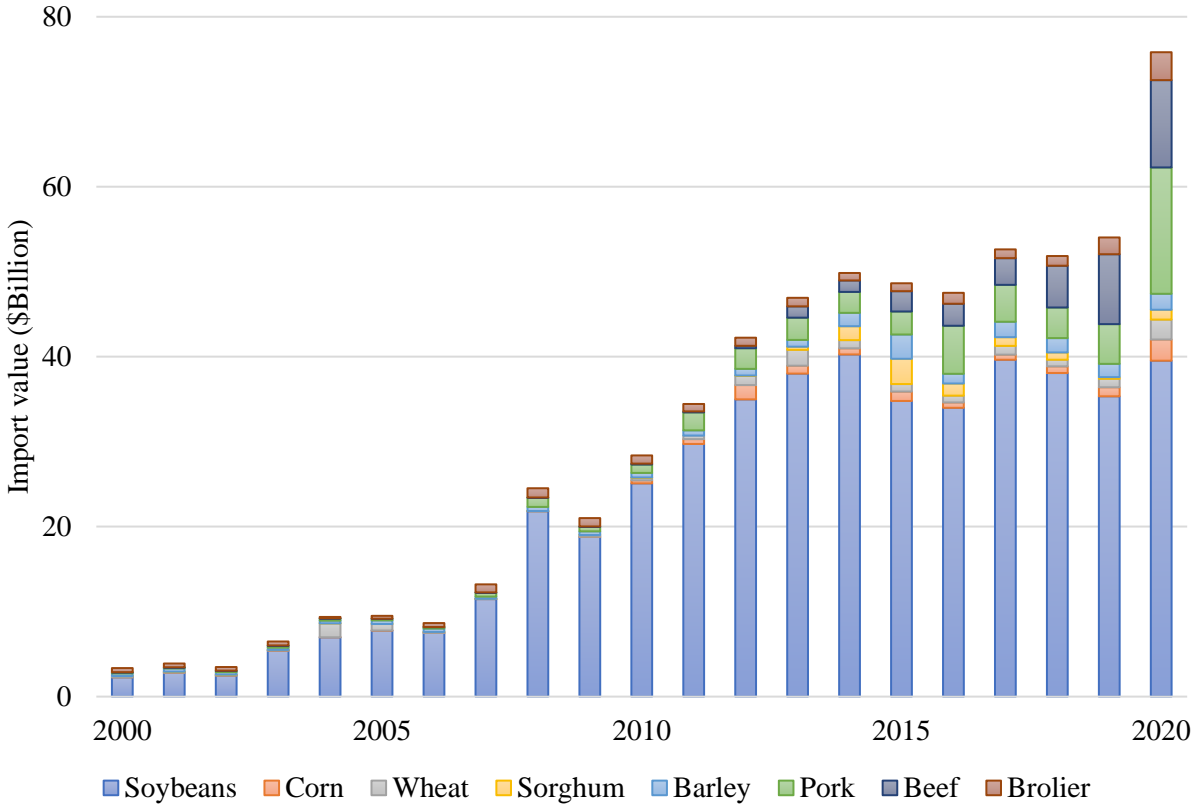
United States Department of Agriculture Foreign Agricultural Service (USDA). (2020b).

*Biofuels*. Available at

<https://www.fas.usda.gov/commodities/biofuels#:~:text=The%20United%20States%20exported%201.5,with%20little%20change%20in%20prices.>

Wright, B. (2014). Global biofuels: Key to the puzzle of grain market behavior. *Journal of Economic Perspectives*, 28(1), 73–98.

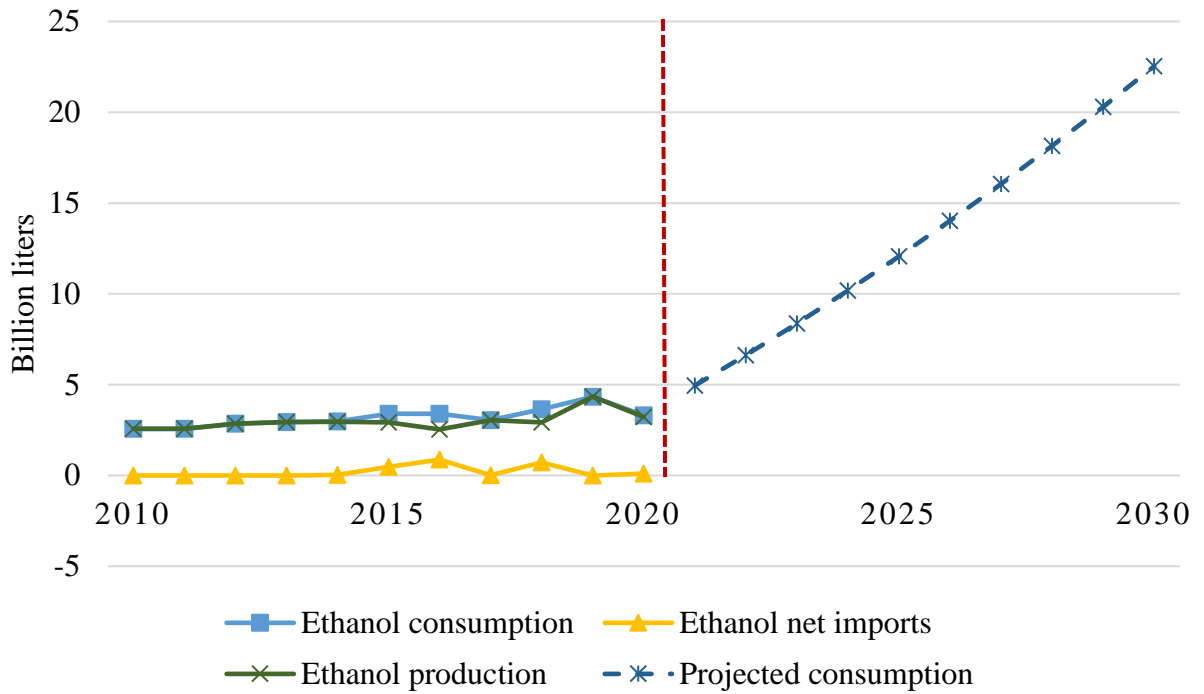
**Figure 1.** China’s imports of major agricultural commodities, 2000–2020.



Note: Data come from USDA FAS (USDA, 2020a).

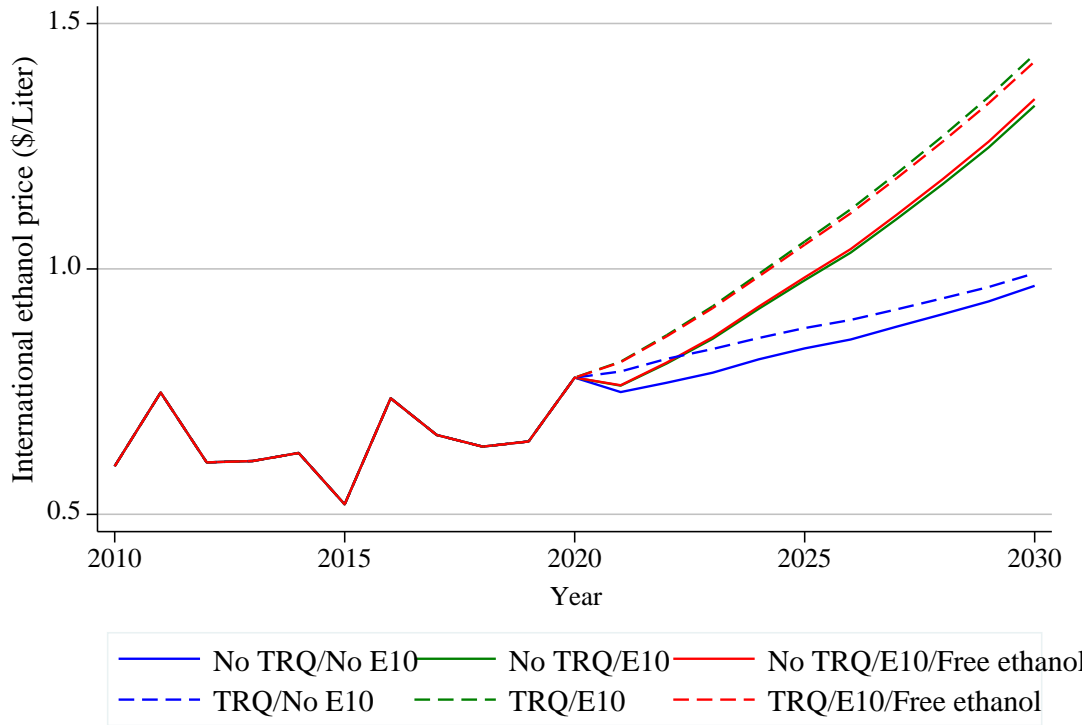


**Figure 2.** China’s actual ethanol production, consumption, and imports from 2010 to 2020 and the projected consumption from 2021 to 2030 if China implements the E10 mandate.

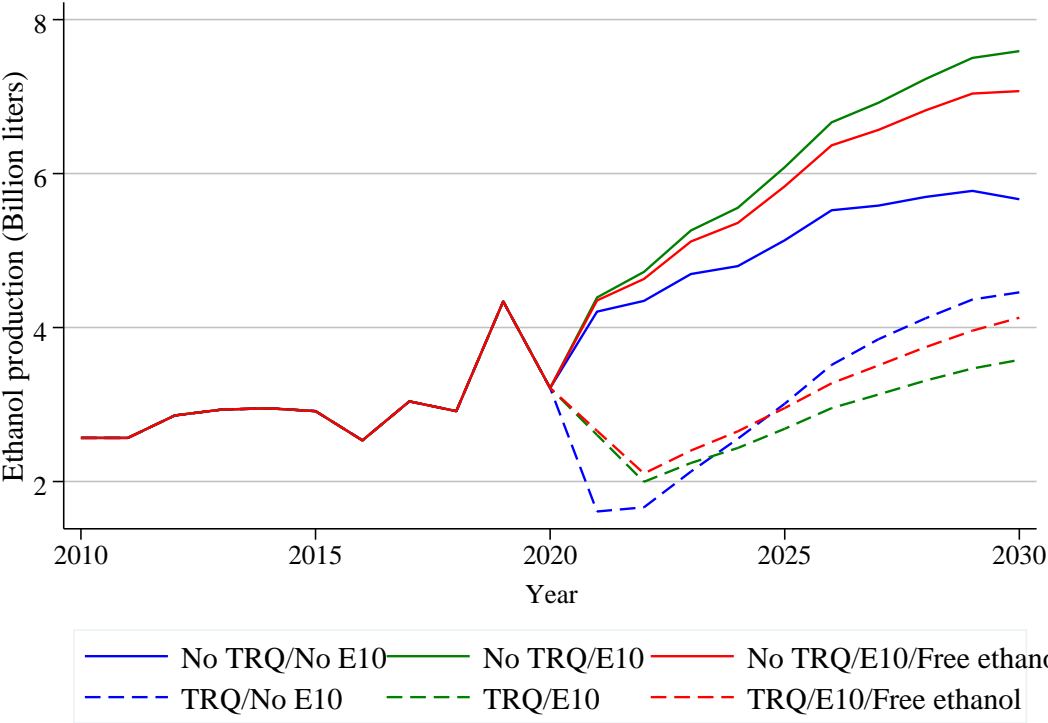


Note: We assume a linear trend of China’s gasoline consumption from 2021 to 2030 and assume China gradually implements the E10 mandate from a blend rate of 2% in 2021 to a blend rate of 10% in 2030.

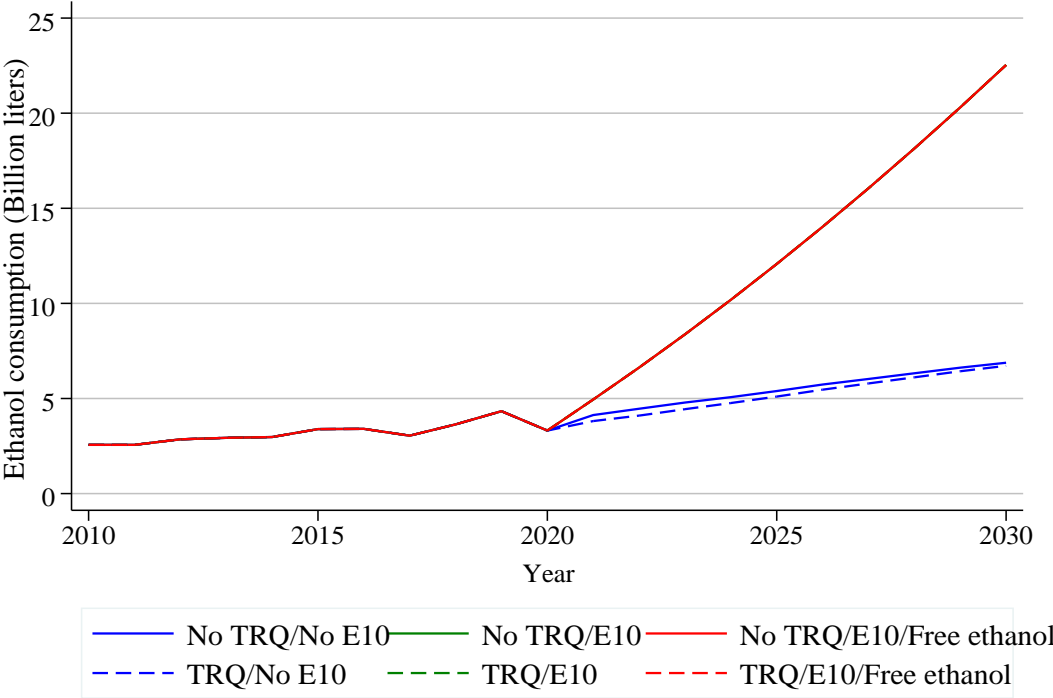
**Figure 3a.** Projected international ethanol price (\$/liter) under the baseline and five other policy scenarios.



**Figure 3b.** China’s projected ethanol production (billion liters) under the baseline and five other policy scenarios.

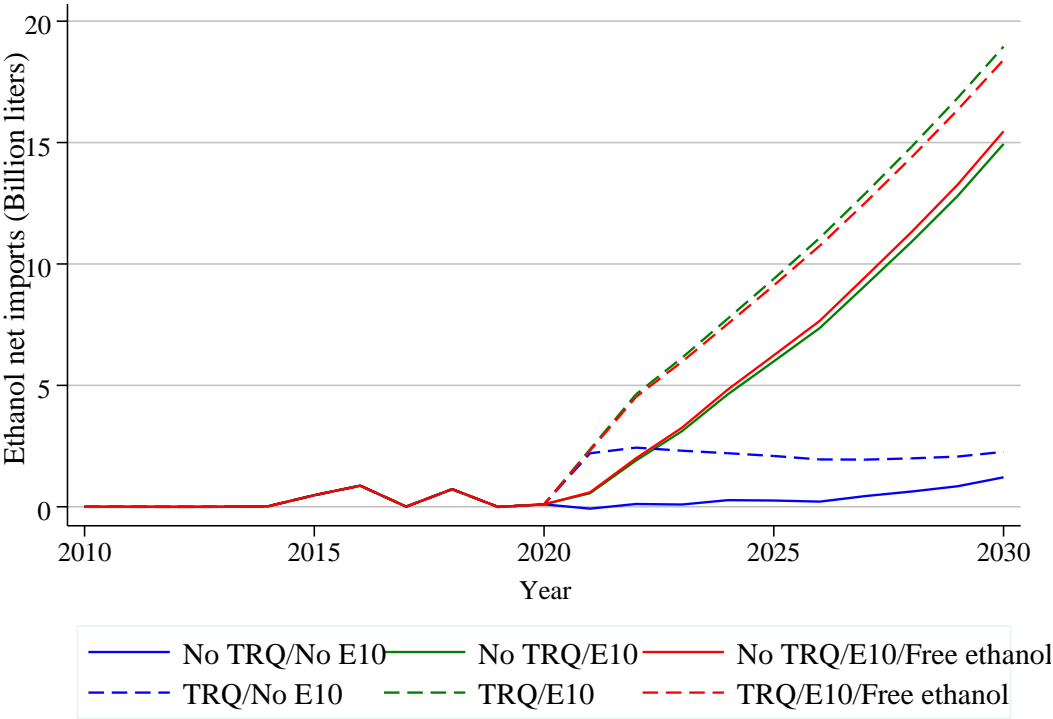


**Figure 3c.** Projected China’s ethanol consumption (billion liters) under the baseline and five other policy scenarios.

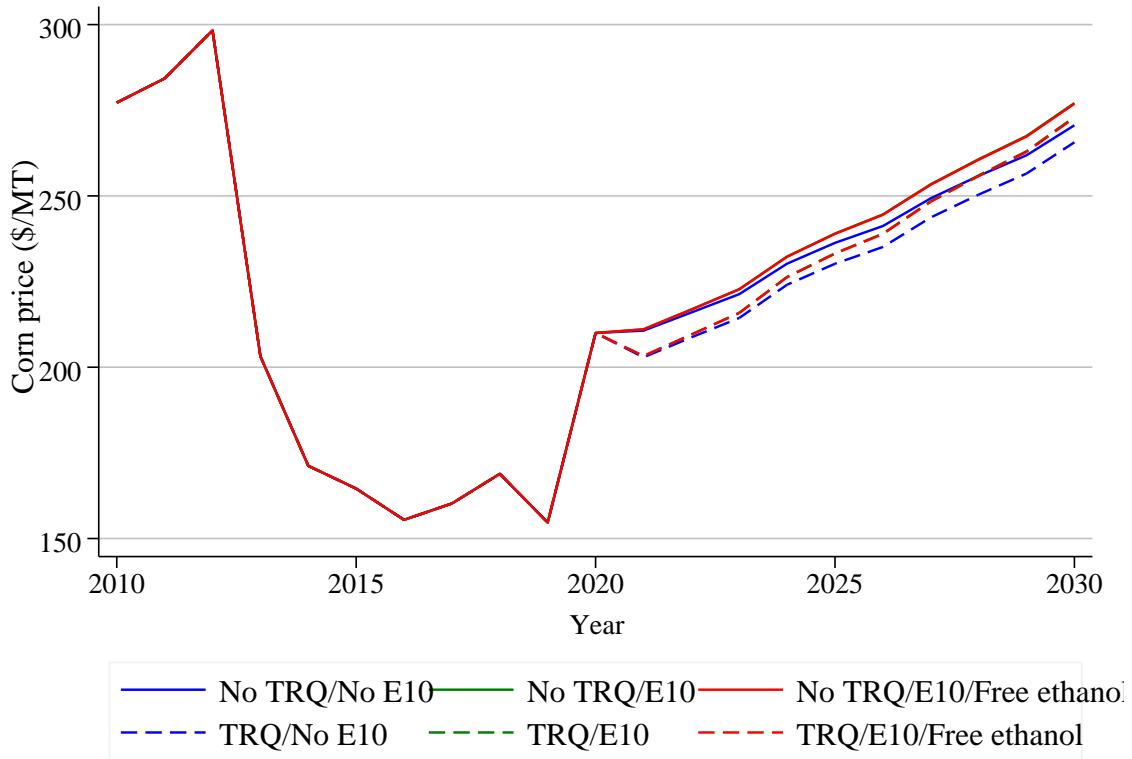


Note: Ethanol consumption under the four scenarios with E10 coincides (solid red line) because the ethanol consumption when China implements the E10 is exogenously determined by the projected gasoline consumption and the assumption that the blend rate would gradually increase from 2% in 2021 to 10% in 2030.

**Figure 3d.** China’s projected ethanol net imports (billion liters) under the baseline and five other policy scenarios.

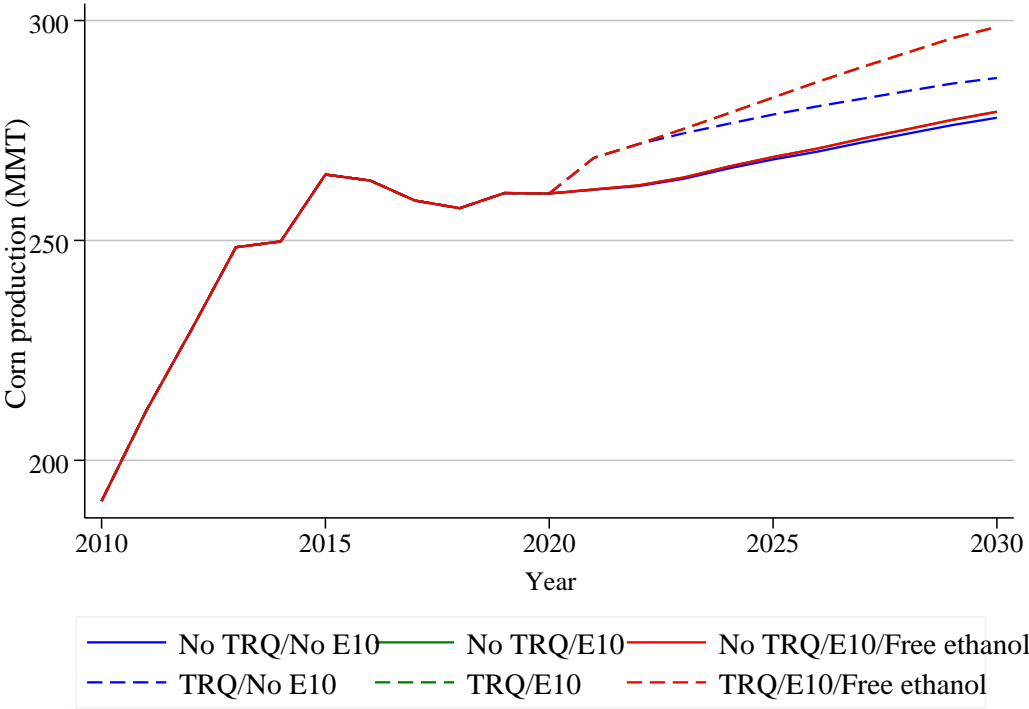


**Figure 4a.** Projected international corn price (\$/metric ton) under the baseline and five other policy scenarios.



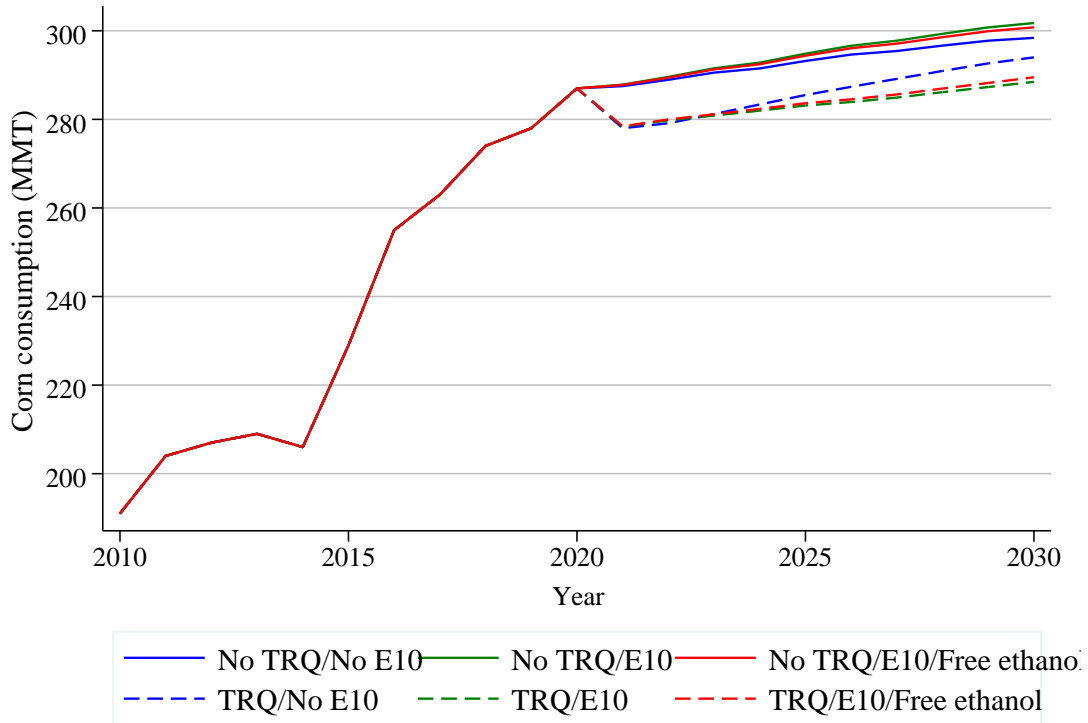
Note: Note that the prices in scenarios “No TRQ/E10” and “No TRQ/E10/Free ethanol” are quite similar, and the prices in scenarios “TRQ/E10” and “TRQ/E10/Free ethanol” are also quite similar.

**Figure 4b.** China’s projected corn production (million metric tons) under the baseline and five other policy scenarios.



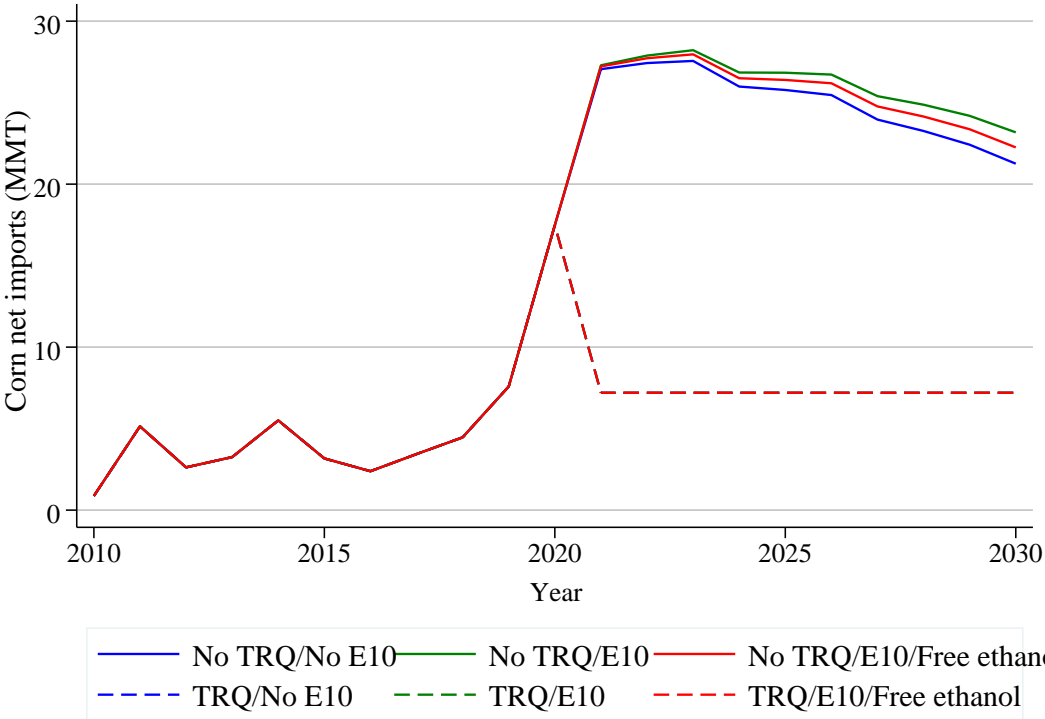
Note: Production in scenarios “No TRQ/E10” and “No TRQ/E10/Free ethanol” are quite similar, and the production in scenarios “TRQ/E10” and “TRQ/E10/Free ethanol” are also quite similar.

**Figure 4c.** China's projected corn consumption (million metric tons) under the baseline and five other policy scenarios.



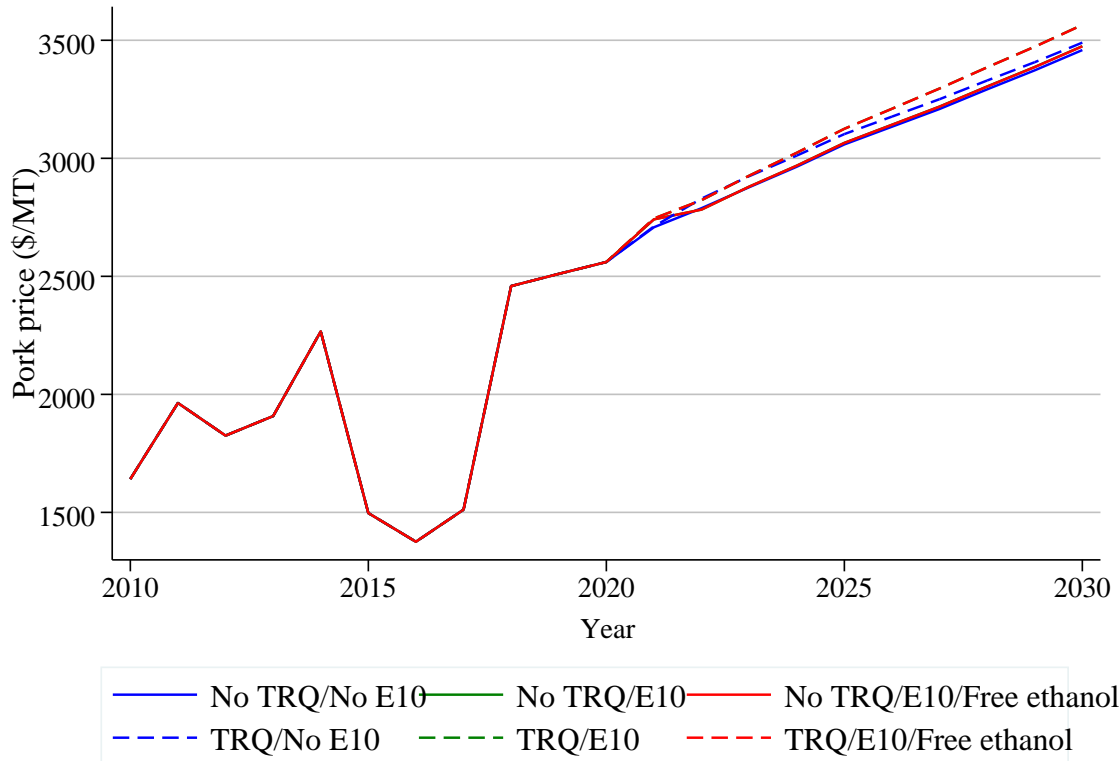


**Figure 4d.** China’s projected corn net-imports (million metric tons) under the baseline and five other policy scenarios.



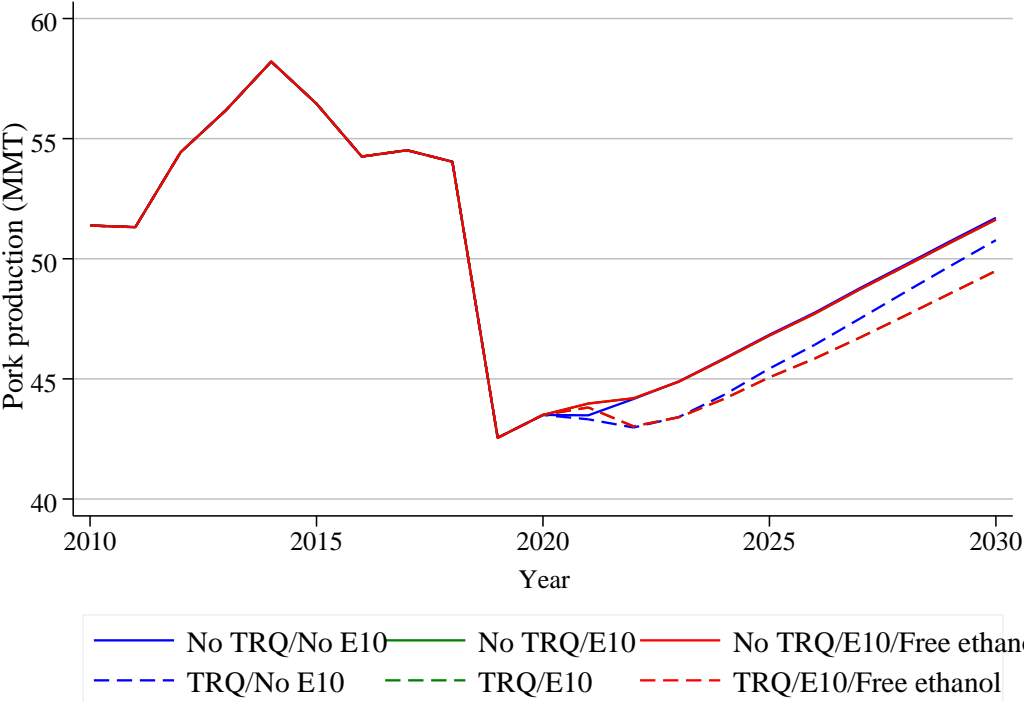
Note: China’s corn imports will be at the TRQ of 7.2 MMT when China imposes corn TRQ.

**Figure 5a.** Projected international pork price (\$/metric ton) under the baseline and five other policy scenarios.



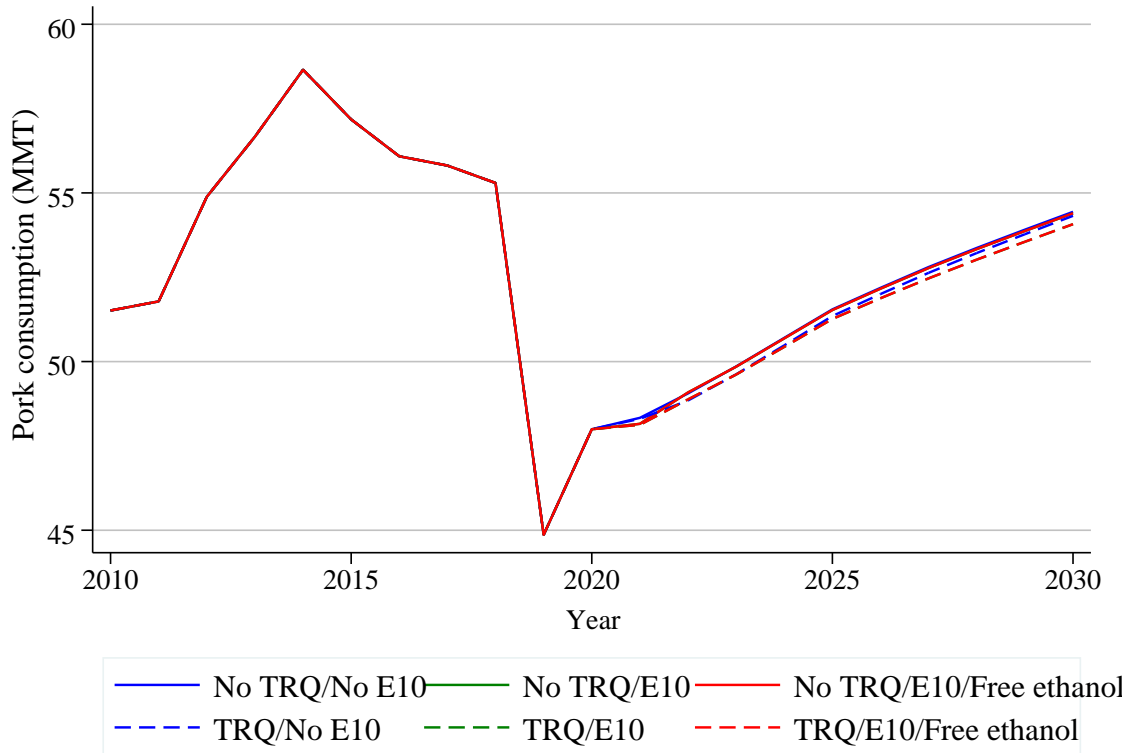
Note: The reason international pork prices are higher when China enforces corn TRQ is that restricted corn imports limit China's pork production and increase China's pork import demand, which further leads to increases in international pork prices.

**Figure 5b.** China’s projected pork production (million metric tons) under the baseline and five other policy scenarios.

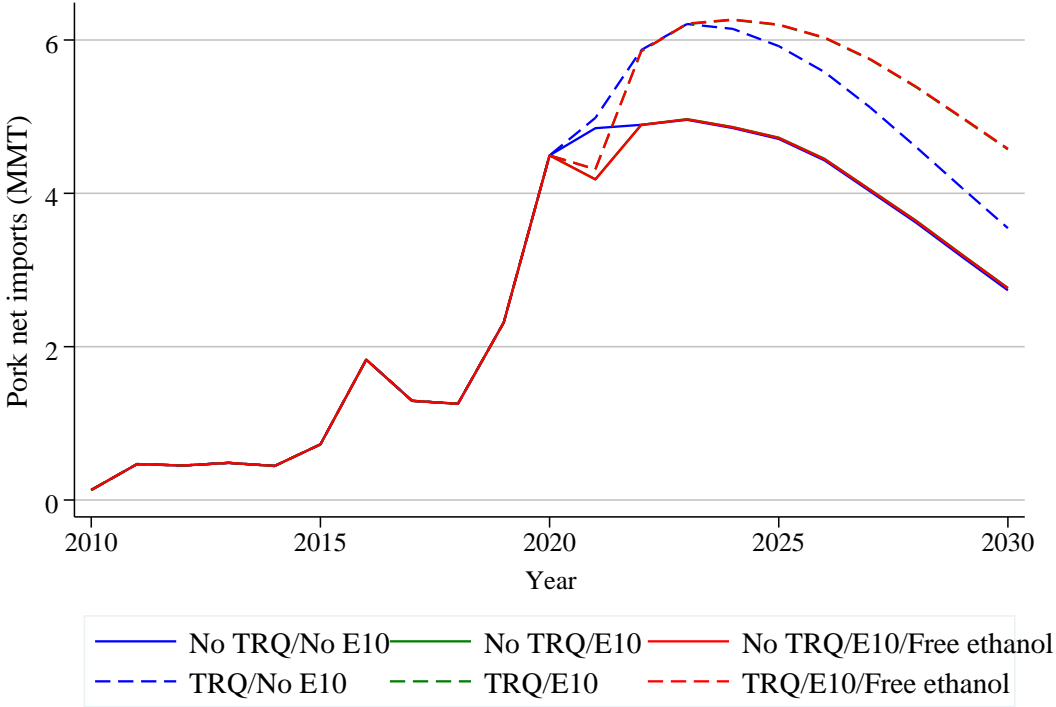


Note: Note that the production in scenarios “No TRQ/E10” and “No TRQ/E10/Free ethanol” are quite similar, and the production in scenarios “TRQ/E10” and “TRQ/E10/Free ethanol” are also quite similar.

**Figure 5c.** China's projected pork consumption (million metric tons) under the baseline and five other policy scenarios.



**Figure 5d.** China’s projected pork net imports (million metric tons) under the baseline and five other policy scenarios.

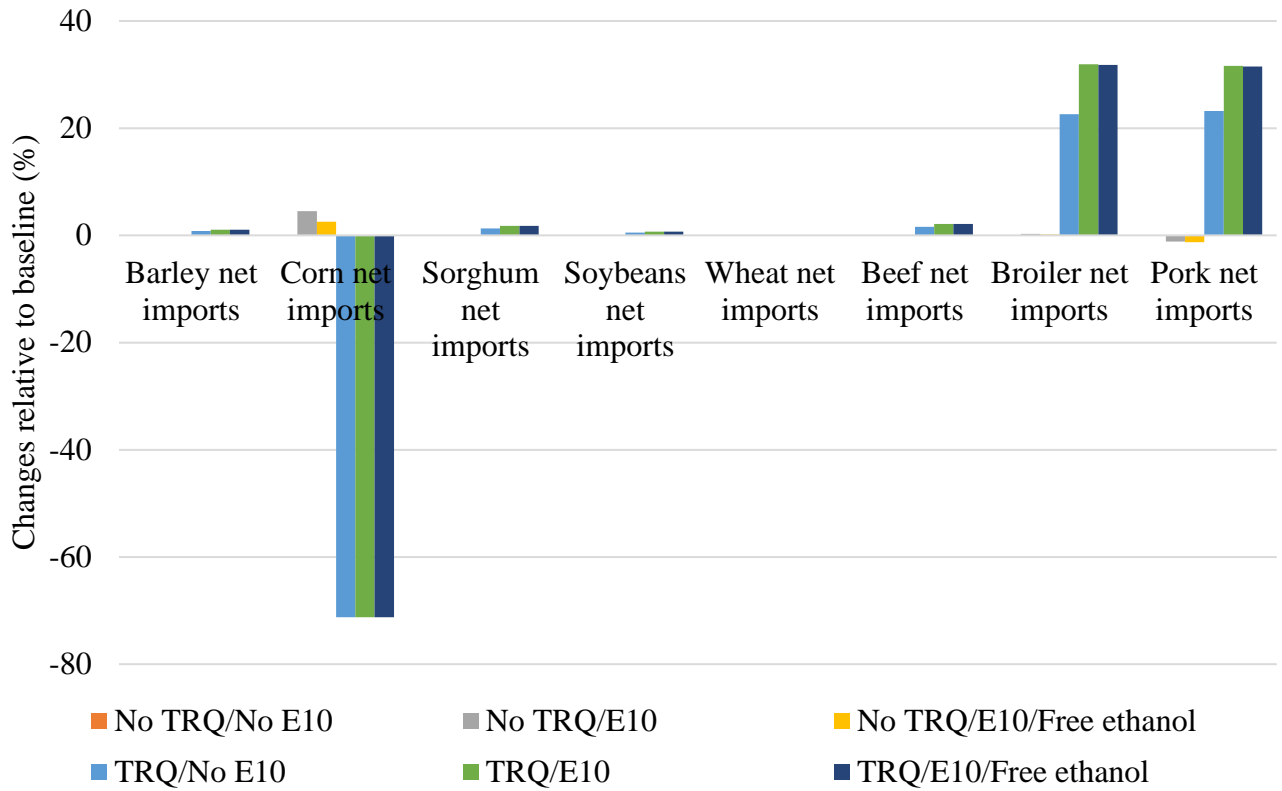


Note: Note that the net imports in scenarios “No TRQ/E10” and “No TRQ/E10/Free ethanol” are quite similar, and the net imports in scenarios “TRQ/E10” and “TRQ/E10/Free ethanol” are also quite similar.

**Figure 6a** Projected percent changes in prices of major feed grains and meat products compared with the baseline scenario, 2021–2030.



**Figure 6b.** Projected percent changes in net imports of major feed grains and meat products compared with the baseline scenario, 2021–2030.



**Table 1.** Baseline and five simulation scenarios

	Corn TRQ	Ethanol tariff (45% on ethanol from the US, 30% on ethanol from non-US countries)	Ethanol Mandate
<b>Baseline: scenario 1</b>	No	Yes	No
Scenario 2	No	Yes	Yes
Scenario 3	No	No	Yes
Scenario 4	Yes	Yes	No
Scenario 5	Yes	Yes	Yes
Scenario 6	Yes	No	Yes

Note: China officially set its corn TRQ at 7.2 MMT; however, in 2020, it imported 17.4 MMT of corn and did not implement the TRQ. Therefore, in the baseline scenario, we assume China does not implement the corn TRQ.



**Table 2.** Comparisons of projected prices, production, consumption, and imports of ethanol, corn, and pork under different scenarios

Value	<u>2020</u>	<u>Average 2021-2030</u>					
		<u>No TRQ</u>			<u>TRQ</u>		
	No TRQ/No E10	No TRQ/E10	No TRQ/E10/Free ethanol	TRQ/No E10	TRQ/E10	TRQ/E10/Free ethanol	
<b><i>Panel A: Value</i></b>							
<b><i>Ethanol</i></b>							
Price (\$/Liter)	0.78	0.85	1.02	1.03	0.89	1.09	1.10
Production (Million liters)	3,214	5,142	6,192	5,916	3,127	3,139	2,840
Consumption (Million liters)	3,314	5,543	13,326	13,326	5,274	13,326	13,326
Net imports (Million liters)	100	401	7,134	7,410	2,146	10,189	10,488
<b><i>Corn</i></b>							
Price (\$/Metric ton)	210.00	239.33	242.53	242.42	233.16	236.67	236.79
Production (Thousand metric tons)	260,670	269,361	270,032	270,009	278,954	284,027.3	284,026.6
Consumption (Thousand metric tons)	287,000	293,462	295,287	294,772	286,131	284,045	283,487
Net imports (Thousand metric tons)	17,480	25,015	26,142	25,650	7,200	7,200	7,200
<b><i>Pork</i></b>							
Price (\$/Metric ton)	2,560	3,086	3,096	3,096	3,123	3,157.06	3,157.24
Production (Thousand metric tons)	47,995	51,621	51,584	51,586	51,455	51,331.2	51,331.2
Consumption (Thousand metric tons)	43,500	47,397	47,410	47,416	46,251	45,771	45,777
Net imports (Thousand metric tons)	4,495	4,224	4,174	4,170	5,205	5,560	5,554

**Panel B: Percent change  
relative to the baseline  
scenario**

**Ethanol**

Price (\$/Liter)	0	20.04%	20.84%	4.54%	28.68%	29.56%
Production (Million liters)	0	20.41%	15.04%	-39.18%	-38.96%	-44.76%
Consumption (Million liters)	0	140.42%	140.42%	-4.86%	140.42%	140.42%
Net imports (Million liters)	0	1681.34%	1750.23%	435.83%	2444.09%	2518.61%

**Corn**

Price (\$/Metric ton)	0	1.34%	1.29%	-2.58%	-1.11%	-1.06%
Production (Thousand metric tons)	0	0.25%	0.24%	3.56%	5.44%	5.44%
Consumption (Thousand metric tons)	0	0.62%	0.45%	-2.50%	-3.21%	-3.40%
Net imports (Thousand metric tons)	0	4.51%	2.54%	-71.22%	-71.22%	-71.22%

**Pork**

Price (\$/Metric ton)	0	0.33%	0.32%	1.20%	2.29%	2.30%
Production (Thousand metric tons)	0	-0.07%	-0.07%	-0.32%	-0.56%	-0.56%
Consumption (Thousand metric tons)	0	0.03%	0.04%	-2.42%	-3.43%	-3.42%
Net imports (Thousand metric tons)	0	1.17%	1.28%	23.22%	31.63%	31.49%

Note: This table presents projected prices, production, consumption, and net imports of ethanol, corn, and pork in 2020 and 2030 and the percentage changes of these outcomes in the five policy scenarios relative to the baseline scenario in 2030.

**Table 3.** Self-sufficiency of major feed grains and meat products

Self-sufficiency	Corn	Soybeans	Wheat	Barley	Rice	Sorghum	Pork	Beef	Broiler	Ethanol
2017	98.69%	13.99%	97.86%	11.76%	97.30%	35.94%	97.68%	87.82%	101.09%	99.84%
2020	93.72%	15.43%	94.38%	11.39%	100.61%	32.57%	90.63%	70.63%	96.72%	96.98%
<b>2021-2030 average</b>										
Baseline:										
No TRQ/No E10	91.50%	15.08%	93.46%	8.98%	99.89%	31.28%	91.82%	72.84%	95.42%	92.77%
Scenario 1:										
No TRQ/E10	91.17%	15.06%	93.46%	9.04%	99.72%	31.30%	91.91%	72.84%	95.41%	46.46%
Scenario 2:										
No TRQ/E10/Free Ethanol	91.32%	15.06%	93.46%	9.04%	99.73%	31.30%	91.92%	72.84%	95.41%	44.39%
Scenario 3:										
TRQ/No E10	97.48%	14.69%	93.46%	8.58%	98.74%	30.44%	89.89%	72.41%	94.39%	59.30%
Scenario 4:										
TRQ/E10	97.53%	14.49%	93.46%	8.48%	97.60%	30.11%	89.17%	72.26%	93.97%	22.93%
Scenario 5:										
TRQ/E10/Free Ethanol	97.53%	14.49%	93.46%	8.48%	97.60%	30.11%	89.18%	72.26%	93.97%	20.69%

Note: This table presents China's self-sufficiency rate, measured as production / (production + imports) of major feed grains and meat products in 2017, 2020, and 2021–2030 under different scenarios.

**Table 4.** Major exporting countries' exports of main agricultural commodities under different scenarios

	<u>2020</u>	<u>Average 2021-2030</u>					
		<u>No TRQ</u>		<u>TRQ</u>			
	No TRQ/No E10 (Baseline)	No TRQ/E10	No TRQ/E10/Free ethanol	TRQ/No E10	TRQ/E10	TRQ/E10/Free ethanol	
<b>Panel A: Value</b>							
<b>Corn (Thousand metric tons)</b>							
Argentina	33,995	29,361	29,765	29,750	28,266	28,679	28,695
Brazil	37,500	39,447	40,885	40,835	36,082	37,555	37,611
Ukraine	23,985	20,754	20,847	20,844	20,538	20,641	20,645
United States	64,138	68,389	65,114	64,802	61,590	57,133	56,970
<b>Ethanol (Million liters)</b>							
United States	4,069	4,498	7,496	7,621	5,379	8,998	9,131
<b>Pork (Thousand metric tons)</b>							
Brazil	1,225	1,225	1,229	1,229	1,301	1,330	1,330
Canada	1,200	1,291	1,298	1,297	1,333	1,364	1,364
EU	4,080	4,057	4,085	4,084	4,290	4,423	4,422
United States	2,826	2,892	2,903	2,901	3,149	3,265	3,264
<b>Panel B: Percent change relative to the baseline scenario</b>							
<b>Corn</b>							
Argentina	0	1.38%	1.33%	-3.73%	-2.32%	-2.27%	
Brazil	0	3.65%	3.52%	-8.53%	-4.80%	-4.66%	
Ukraine	0	0.45%	0.43%	-1.04%	-0.54%	-0.53%	
United States	0	-4.79%	-5.24%	-9.94%	-16.46%	-16.70%	
<b>Ethanol</b>							
United States	0	66.64%	69.41%	19.59%	100.04%	103.00%	
<b>Pork</b>							
Brazil	0	0.29%	0.28%	6.15%	8.58%	8.56%	
Canada	0	0.51%	0.50%	3.27%	5.66%	5.65%	
EU	0	0.69%	0.67%	5.76%	9.03%	9.02%	
United States	0	0.37%	0.32%	8.89%	12.90%	12.86%	

Note: This table shows the projected major exporting countries' exports of corn, ethanol, and pork during 2021–2030.

Table 5. Global exports of corn, ethanol, and pork

	<u>2020</u>		<u>Average 2021-2030</u>				
			<u>No TRQ</u>		<u>TRQ</u>		
		No TRQ/No E10 (Baseline)	No TRQ/E10	No TRQ/E10/Free ethanol	TRQ/No E10	TRQ/E10	TRQ/E10/Free ethanol
<b>Panel A: Value</b>							
<i>Corn (Thousand metric tons)</i>	165,826	169,020	167,116	166,319	158,603	154,563	154,432
<i>Ethanol (Million liters)</i>	4,084	5,797	15,858	16,288	6,346	18,788	19,248
<i>Pork (Thousand metric tons)</i>	9,624	9,303	9,328	9,322	9,852	10,563	10,561
<b>Panel B: Percent change relative to the baseline scenario</b>							
<i>Corn</i>		0	-1.13%	-1.60%	-6.16%	-8.55%	-8.63%
<i>Ethanol</i>		0	173.57%	180.99%	9.47%	224.12%	232.05%
<i>Pork</i>		0	0.26%	0.21%	5.90%	13.54%	13.52%

Note: This table shows the projected world exports of corn, ethanol, and pork during 2021–2030.