**Title page**

# 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**

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Acknowledgments: 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 IOW04099 and grant 2019-67023-29414.

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

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**Abstract**

We calibrate the Center for Agricultural and Rural Development 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 plausible policy scenarios focusing on ethanol, corn, and pork from 2021 to 2030. Our baseline projection reflects China’s current policy of relaxing the tariff rate quota (TRQ) for corn and imposing ethanol tariff without any ethanol/gasoline blend mandate. Baseline projections show China’s ethanol imports grow from 100 million liters in 2020 to 1.21 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, adopting the ethanol mandate increases China’s corn and pork imports, and resuming 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:** Chinese 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

After China's accession to the World Trade Organization (WTO) in 2001, its agricultural imports persistently increased from $15.4 billion in 2001 to $170.8 billion in 2020 (USDA GATS, 2021). However, China's pursuit of self-sufficiency in food production has restricted its agricultural imports far below the import potential under free trade (Li et al., 2018). For example, prior to 2019, China's corn imports never exceeded its tariff rate quota (TRQ) of 7.2 million tons despite a relatively high domestic corn price relative to the world price. China has shown a willingness to liberalize its agricultural trade recently due to a confluence of factors including, but not limited to, continuously growing domestic demand, the need to restock after an African swine fever (ASF) outbreak, the phase one trade deal with the United States, and structural changes in food consumption patterns and constrained land and water resources (Huang et al., 2017; Sheng & Song, 2019). In 2020, China suspended its TRQ for corn, and imports reached a historical 17.4 million tons, far exceeding the previous TRQ. Partially due to China's greater corn demand, corn futures prices surged from about $3 per bushel in June 2020 to about $6 per bushel in June 2021.

China is the world's second-largest corn producer after the United States and the fourth-largest fuel ethanol producer, with corn being the main feedstock in its ethanol production. As China liberalizes its corn import market, its domestic policies on corn-related products will have even greater effects on the international market. In particular, China has long been interested in promoting fuel ethanol, but the lack of feedstock, the most important of which is corn (Li et al., 2017), has hampered this effort. In its recent attempt in September 2017, China announced an expansion of the mandatory use of 10% ethanol blend gasoline (E10) from 11 trial provinces to the entire country by 2020.[1] This mandate had to be abandoned in 2020 because of the shortage of feedstock. Relaxing corn and ethanol import policies will make a nationwide ethanol mandate feasible. In this study, we model how different combinations of corn TRQ, ethanol tariffs, and the ethanol mandate would drive the markets of corn, ethanol, and related commodities such as pork.

The title of Li et al. (2018) "The Impossible Trinity of China's Corn Related Policies" helps motivate this study and summarizes our results. China has put in place a set of mutually inconsistent agricultural policies—it cannot achieve its goal of self-sufficiency in grains and meats while also improving diets and enforcing an E10 mandate. This has created instability in its agricultural policies, as witnessed by the sudden abandonment of the corn import quota in the fall of 2020. Had it not done so, its hog herd would not have been able to recover from ASF; however, in doing so, it made it more challenging to incentivize domestic corn production. This state of flux and associated changes in policy have roiled world commodity markets, and we expect it to continue. This paper presents a set of plausible policy scenarios that reflect Chinese government's competing desires for grain self-sufficiency and energy independence. We show how these policy changes might impact world trade and commodity prices.

While some studies investigate how China's biofuel expansion and E10 mandate affects China's crop and ethanol markets (Si et al., 2017), few studies examine and project the potential impacts of China's corn and ethanol policies on global agricultural markets (Li et al., 2017; Ge & Lei, 2017; Weng et al., 2019). In particular, Weng et al. (2019) build a general equilibrium model that incorporates an explicit land use module to quantify land use changes induced by bioethanol expansion and suggest suitable approaches for land use management and feedstock selection to avoid potential negative impacts on land resources and food security. Si et al. (2017) examine the effect of the E10 mandate and ethanol production subsidy on ethanol supply, ethanol price and crop production.

In this paper, we use the International Agricultural Commodity Market (IACM) model, which is a deterministic partial equilibrium modeling system, to project China's agricultural imports from 2021 to 2030. This model 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 that affect world food supply and demand, including arable land resources, population, and income level changes.[2] The IACM model is an updated version of the FAPRI model (Meyers et al., 2010). FAPRI and USDA baseline reports have been the primary sources of long-run projections about the US farm economy for the last three decades (FAPRI, 2021; USDA Office of the Chief Economist, 2021). Bora et al. (2021) test the accuracy and informativeness of the FAPRI baseline projections and find that the USDA and the FAPRI projections have comparable predictive ability. Moreover, Bora et al. (2021) suggest that, for most variables, projections from the FAPPRI model are informative and accurate for the first 4-5 years. We run the IACAM model to establish 10-year projections for supply, utilization, and prices for six scenarios. For the purpose of this article, we focus on the trade of agricultural commodities in China and major producing countries.

We first project China's agricultural imports in the baseline scenario, reflecting current policies, 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 prices and trade flows of corn, ethanol, and related products, especially pork, across a series of plausible policy scenarios; and, (*b*) to investigate China's substitution between imports of corn, pork, and ethanol under these 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 (2020–2030), while 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 to varying degrees. 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 findings focuses on the exports of corn, ethanol, and related products for 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.

The third 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 meats. 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.

This article contributes to current literature in several ways. First, the projections provide a much needed update of China's import potential after the major shift in its corn import policies. Second, we spell out how an ethanol mandate, made more feasible by expanded imports, would interact with trade policies on corn and ethanol. Third, this study provides insights into China's substitution of imports between ethanol, feed grains, and meat products under different ethanol and corn policies.

The rest of the article is organized as follows. Section 2 describes the trend of China's agricultural imports and relevant corn and ethanol policies. Section 3 describes the Center for Agricultural and Rural Development (CARD) IACM model and presents the baseline and five policy scenarios. Section 4 presents our main findings. Section 5 offers our conclusions.

## 2. Overview of China's Corn and Ethanol Policies and Their Potential Impacts on Global Agricultural Markets

### *2.1 Corn and Ethanol Policies*

China's corn market has been turbulent in the past two decades (He et al., 2020). In 2008, to support farmers' incomes, China started a stockpiling program in which the government purchased corn from farmers at higher than market price. 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, China ended the stockpiling program, reduced corn subsidies, and promoted fuel ethanol. 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, China suspended its corn TRQ. As a result, for the first time since China agreed to an optional corn TRQ of 7.2 MMT in 1996, China's corn imports reached 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.

China's ethanol program has existed for two decades. In 2019, to reduce corn stocks, China announced plans to expand the E10 mandate from several provinces/cities to a nationwide level 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 of 45% in total on US ethanol. Due to a lack of corn supplies and limited ethanol production/import availability, China later suspended the national E10 mandate in 2020.

*2.2 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 we solve 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 embedded in the model.

The enforcement of the corn TRQ would also affect the agricultural and biofuel markets in several ways, depending on whether China implements the E10 mandate. 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 with corn for land including soybeans, wheat, rice, sorghum, and consequently, the production of other major meat products substitutable for pork products, including beef and broilers. Figure A1 in the Appendix 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. As a result, soybeans have accounted for the lion's share of China's agricultural imports and China's imports of corn and wheat were quite limited prior to 2020. We also present the impacts of China's corn and ethanol policies on other related agricultural markets in Section 4.3.

## 3. CARD IACM Model and Policy Scenarios

### *3.1 CARD-IACM Model*

Baseline and scenario projections are determined using the CARD-IACM model, which is a deterministic agricultural modeling system that can quantify the impact of market changes and policies on global land allocation. The older version of this model has been widely used in agricultural and biofuel policy evaluations (Meyers et al., 2010; Elobeid et al., 2012; Carriquiry et al., 2020). The updated 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). Dumortier et al. (2021a, b) use the modified model to analyze the effect of vehicle fuel efficiency on biofuel demand and, consequently, on global agricultural markets, as well as the effects of climate change on trade.

The model is comprised of 22 countries/regions with all agricultural sectors (commodities) contained within each country or region.[3] The countries/regions are selected according to their significance in the agricultural commodity marketplace. Within each country or region, we place each sector's land use 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).[4]

To determine the market equilibria for each year from 2021 to 2030, the model solves for international prices for 10 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.[5]

Based on China's historical gasoline consumption from 2010 to 2020,[6] we project China's gasoline consumption from 2021 to 2031 using a linear trend and then assuming China gradually ramps up the E10 mandate (from a 2% blend rate in 2021 to a 10% blend rate in 2030). Figure 1 shows China's fuel ethanol production, consumption, and imports from 2010 to 2020, and the projected consumption from 2021 to 2030 if China implements the E10 mandate. China's fuel ethanol 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.

There are several critical links between corn and ethanol markets. Ethanol production is a function of the prices of ethanol, corn, and wheat. In particular, the model parameters indicate that ethanol production increases with ethanol price and decreases with corn and wheat prices. Per capita ethanol consumption is a function of the ratio of ethanol price and crude oil price. In addition, the quantity of corn used as feedstock in ethanol production is a function of ethanol production times the share of corn used as feedstock in ethanol production in 2020.

China's corn and ethanol policies will also affect its production of major crops that compete with corn for land 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*

#### *4.1.1 Projected trend*

Figures 2–4 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 (Figure 2a). Over the same period, the international corn price increases 29% from $210/metric ton to $270/metric ton (Figure 3a), and the international pork price increases 35% from $2,560/metric ton to $3,458/metric ton (Figure 4a). China's ethanol imports will grow from 100 million liters in 2020 to 1.213 billion liters in 2030 (Figure 2d). China's corn imports grow from 17.4 MMT in 2019/20 to 27.56 MMT in the 2022/23 marketing year, then gradually decline to 21.25 MMT in the 2029/30 marketing year (Figure 3d). China's pork imports increase from 4.5 MMT in 2020 to 4.95 MMT in 2023, then gradually decline to 2.73 MMT in 2030 (Figure 4d).

The increase in ethanol production in the baseline is in line with the continuing investment in fuel ethanol plants (USDA GAIN, 2021) and the ethanol consumption increase in the baseline is driven by the model parameters that link per capita ethanol consumption to the price ratio of ethanol and crude oil, a ratio that increases over time in the baseline scenario.

For corn production, China's increase results from both higher harvested area (from 41.3 million hectares in 2019/20 to 41.7 million hectares in 2029/30) and increased yield (from 6.32 metric tons per hectare in 2019/20 to 6.67 metric tons per hectare in 2029/30). The increase in corn area partially comes from the reduced area of soybeans, barley, and sorghum. On the consumption side, we project corn feed consumption will 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 2023 and then gradually decline because we project China's pork production will grow faster than consumption as the industry recovers from ASF. In the model, behavioral equations that capture cost as well as technical and biological relations drive pork production. On the demand side, income and prices of pork and competing meats primarily determine pork consumption. 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.

One interesting finding is that Figures 2–4 show an abrupt change in 2021 when China implements the E10 mandate with restricted corn imports. Specifically, in Figures 2a–2d, 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 3a–3d, 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 4a–4d, 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.

*4.1.2 Comparisons between projections in different scenarios*

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 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).

Another interesting finding in Figure 3b (Figure 4b) is that China's corn (pork) production in scenarios "No TRQ/E10" and "No TRQ/E10/Free ethanol" are quite similar, and corn (pork) production in scenarios "TRQ/E10" and "TRQ/E10/Free ethanol" are also quite similar. The comparison of the projections in different scenarios in Table 2 shows some small differences between corn (pork) production in the scenarios with and without free ethanol imports. A major reason for the small difference is that the implementation of the E10 mandate would require China to import large quantities of ethanol regardless of whether China imposes tariffs on ethanol. Therefore, the international corn and pork prices would not change much whether China has free access for ethanol imports or not. Given that China's corn and pork production would also depend largely on international corn and pork prices, China's corn and pork production would not be significantly impacted whether China has free access for ethanol imports or not.

Finally, the results in Table 2 show that China would import more ethanol rather than more corn if it implements the E10 mandate due to the difficulty of expanding ethanol production capacity within a limited time horizon.

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

Figures A2 and A3 in the Appendix 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 A2 in the Appendix 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 A2 in the Appendix 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 for feed grains and ethanol decrease from their 2020 levels. However, China's pork and beef self-sufficiency rates increase slightly 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 access for ethanol and corn imports. China's corn self-sufficiency rate is the lowest, 91.17%, when it implements an E10 mandate with free access for 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 access for 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 and Discussion

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 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.

We project that baseline international prices of ethanol, corn, and pork to increase by 24%, 29%, and 35%, respectively. In addition, we project that China's ethanol imports will gradually grow from 100 million liters to 1.21 billion liters, while China's corn (pork) imports will peak in 2022/23 (2023) 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. This result has certain policy implications, namely that pursuing corn self-sufficiency comes at the expense of pork (meat) self-sufficiency. Moreover, China would import more ethanol rather than more corn if it implements the E10 mandate. Finally, both the E10 mandate and corn import restriction would shift US and world exports from corn to ethanol and pork. Thus, policies that create a larger feed deficit in China would have a significant impact on international grain, biofuel, and livestock markets. These effects would be exacerbated by demand or supply shocks such as those experienced due to the U.S.-China trade war, COVID-19, and the most recent conflict in Ukraine.

As the fourth largest producer of ethanol in the world, China's biofuel policies will affect its corn imports and the world ethanol and agricultural markets. China made an international commitment to peak carbon dioxide emissions by 2030 and biofuels have the potential to be the tool in reaching this goal (USDA GAIN, 2021). This is especially true if biofuels are produced from crop residue and bioenergy crops that do not compete with food production and self-sufficiency (Qin et al., 2017). 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 and comparisons of projections under different policy scenarios provide useful benchmarks and insights for predicting China's agricultural trade prospects and understanding the impacts of China’s corn and biofuel policies on global agricultural markets and the policy mix that would achieve China’s self-sufficiency and climate mitigation goals.

**Endnotes**

1. 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%.

2. 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 et al., 2015).

3. 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.

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

5. 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.

6. Gasoline consumption data come from the US Energy Information Administration (EIA). Available at https://www.eia.gov/international/overview/world.

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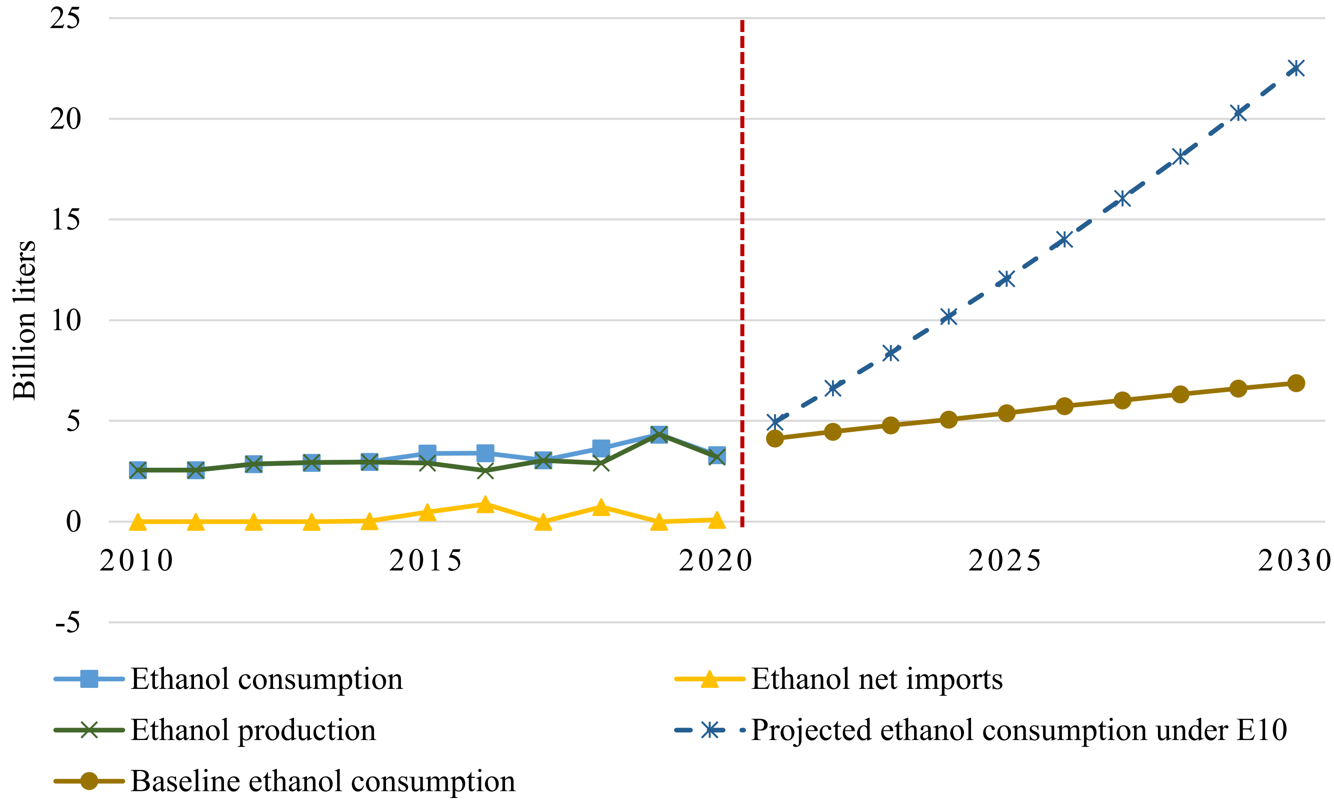
**Figure 1**. China's actual ethanol production, consumption, and imports from 2010 to 2020 and the projected consumption from 2021 to 2030 in the baseline and if China implements the E10 mandate.




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. Historical gasoline data come from US Energy Information Administration (EIA).

**Figure 2a.** Projected international ethanol price ($/liter) under the baseline and five other policy scenarios.

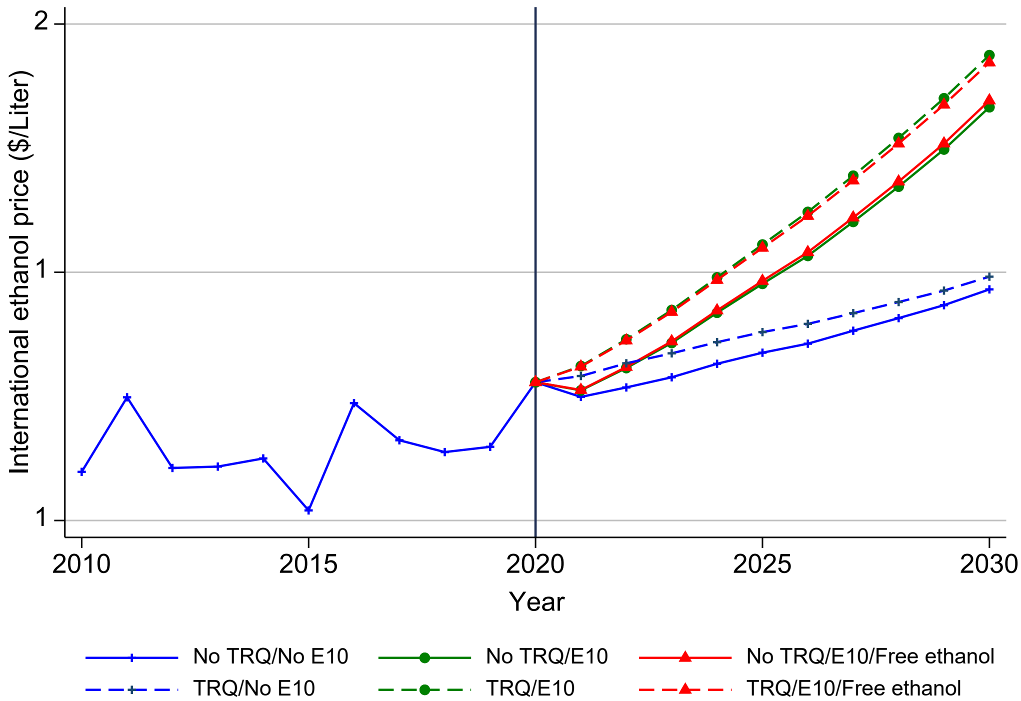


**Figure 2b.** China's projected ethanol production (billion liters) under the baseline and five other policy scenarios.

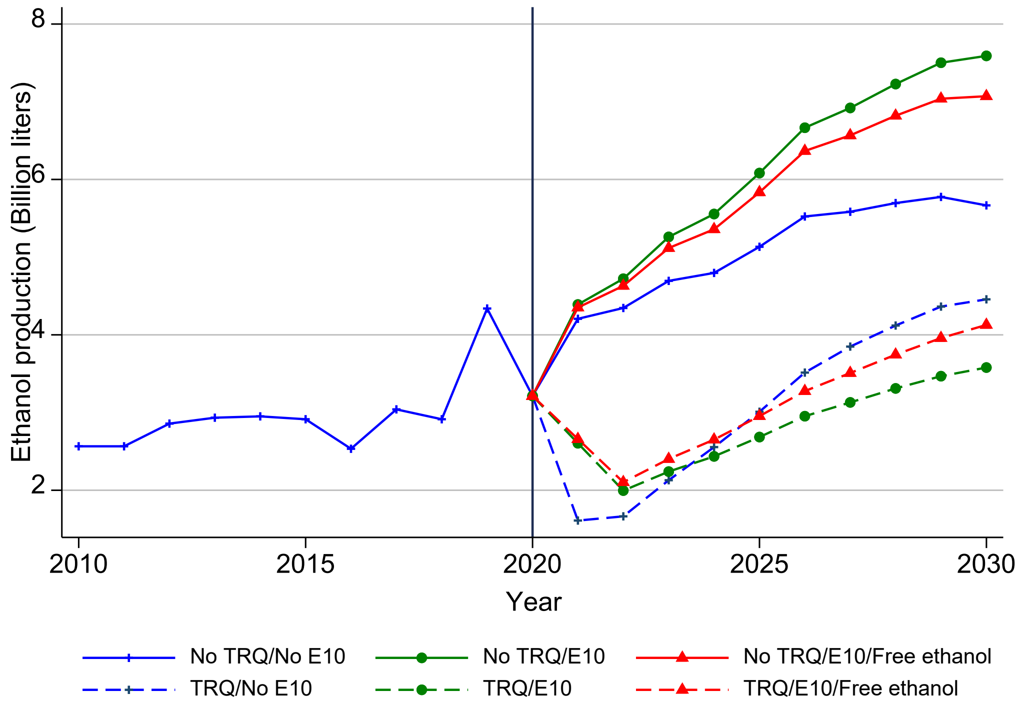
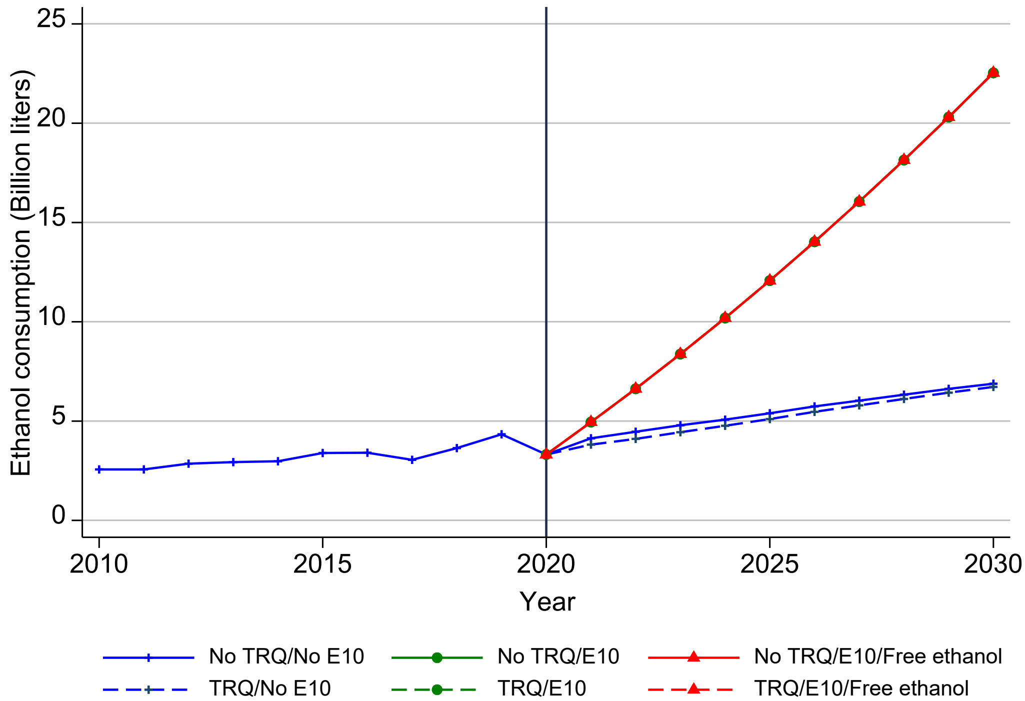


**Figure 2c.** China's projected ethanol consumption (billion liters) under the baseline and five other policy scenarios.




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 2d.** China's projected ethanol net imports (billion liters) under the baseline and five other policy scenarios.

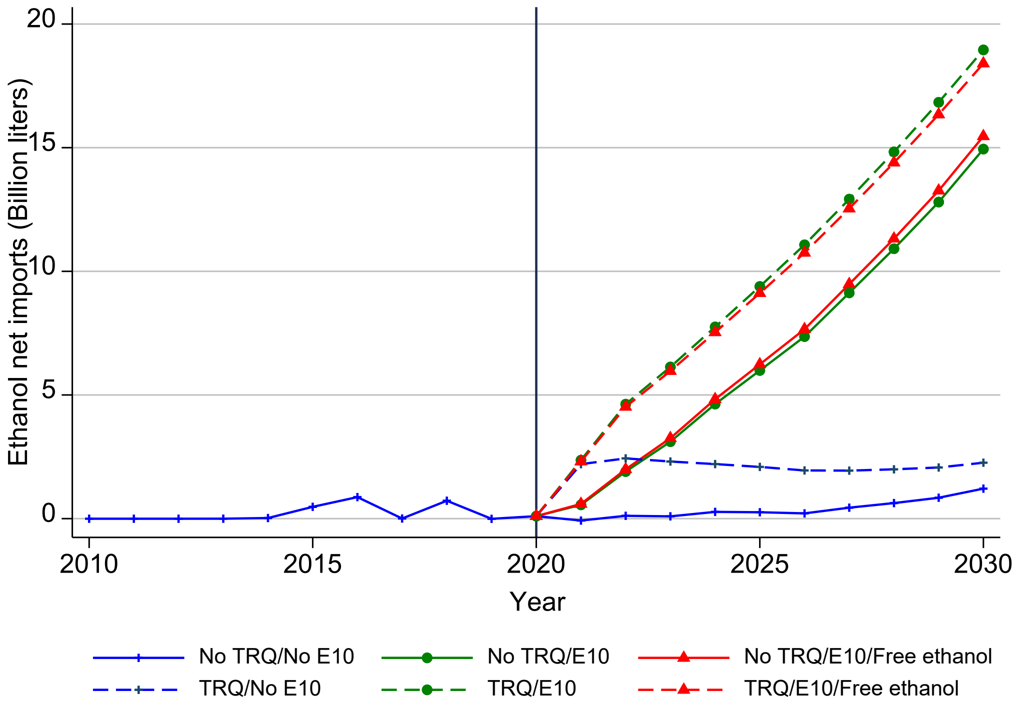
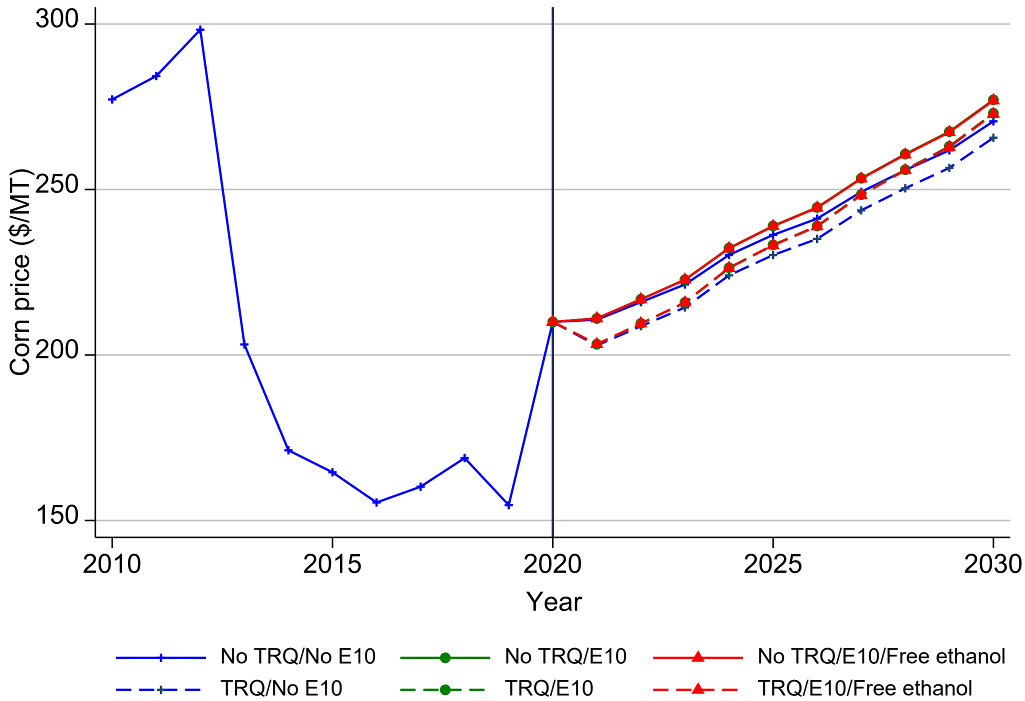
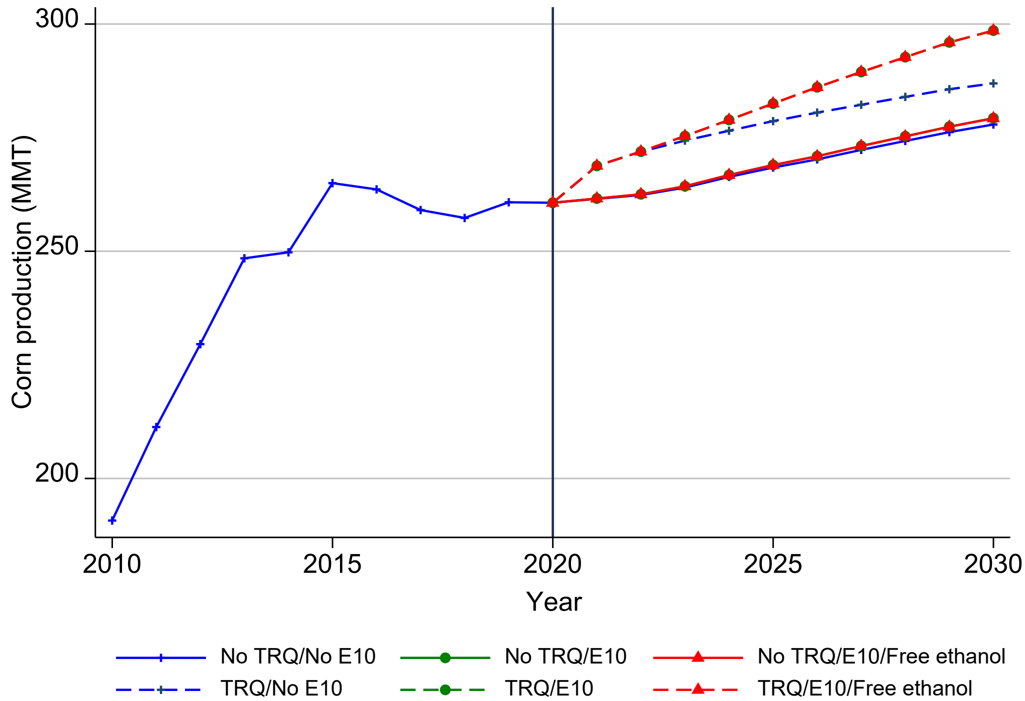


**Figure 3a.** Projected international corn price ($/metric ton) under the baseline and five other policy scenarios.




Note: 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 3b.** 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 3c.** China's projected corn consumption (million metric tons) under the baseline and five other policy scenarios.

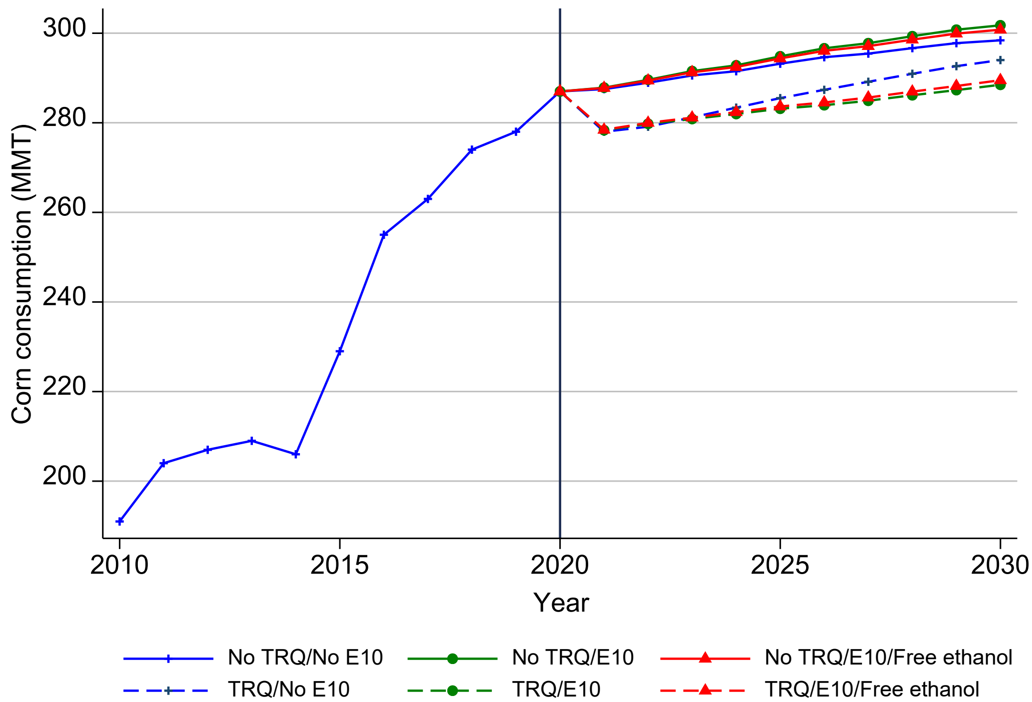



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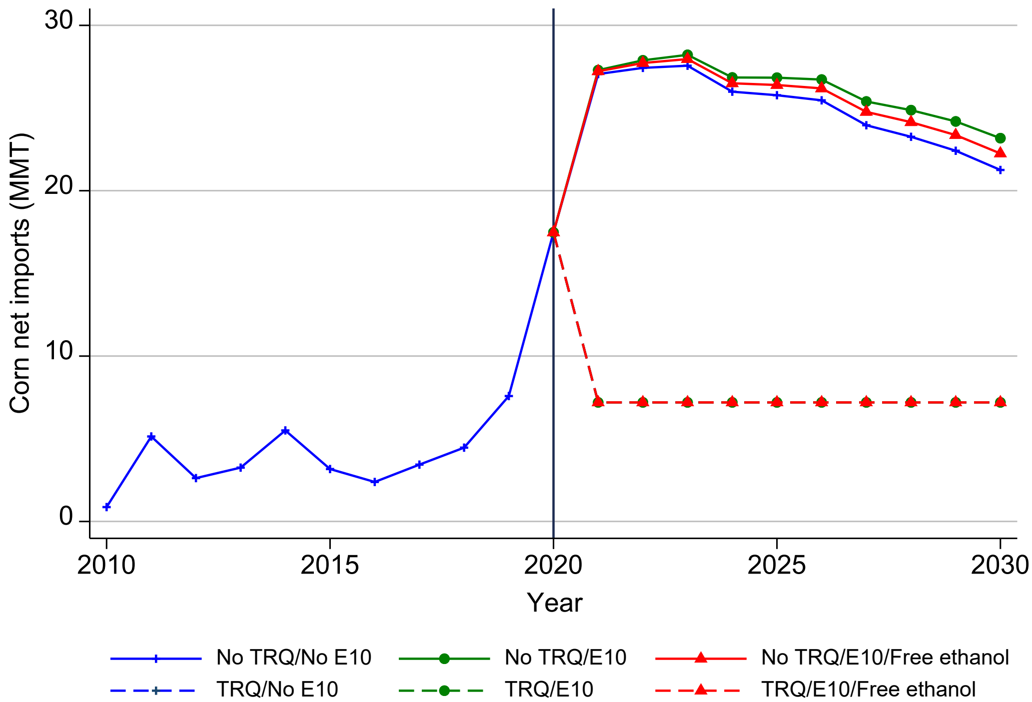
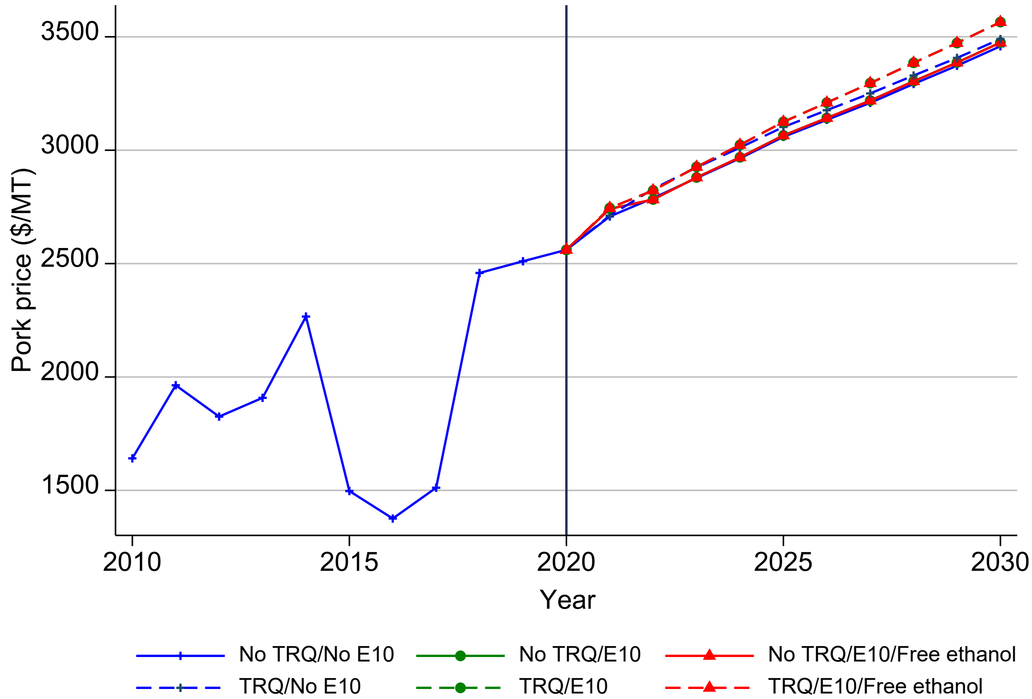
**Figure 3d.** China's projected corn net imports (million metric tons) under the baseline and five other policy scenarios.



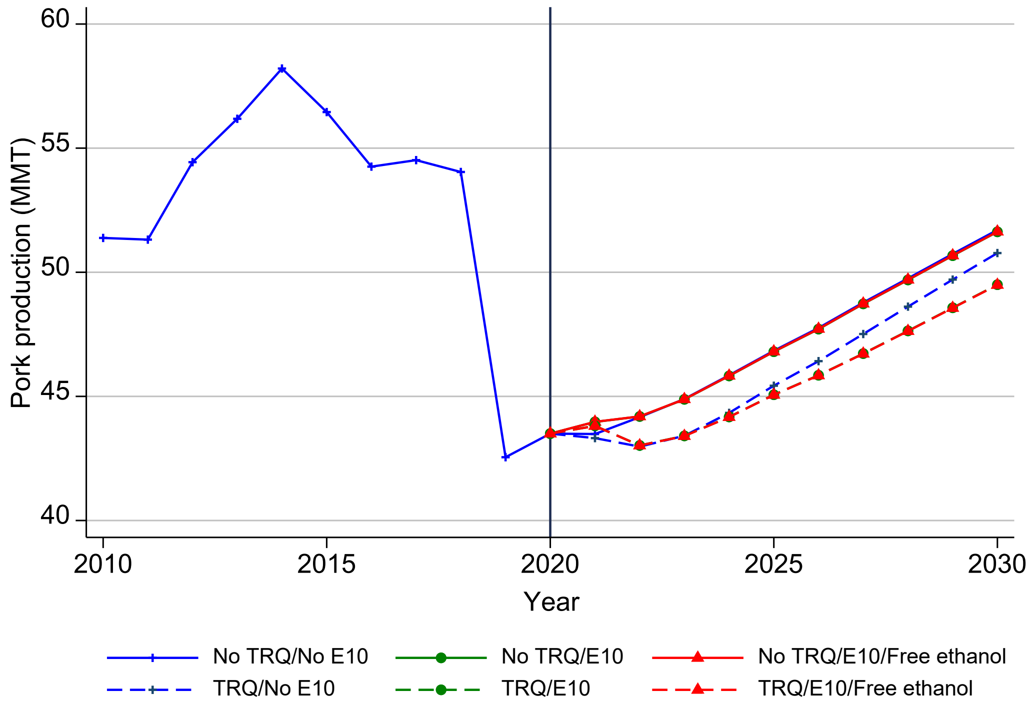

Note: China's corn imports will be at the TRQ of 7.2 MMT when China imposes corn TRQ.

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

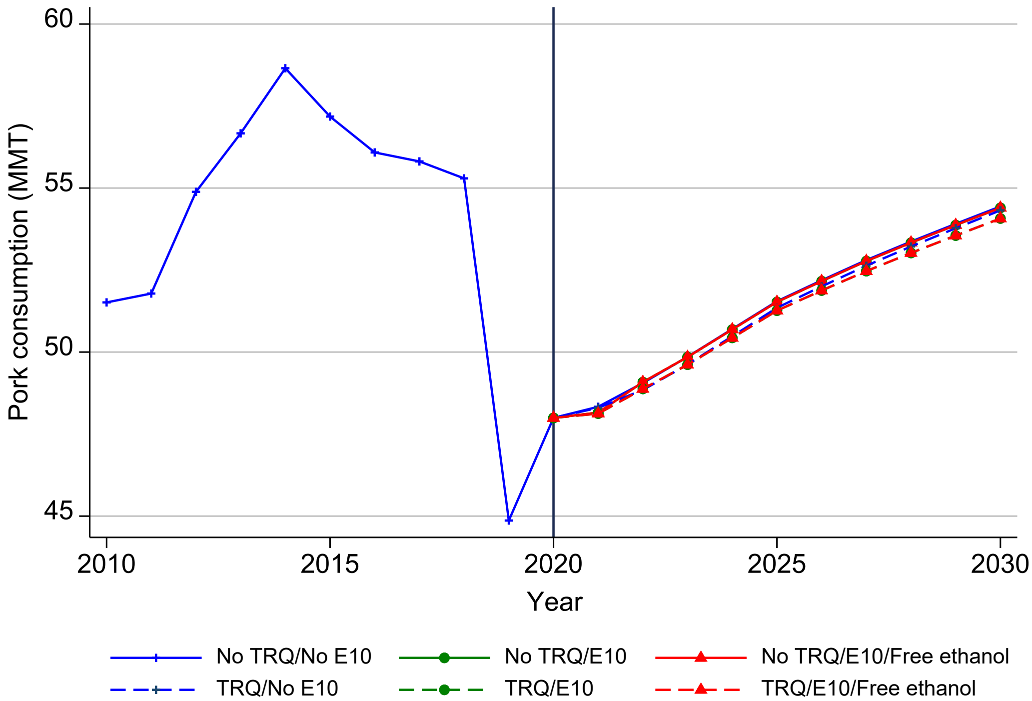
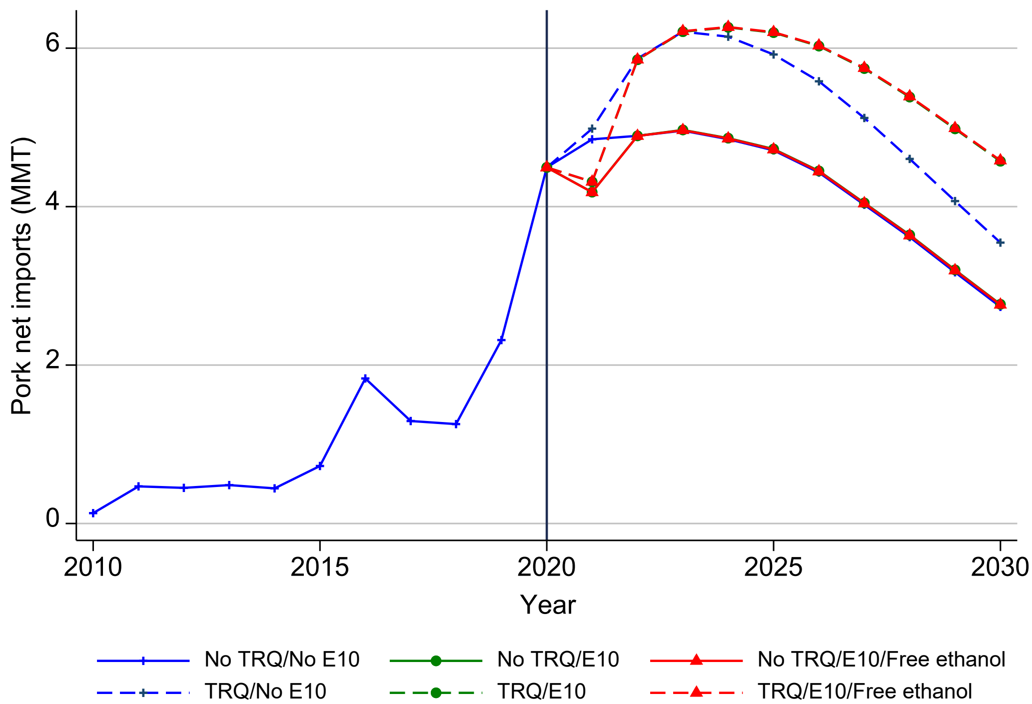


**Figure 4d.** China's projected pork net imports (million metric tons) under the baseline and five other policy scenarios.




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.

**Table 1.** Baseline and Five Simulation Scenarios

| | Scenarios | Corn TRQ | Ethanol Tariff (45% on ethanol from the US, 30% on ethanol from non-US countries) | Ethanol Mandate |
|---|---|---|---|---|
| Baseline: Scenario 1 | No TRQ/No E10 | No | Yes | No |
| Scenario 2 | No TRQ/E10 | No | Yes | Yes |
| Scenario 3 | No TRQ/No E10/Free Ethanol | No | No | Yes |
| Scenario 4 | TRQ/No E10 | Yes | Yes | No |
| Scenario 5 | TRQ/No E10 | Yes | Yes | Yes |
| Scenario 6 | No TRQ/No E10/Free Ethanol | 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

| | 2020 | Average 2021–2030 | | | | | |
|---|---|---|---|---|---|---|---|
| | | No TRQ | | | TRQ | | |
| Value | | No TRQ/No E10 | No TRQ/E10 | No TRQ/E10/Free ethanol | TRQ/No E10 | TRQ/E10 | TRQ/E10/Free ethanol |
| ***Panel A: Value*** | | | | | | | |
| ***Ethanol*** | | | | | | | |
| Price ($/Liter) | 0.78 | 0.85 | 1.02 | 1.03 | 0.89 | 1.09 | 1.10 |
| Production (Million liters) | 3,214 | 5,142 | 6,192 | 5,916 | 3,127 | 3,139 | 2,840 |
| Consumption (Million liters) | 3,314 | 5,543 | 13,326 | 13,326 | 5,274 | 13,326 | 13,326 |
| Net imports (Million liters) | 100 | 401 | 7,134 | 7,410 | 2,146 | 10,189 | 10,488 |
| ***Corn*** | | | | | | | |
| Price ($/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 |
| ***Pork*** | | | | | | | |
| 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% |
| ***2021–2030 average*** | | | | | | | | | | |
| 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

| | 2020 | Average 2021–2030 | | | | | |
|---|---|---|---|---|---|---|---|
| | | No TRQ | | | TRQ | | |
| | | No TRQ/No E10 (Baseline) | No TRQ/E10 | No TRQ/E10/Free ethanol | TRQ/No E10 | TRQ/E10 | TRQ/E10/Free ethanol |
| ***Panel A: Value*** | | | | | | | |
| ***Corn (Thousand metric tons)*** | | | | | | | |
| 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 |
| ***Ethanol (Million liters)*** | | | | | | | |
| United States | 4,069 | 4,498 | 7,496 | 7,621 | 5,379 | 8,998 | 9,131 |
| ***Pork (Thousand metric tons)*** | | | | | | | |
| 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 |
| ***Panel B: Percent change relative to the baseline scenario*** | | | | | | | |
| ***Corn*** | | | | | | | |
| 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% |
| ***Ethanol*** | | | | | | | |
| United States | | 0 | 66.64% | 69.41% | 19.59% | 100.04% | 103.00% |
| ***Pork*** | | | | | | | |
| 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

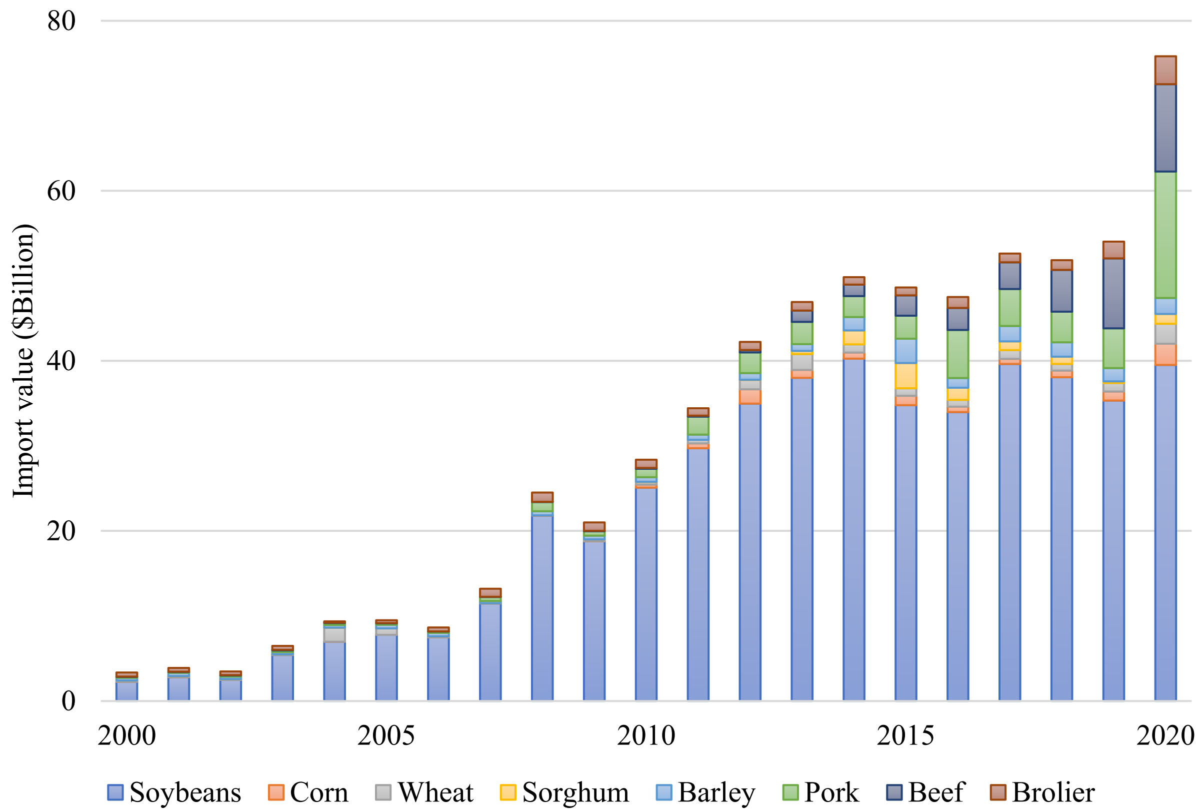
| | 2020 | Average 2021-2030 | | | | | |
|---|---|---|---|---|---|---|---|
| | | No TRQ | | | TRQ | | |
| | | No TRQ/No E10 (Baseline) | No TRQ/E10 | No TRQ/E10/Free ethanol | TRQ/No E10 | TRQ/E10 | TRQ/E10/Free ethanol |
| ***Panel A: Value*** | | | | | | | |
| *Corn (Thousand metric tons)* | 165,826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

**Online Appendix for**

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

**Figure A1.** China's imports of major agricultural commodities, 2000–2020.




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

**Figure A2.** Projected percent changes in prices of major feed grains and meat products compared with the baseline scenario, 2021–2030.

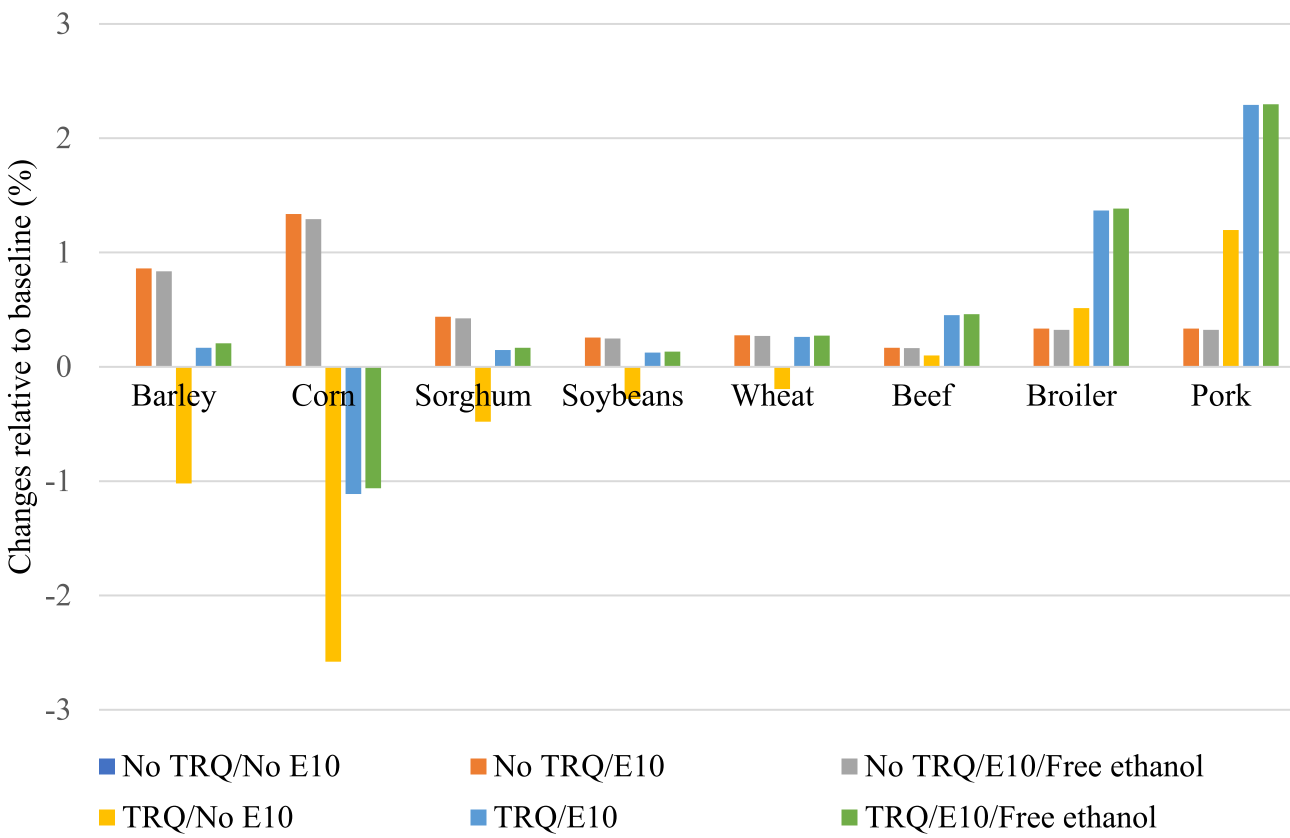


**Figure A3**. Projected percent changes in net imports of major feed grains and meat products compared with the baseline scenario, 2021–2030.