The Economic Impacts of a Mexican Ban on GM Corn Imports

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Table of Contents

Table of Figures

I. Executive Summary

Mexico's proposed GM corn ban, expected to take effect in 2024, has the potential to increase the country's food insecurity, add $4.4 billion to its corn import costs, and impose fundamental and costly changes on the U.S. and Canadian farming and grain handling sectors. This study finds the proposed ban will force North American grain handing systems into two streams (GM and non-GM corn), an approach that is costlier, disincentivizes innovation and subjects supply chains to greater volatility.

Using USDA baseline forecast data, propriety supply/demand/price models from World Perspectives, Inc. (WPI), and IMPLAN economic input-output models, this study estimates the changes that will occur in the U.S. and Canadian farm and grain handling sectors, along with the "ripple" effects these changes will have on the broader national economies.

WPI estimates that U.S. and Canadian non-GM corn prices spike in the first two years of Mexico's ban as the market tries to incentivize producers to plant non-GM corn to supply the Mexican market. GM corn prices fall sharply during the same period, but over time, the price differences decrease, and non-GM corn holds an 8-10 percent premium to GM corn, largely present to offset the effects of lower non-GM yields. Production follows a similar pattern of sharp gains in non-GM production immediately following the ban but remain stable in the latter part of the forecast period. In total, these price and production responses create a net economic loss of $2.87 billion for U.S. farmers and CAD$87.7 million in losses for Canadian farmers. Additionally, the U.S. rail transportation sector suffers a significant contraction in the first two years of the ban with sales losses approximately equivalent to three-quarters the Kanas City Southern railroad's 2020 revenues.

These impacts combine over the 10-year forecast period to reduce U.S. economic output by $16.5 billion and shrink GDP by $7.95 billion. Additionally, U.S. employment falls by 8,700 jobs annually, 1,140 of which are directly tied to grain farming. U.S. grain handling firms will realize $10.08 billion in additional costs to segregate, and identity-preserve non-GM corn destined for Mexico. It is unclear exactly how these costs will be absorbed or passed on through the U.S. economy, but they will have pronounced, negative impacts for producers and consumers.

As a result of its ban, Mexico pays an additional $4.4 billion over the next 10 years for corn imports and prices for corn tortillas rise 30 percent in the first year of the ban and by 42 percent in the second year. The higher food costs represent not only a significant increase in food security risks, but also reduce consumer spending on non-food items. The impact of contracted consumer spending could cause 138,000 jobs to be cut from the economy and a likely $4.3 billion reduction in Mexican GDP over the 10-year forecast period.

Because of the integrated relationship of the U.S. and Canadian corn and grain handling systems, Canada also experiences negative impacts from Mexico's ban on GM corn. The Canadian economy sees GDP fall by $72.8 million and economic output reduced by $170 million over the next 10 years.

Mexico's GM corn ban will force the North American grain handling systems, along with those of other major world exporters (e.g., Brazil, and Argentina) to shift production to meet Mexico's demands. Elbehri (2007) notes that the activities required for identity preservation (IP) in grain markets means they are "also inherently riskier, with volatile supply, inelastic demand, and fluctuating price premiums." Consequently, Mexico's policy decisions will likely exacerbate existing supply chain constraints and subject its economy – and those of its trading partners – to additional volatility in grain supply and pricing.

Additional impacts will be felt in the U.S. ethanol and corn milling industry, which produces distillers grain (a livestock feed ingredient), and in industries that create competing feed ingredients (e.g., soybean meal, a high proportion of which is produced from GE soybeans). Perhaps more importantly, development of future biotech crops may be delayed or abandoned, which could cause losses of $380 billion or more over the 10-year forecast horizon.

II. Introduction

On 31 December 2020, Mexico's government published a decree aimed at phasing out GM corn and glyphosate use in the country. Two days later, Mexico's president, Andres Manuel Lopez Obrador, announced the country would end the import of genetically modified (GM) corn for human consumption by 2024. For additional background on Mexico's policy decision and U.S. and Mexican corn markets and trade, please see this study's companion report, *Setting the Stage: An Overview of Mexico's Corn Market and GM Corn Import Ban*, written by World Perspectives, Inc.

The announcement represents a major shift in Mexico's food security strategy and one that will profoundly impact its trading partners, including the United States and Canada. This study estimates the economic impacts this decision will have on the U.S., Canadian, and Mexican economies, particularly the farming, grain handling, and transportation sectors.

One fact that makes Mexico's decision unique is that there is little or no value creation as a direct result of the new policy. Rather, the GM corn ban acts as a trade protectionist measure against U.S. (and global exporting countries) farmers, who will be forced to take on additional cost and complexity to meet Mexico's unscientifically supported import standards or lose access to one of the U.S.' largest historic corn export markets[1]. Fundamentally, non-GM corn is worth no more than GM corn[2], except for Mexico's political decision. So, the question arises: where will the value come from that will offset the costs imposed by the ban? The answer is simple: without something intrinsic in the process that will add value, the corn marketing chain will eventually pass along the costs to consumers, both in the U.S. and Mexico.

To further motivate the magnitude of the proposed ban, consider that Mexico has long been the largest export market for U.S. corn. From 2018 through 2020, Mexico accounted for 29 percent of U.S. total corn exports, on average, and was the largest market. In 2021, China overtook Mexico as the largest importer of U.S. corn, but Mexico's imports still increased 16 percent to 16.9 MMT. Mexico's 2021 corn imports accounted for 4.4 percent of the 2021/22 U.S. crop (and 24 percent of U.S. corn exports) and exceeded the production of Ohio, the eighth largest corn producing state in the U.S. Mexico is clearly a profoundly important market for U.S. corn producers and its loss would have significant impacts not only in the U.S., but in nearly all connected markets.

[1] According to the USDA FAS, Mexico was the largest importer of U.S. corn in 2020 and accounted for 28% of U.S. corn exports.
[2] With the possible exception of consumer willingness-to-pay for non-GM foods, which has been shown to be inconsistent and often secondary to other attributes, such as "locally grown" (Spalding and Kiesel, 2018; Loureiro and Hine, 2002; Lusk et al, 2005).

III. Conceptual Model and Baseline Analysis

Conceptual Model

Should Mexico choose to ban GM corn imports, there are multiple impacts that will be felt throughout the world grain industry. The following section outlines, in simple terms, the probable impacts of such a ban and WPI's approach for accounting for the sudden shift in world trade. Each of these conceptual events is run through supply/demand forecasting models to obtain a numeric estimate of the industry's response to a Mexican GM ban.

Conceptual Model for Impacts During the First Year of GM Import Ban

1. Assume Mexico stops all GM corn imports and that U.S. producers cannot alter production in Year 0.
2. Estimate the U.S. potential non-GM corn exportable surplus based on estimated non-GM corn supplies and export/domestic use demand elasticities. Note that not all non-GM corn produced in Year 0 will be available for export as some is already contracted for domestic/other use.
3. Use demand elasticities to estimate the new price of non-GM corn.
4. Based on the loss of a major export market, estimate GM corn exports, ending stocks, and prices under a Mexican import ban.
5. Use historic U.S./Canada corn price relationships to estimate the impact on Canada's corn price.
6. Use the new non-GM corn prices and Mexico's import demand elasticity to estimate Mexico's Year 0 import demand for now-higher U.S. non-GM corn prices.
7. Estimate the volume of non-GM corn Mexico needs to procure from non-U.S. suppliers.

Conceptual Model for Long-Run Impacts of GM Import Ban

1. Forecast U.S. GM and non-GM acreage based on prior year GM and non-GM prices.
2. Estimate Mexico's production response to increased non-GM corn prices [note, WPI's research strongly indicates that Mexico is resource-constrained and production gains are only on the margin.]
3. Estimate Mexico's import demand based on prior year prices.
4. Estimate U.S. non-GM and GM corn supplies, domestic consumption, and export demand based on prior year prices and demand elasticities.
5. Estimate non-U.S. non-GM corn exports to Mexico and Mexico's non-U.S. import price.

One key impact of Mexico's GM corn ban is that it effectively requires segregation and identity preservation to ensure GM corn is not inadvertently imported. Consequently, it essentially creates two separate commodities in the U.S. and Canada (GM and non-GM corn), each with their own supply/demand balance sheets, but where U.S. law makes no distinction between the two. In other words, the presence of GM material is not a characteristic relevant to the U.S. grain handling system since the U.S. has implemented a policy of non-differentiation for purposes of commodity marketing.

To date, there is already some IP and segregation present in the U.S. corn market to maintain domestic supplies of non-GM corn or serve specific markets. Moreover, the U.S. segregated white corn from yellow feed corn as Mexico has distinct use cases and demand for these two classes of corn. For this research, WPI makes no distinction between U.S. white and yellow corn as both are already heavily dominated by GM varieties. Consequently, a Mexican ban on GM imports will create a similar response in both U.S. white and yellow corn markets. The *only* reason to distinguish between white and yellow corn for analyses like this one is *if* Mexico can adequately separate and identity-preserve food versus feed imports, which WPI's research suggests is unlikely at best.

Baseline Analysis

This section details some of the baseline research, assumptions, and approaches that are used further in this study as inputs into WPI's long-run forecasting models.

In modeling the economic impact of Mexico's proposed ban on GM corn imports, the year the ban takes effect is herein denoted as "Year 0", or Y0. While the ban takes effect (assuming no Mexican court or elected party changes the decree) in January 2024, WPI assumes the ban is in place in January 2022 (i.e., Y0 occurs in the middle of the 2021/22 U.S. corn marketing year). This approach was chosen for several reasons, the chief of which is that assuming Y0 occurs in 2022 allows for the full use of USDA's latest 10-year baseline agricultural projections. The latest available baseline projections cover the ten-year period from 2021-2030 and will be used as the baseline against which estimated impacts of the GM corn ban will be compared. Had Y0 been assumed to start in 2024 (as decreed by the government) additional baseline projections for the years 2031-2034 would have needed to be generated.

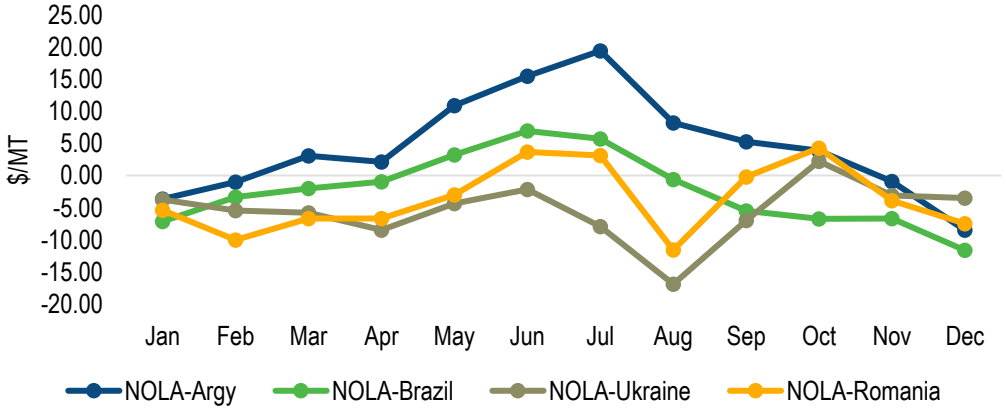
USDA's baseline agricultural projections identify Mexico's expected future imports of corn but does not specifically identify the volume that would be fulfilled by U.S. suppliers. On average, however, from 2015/16 to 2020/21, the U.S. supplied 92 percent of Mexico's annual corn imports and this study assumes that market share is unchanged for the forecast period (i.e., 2021/22 through 2030/31).

The proportion of U.S. corn acres planted to biotech (GM) varieties was obtained from the USDA NASS Quick Stats database. USDA's data shows that, on average from 2014-2021, 92.25% of U.S. corn acres were planted to GM varieties. The proportion of biotech corn acres has not changed significantly in the past 7 years and WPI assumes the 92.25% biotech acres will continue, assuming no outside market shocks occur, for the next 10 years.

Additionally, data from the ISAAA (2019) provides clarity on the prevalence of GM corn produced by other global suppliers. Specifically, ISAAA reports that Argentina's GM production share is comparable to the U.S. at 93 percent, but that Brazil's is lower at 89 percent. Moreover, differences exist between Brazil's first and second (*safrinha*) corn crops, with USDA indicating that 90.7 percent of the smaller first crop is GM varieties while just 84.8 percent of the *safrinha* crop utilized GM seeds (USDA GAIN 2020). Canadian farmers planted 89 percent GM corn varieties in 2019 (ISAAA) while Ukraine's corn production is only 2 percent GM as GM seeds are not officially approved for cultivation in the country.

Analysis of FOB price data (Figure 1) shows that, on average, U.S. Gulf corn is typically offered at a lower price than key competing origins (Brazil, Argentina, Ukraine, and Romania). Strong seasonal effects are present in the data, due to the timing of harvest in the Northern and Southern Hemispheres. On average across the past 5 years, however, FOB NOLA corn is priced $2.46/MT below Brazilian corn and $5.80/MT below Ukrainian offers, while Romania's non-GM corn export price averages $3.88/MT above the U.S. Gulf. The data show Argentina's corn is typically priced at a $3.94/MT discount to the U.S. Gulf, but the use of FOB prices alone discounts the higher freight cost of shipping Argentine corn from Upriver terminals. For the purposes of this analysis, WPI assumes Mexico will pay an additional $4.60/MT (the average premium Ukrainian and Romanian non-GM corn holds to U.S. prices) for non-GM corn imports.

Figure 1: Seasonal Differences in FOB Corn Prices, FOB U.S. Gulf (NOLA) vs. Competing Origins



Source: DTN ProphetX, World Perspectives, Inc.

Beyond flat prices for corn, Mexico – and the world marketplace – will have to pay freight differences to obtain non-GM corn from outside the U.S. According to the OECD (2014), both Mexico and Brazil have comparatively small and underdeveloped railway systems, though investment in the Mexican rail system is growing.

Because of the lack of immediate rail access to South America, WPI assumes that Mexico's non-GM corn imports from non-U.S. countries will be executed via ocean freight and not rail. WPI estimated ocean freight rates by taking market-quoted values from WPI's proprietary databases and adjusting by nautical miles for given routes. The routes assumed for this study are shown in Figure 2.

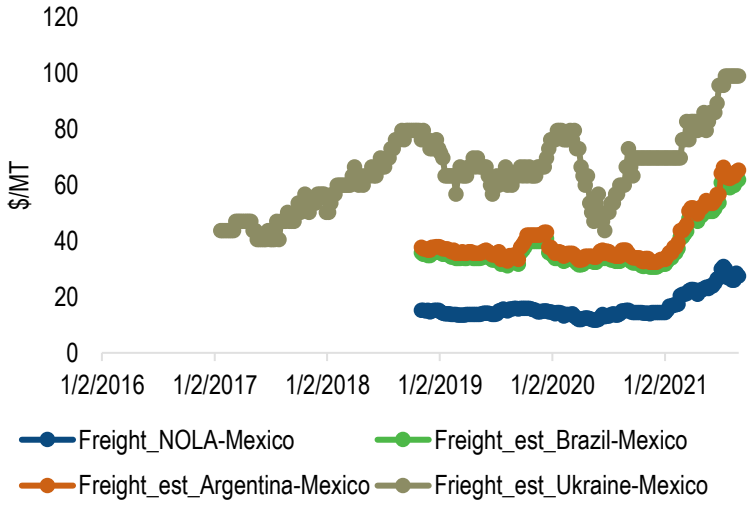
Figure 2: Ocean Freight Routes for World Corn Trade with Mexico

Origin	Destination	Route	Nautical Miles
Santos, Brazil	Veracruz, Mexico	Direct	5,442
Bahia Blanca, Argentina	Manzanillo, Mexico	Strait of Magellan	5,745
Odessa, Ukraine	Veracruz, Mexico	Strait of Gibraltar	6,961
New Orleans, USA	Veracruz, Mexico	Direct	810

Source: World Perspectives, Inc.

Based on the estimated ocean shipping distances, the U.S.' trade advantage with Mexico becomes abundantly clear and is further highlighted by the estimated ocean freight rates (Figure 3). Even during the 2021 freight market rally, ocean freight from the U.S. Gulf to Veracruz, Mexico cost between $25-30/MT while estimated freight from Argentina and Brazil is $60-65/MT and from Odessa, Ukraine to Mexico is $100/MT.

Figure 3: Estimated Ocean Freight Rates for Select Routes



Source: World Perspective, Inc.

Estimating Non-GM Corn Prices

Despite the increase in demand for non-GM food products, price reporting on such commodities remains sparse at best. Some industry sources note non-GM corn supplies have grown quickly in the U.S. as producers sought to achieve higher prices during the prolonged commodity price downturn from 2015-2020 (Murray Wise Assoc. LLC, 2021). Reportedly, premiums for non-GM corn run 5-7 percent of the GM-corn price. On a $3.50/bushel corn price, a 5 percent premium would equate to 17.5 cents and a 7 percent premium converts to 24.5 cents. Moreover, WPI's research finds that, on average from 2015-2021, U.S. white corn exports to Mexico commanded a $0.62/bushel (13.3 percent) premium over yellow corn.

Non-GM Corn Balance Sheet Estimation

Despite the growing popularity of organic and non-GM food products in the U.S., production and distribution data remain limited (Fernandez-Cornejo, 2014). USDA provides some price reporting data but minimal production information regarding non-GM and organic crops specifically. WPI is unaware, despite heavy desk research and interviews with contacts in the U.S. grain industry, of any source for "grain balance sheet" information on non-GM or organic corn production. Because this research depends heavily on balance sheet information to estimate how much

non-GM corn could be available for export to Mexico, among other such data points, some attempt at developing a non-GM corn balance sheet was required.

Multiple methods of estimating non-GM corn (distinct, of course, from organic corn as organic corn is necessarily non-GM but the reverse does not hold) balance sheets were tried, but significant issues with each approach made full estimation impossible. Instead, this study uses USDA data on the share of corn plantings dedicated to GM and non-GM corn and we extrapolate that share to the rest of the corn balance sheet. For example, in 2020 USDA estimated that 92 percent of U.S. corn plantings were GM varieties, and we assume that 92 percent share holds for other balance sheet items, including that non-GM ending stocks were 8 percent of the U.S. total. This approach has flaws as well, notably the assumption that GM and non-GM corn are perfect substitutes in U.S. consumption when in fact they are likely two very different markets.

While discussed later in this report, it's worth noting that non-GM corn currently produced in the U.S is not necessarily stored or handled separately from GM corn. Rather, the legal and commercial grain handling standards and practices dictate that much of the non-GM corn is co-mingled with GM varieties. This occurs, partly, because sufficient incentives (either market or policy driven) do not exist to separate all non-GM and GM corn.

Short-Run Response to Mexico's GM Corn Ban

In the very short run, this research assumes supplies are fixed for the marketing year and that no additional production can occur before the next marketing year. Due to the nature of Mexico's GM ban and the complications of IP corn shipments from the U.S. or other destinations, this research (as noted earlier) assumes *all* Mexican corn imports will be non-GM. Consequently, based on USDA's long-term projections, 16.5 MMT of non-GM corn are forecast to be imported into Mexico the first year of the GM corn ban (which is assumed to be 2021/22). WPI's proprietary models also predict that 2.1 MMT of ethanol co-products (DDGS, corn gluten feed, and corn gluten meal) would be imported by Mexico during the first year of the ban.

WPI estimates that the initial exportable surplus of non-GM corn from the U.S. is 6.7 MMT, roughly two-thirds of which could be shipped to Mexico. The balance, approximately 2.5 MMT, will be purchased by Japan and South Korea, two countries with long histories of importing non-GM corn and whose comparative wealth will allow them to outbid Mexican buyers as prices rise. Note that current non-GM corn exports to Japan and South Korea (which are not explicitly identified in official trade data) is reportedly[3] greater than 2.5 MMT. Their minimum import requirements, however, are thought to total 2.5 MMT, and WPI's models consequently assume that only the minimum purchases are made in the first year of the ban as prices rise sharply.

Moreover, as Mexico's ban will increase the price of non-GM corn in the U.S. and world markets, Mexico's total imports will fall accordingly. WPI estimates Mexico's Year 0 equilibrium imports to be 13.07 MMT (down 3.5 MMT from USDA's long-term forecasts), which means Mexico needs to secure 7.137 MMT of non-GM corn from outside the U.S. WPI estimates Brazil, Ukraine, and Argentina will fill 96 percent of this import demand, with Canada filling in the balance.

The 7.137 MMT of "new" import demand for Brazilian, Ukrainian, and Argentine corn will siphon away corn supplies from countries that would otherwise import from these origins. WPI's models assume U.S. GM corn imports will shift to fill this void and help offset the impacts of losing the Mexican market to GM corn.

[3] According in industry sources interviewed by WPI.

IV. Methods

Supply, Demand, and Price Forecasting Models

WPI has developed proprietary models for predicting supply and demand responses to price changes and forecasting long-run supply/demand relationships. These models were used to assess the impact of a potential Mexican ban on GM corn imports. As noted earlier, WPI relies on USDA's long-term forecasts to establish a baseline scenario for production, trade, and demand under "normal" (i.e., without a Mexico GM import ban) conditions. These USDA baseline data include price forecasts but WPI re-estimated baseline prices (using proprietary models) to reduce any possible error or "noise" when comparing results against the baseline scenario.

Economic Input-Output Models

The final step in this analysis is to estimate the impact a stoppage of GM corn imports would have on the broader U.S. economy. Due to forward and backward economic linkages between the corn farming sector and other industries, a negative impact to the corn farming economy will "ripple" through the rest of the U.S. economy. Economic input-output models estimate these economic linkages and assess how a change in one industry affects others.

IMPLAN is a widely recognized economic input-output model software that has been used in myriad government, academic, and industry research projects. IMPLAN models account for industry spending linkages (how costs in one industry are tied to revenues in another), labor income (wages and salaries), employment, tax implications (at local, state, and federal levels), and the total "value added" by given industry(ies). The "value added" metric can be thought of as the industry's contribution to the U.S. Gross Domestic Product (GDP).

IMPLAN models account for three types of impacts:

- **Direct impacts** are those incurred by the industry in which a shock occurs. In the present case, the direct impacts would be those to the U.S. corn farming industry because of Mexican GM corn ban. Also, Mexico will incur direct economic impacts to its corn-consuming sectors by reducing the supply of corn and raising prices.
- **Indirect impacts** are those incurred by economic sectors with links to the industry directly being impacts. For the GM corn ban base, indirect impacts would occur in the fertilizer and agro-chemical industries through reduced demand from the corn farming sector.
- **Induced impacts** are those created by changes in employee spending for workers in a given industry. For example, employees of corn farming operations that experience a loss of revenue will likely see a reduction in wages or salaries. Consequently, workers will change their spending patterns and create induced impacts in industries where those employees spend their wages.

Note that the total economic impact of a change in an industry can be obtained by summing the three individual impacts. That is, the sum of direct, indirect, and induced impacts is the entire economic shock felt by the U.S. economy.

V. Results

U.S. Acreage and Supply/Demand Responses

The U.S. corn farming sector adjusts quickly to supply the Mexican non-GM import market **but experiences significant and persistent net losses over the 10-year forecast horizon**. The GM corn sector suffers the impacts of a sudden reduction in demand that is only partly offset by exports to other countries, and prices fall as a result. Conversely, the non-GM corn industry experiences a sudden demand surge but, due to the fact only one crop is produced each year, cannot alter production in the first year. Moreover, acreage expansion in the subsequent years is constrained by seed availability, prolonging the industry's adjustment time. Prices for non-GM corn rise sharply in the first two years of the ban as markets work to ration demand and buyers in the U.S., Japan, South Korea, and Mexico vie for relatively small supplies. Overall, the net impacts of lower GM corn prices offset the economic expansion of the non-GM corn industry, and the U.S. economy contracts accordingly.

In the first year of the ban, the U.S. non-GM ending stocks-to-use ratio falls from 15.2 percent in the baseline scenario to 7.0 percent and the non-GM price increases from $3.78/bushel to $5.37/bushel. This price increase causes Mexico to reduce its corn imports, which may add to existing food insecurity. In contrast, the U.S. GM ending stocks-to-use ratio increases from 15.2 percent to 17.5 percent and the GM price falls by $0.32/bushel. The ban's first-year impacts are not as large in the GM market as the U.S. shifts its export program to fill the void left by Brazilian and Ukrainian (and, to a lesser extent, Argentine and Canadian) exports that are now increasingly destined for Mexico.

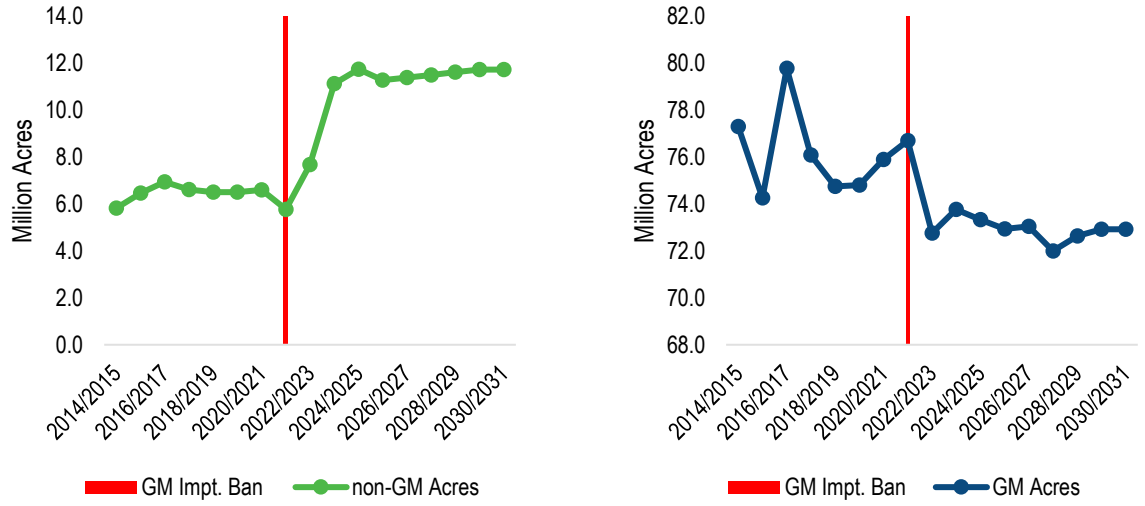
Based on the price changes, WPI estimates the U.S. GM corn farming sector loses $4.4 billion in revenue that is only partly offset by gains in for non-GM corn farms. The non-GM corn farm economy gains approximately $1.86 billion in additional revenue, due solely to higher prices as models assume production cannot be altered in the ban's first year.

In the first year of the ban, the U.S. GM corn farming sector loses $4.4 billion in revenue while non-GM corn faming revenue increases by $1.86 billion.

Higher prices for U.S. non-GM corn cause farmers to expand production and, 2 years after the ban becomes effective, the U.S. produces enough non-GM corn to fully supply Mexico's import needs. One caveat to this response is that it may take longer than 2 years for seed producers to scale-up production to completely fill the Mexican market. On this point, there are a wide range of views about the timing of the seed industry's response. Moreover, factors such as the point in the marketing year at which the ban becomes effective, as well as advance contracting before the ban, have large impacts on estimates of the seed industry's response.

The second year of Mexico's GM corn import ban begins a series of supply changes for the non-GM and GM corn farming sectors. This study, assuming U.S. farmers respond to the sudden price increase in non-GM corn, finds that non-GM corn acres will likely increase 33 percent in the year following the ban. The acreage increase (1.9 million acres) is not as great as would be implied by price analysis alone as seed supplies are a binding constraint (that is, a lack of non-GM seed supplies prevents a larger acreage switch). In the same year, GM corn acres fall 5 percent and total corn acres fall from 82.5 million to 80.4 million. The additional non-GM corn supplies in the U.S. push American exports to Mexico to 7.9 MMT, nearly double the prior year's levels. The ending stocks-to-use level remains extremely low at 7.0 percent, which pushes the non-GM corn price to $5.97/bushel. The smaller GM acreage figure pulls the ending stocks-to-use ratio lower to 15.8 percent, but price impacts are modest and the $3.17/bushel price remains $0.18 below the baseline forecast.

Figure 4: U.S. Corn Acreage Response to Potential Mexico GM Corn Import Ban



Source: World Perspectives, Inc.

The third year after Mexico institutes a ban on GM corn imports sees perhaps the greatest impacts in the market. With non-GM seed supplies increasing and either no longer or minimally restricting U.S. acreage responses, non-GM plantings rise 44 percent to 11.1 million acres. This added acreage comes mostly from under other crops (not specifically identified in this study) and the GM corn harvested area increases fractionally. The increase in non-GM area allows the U.S. to fully – for the first time – supply the Mexican market and 20.47 MMT of non-GM corn are shipped to Mexico.

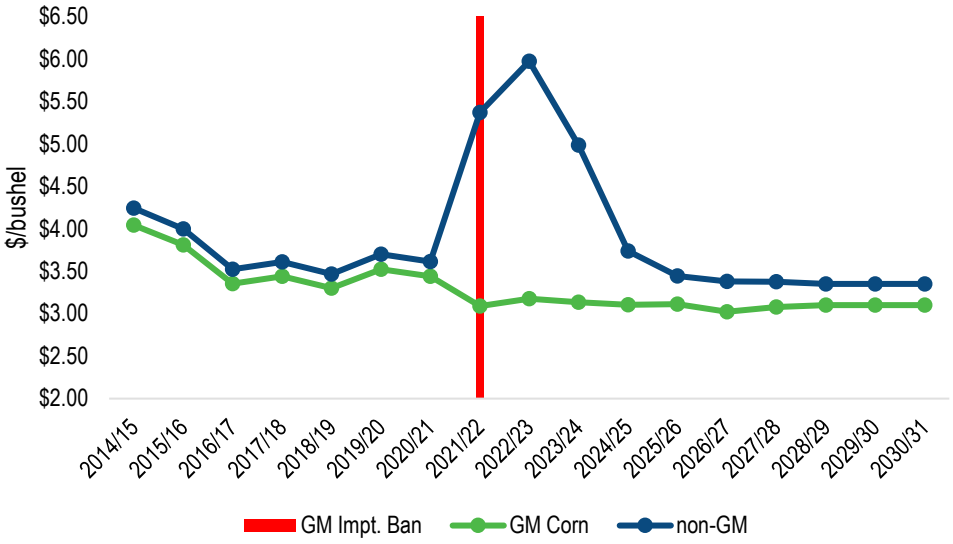
The massive acreage response in the third-year boosts non-GM corn supplies significantly and the ending stocks-to-use ratio rises to 10.1 percent and the non-GM corn price falls to $4.99/bushel. Fourth year non-GM corn plantings increase modestly as producers weigh the declining non-GM corn price against the comparative returns and costs of planting GM corn (or other crops). From that point, however, acreage, ending stocks, and prices stabilize through the end of the 10-year forecast period, though yield gains keep production trending higher.

Despite receiving modestly higher prices near the end of the forecast period, non-GM corn production remains "riskier" and GM corn production still dominates U.S. acreage.

Finally, non-GM and GM corn prices gradually converge as greater non-GM corn production lowers prices. From an agronomic perspective, U.S. farmers now must choose GM or non-GM corn *relative to other crops and crop rotations* and GM corn versus non-GM corn become substitutes for each other.

Two factors remain crucial for individual farmers' decisions to plant GM or non-GM varieties. The first is that non-GM varieties may be perceived as "riskier" in terms of yield potential in the face of drought and pest infestations (Fernandez-Cornejo, et al. 2014). Taheripour, Mahaffey, and Tyner (2016) find that non-GM corn varieties yield 5.2 to 17.1 percent less than GM varieties, an agronomic reality farmers must account for when making planting decisions. Additionally, most farmers plant GM varieties with the intention of increasing yields or decreasing input costs (Fernandez-Cornejo, et al., 2014), and forgoing these advantages when switching to non-GM corn must be considered. Finally, there are direct economic costs farmers must bear to maintain IP on their own farms, including buffer zones, cleaning planters and combines, etc. Bullock and Desquilbet (2002) found on-farm IP and segregation costs for $0.18/bushel for soybeans, which equates to $0.26/bushel when adjusted for inflation to 2021 dollars. Non-GM corn prices must be sufficient to cover these added expenses and risks, otherwise farmers will not choose to seed non-GM varieties.

Figure 5: U.S. Corn Price Responses to Mexico GM Corn Ban



Source: World Perspectives, Inc.

Crucially, because Mexico's ban is effectively a punitive measure that does not add value to global economy, **the U.S. corn farming industry sustains a cumulative net loss of $2.87 billion** over the ten years following Mexico's ban (Figure 6). Ten years after the ban is implemented, GM corn is still the predominant variety in the U.S., but its producers receive lower prices than they would have otherwise. Non-GM corn growers do realize higher prices, but the returns are insufficient to offset other costs and risks to incentivize GM corn farmers to switch crops. Consequently, Mexico's policy decision results in a net loss for U.S. farmers.

Figure 6: Revenue Impacts of Mexico GM Corn Ban on U.S. Corn Farming Sector

	Production System		
	GM Corn	non-GM Corn	Industry Net
	Million USD		
Year 1	-$4,409	$1,868	-$2,540
Year 2	-$4,191	$3,300	-$891
Year 3	-$3,494	$4,997	$1,503
Year 4	-$3,186	$3,201	$14
Year 5	-$2,335	$2,470	$135
Year 6	-$2,918	$2,492	-$427
Year 7	-$2,815	$2,575	-$241
Year 8	-$2,853	$2,554	-$299
Year 9	-$2,712	$2,649	-$62
Year 10	-$2,740	$2,677	-$63
Total	**-$31,653**	**$28,782**	**-$2,871**

Source: World Perspectives, Inc.

Farm Shocks Ripple Through U.S. Economy

As a result of Mexico's GM corn ban and the farm-level changes detailed above, the U.S. economy receives a sudden shock that ripples through nearly every other industry. The following section details the cumulative impacts stemming from four distinct shocks: changes to the U.S. farm sector, increased costs of segregating GM and non-GM grain and

identity preservation (IP), economic contraction in the U.S. rail transportation industry, and changes to the U.S. corn milling industry.

WPI estimates **the cumulative impacts of these changes will reduce U.S. economic output by $16.5 billion over the 10-year forecast period and cut U.S. GDP by $7.95 billion**. Approximately, 8,700 jobs will be lost each year of the ban and U.S. labor income falls $4.9 billion in 10 years.

Figure 7: 10-Year Total Impacts[4] on U.S. Economy from Mexico GM Corn Ban

Impact	Annual Avg. Employment	Labor Income	US GDP	Output
	Full-time Equiv.		*Billion USD*	
Direct	-1,405	-$0.81	-$1.25	-$4.43
Indirect	-2,424	-$1.26	-$1.62	-$3.02
Induced	-4,881	-$2.87	-$5.08	-$9.06
Total	**-8,710**	**-$4.93**	**-$7.95**	**-$16.51**

Source: World Perspectives, Inc.

The following sections detail the sources of these economic impacts and their calculations.

Impacts of Lost Farm Revenue

As noted in Figure 6, the value of U.S. farm production falls $2.87 billion, cumulatively, over the 10-year forecast horizon due to Mexico's GM ban. These impacts are not isolated to the farm sector, rather the economic impacts ripple through the rest of the American economy. As farmers face lower prices and farm income, they invest less in equipment, farm inputs (fertilizer, etc.), and change household spending. IMPLAN input-output models can estimate these "ripple effects" and offer a holistic view of how the shock of a Mexican ban on GM corn imports will impact the U.S. economy.

IMPLAN results (Figure 8) show that across the 10-year time horizon, the lost farm revenue causes U.S. economic output to fall by $12.9 billion and GDP to contract by $6.1 billion. Additionally, annual employment falls by 7,418 jobs annually, 1,140 of which are directly tied to the grain farming sector. Notable for policy makers is the fact that Federal tax revenue falls by $0.817 billion over the 10-year horizon and state tax revenues fall by $42 million. Local taxes, however, increase by $19 million.

Figure 8: 10-Year Impacts on U.S. Economy from Lost Farm Revenue

Impact	Annual Avg. Employment		Labor Income	US GDP	Output
	Full-time Equiv.			*Billion USD*	
Direct	-1,140	0	-$0.46	-$0.57	-$3.03
Indirect	-1,954	0	-$0.91	-$1.03	-$1.85
Induced	-4,324	0	-$2.54	-$4.50	-$8.02
Total	**-7,418**	**0**	**-$3.90**	**-$6.10**	**-$12.90**

Source: World Perspectives, Inc.

[4] The combined impacts of lost farm income, contraction in the rail transportation industry, and changes to the corn milling sector, as detailed in following sections.

With regards to specific industries, the grain farming sector experiences a pronounced contraction due to Mexico's proposed policy and the industry output (i.e., farm revenue) falls $3.08 billion over 10 years. As expected, industries that support agriculture and farming, e.g., chemical manufacturing and fertilizer industries, experience negative impacts as well, with economic growth contracting 0.9 percent, on average, for these industries.

Figure 9: 10-Year Impacts on U.S. Economic Sectors

Economic Sector	Economic Growth	Impact on Output (Bill USD)
Grain farming	-4.5%	-$3.08
Ag support activities	-2.5%	-$0.87
Pesticide/Ag Chem. mfg.	-1.1%	-$0.22
Nitrogen fertilizer mfg.	-1.0%	-$0.11
Fertilizer mixing	-0.9%	-$0.05
Phosphatic fertilizer mfg.	-0.9%	-$0.05
Phosphate rock mining	-0.7%	$0.00
Potash mining	-0.5%	-$0.01
Greenhouse production	-0.1%	-$0.01
Other chem & fertilizer	-0.1%	$0.00
Total	**N/A**	**-$4.41**

Source: World Perspectives, Inc.

The industry-specific impacts can also be examined on a labor-basis. As expected, the grain farming sector sees the largest job losses, with 1,140 FTE jobs lost each year, on average, in that industry alone. The full "ripple effects" of the economic shock to the corn farming industry creates a total job loss of approximately 1,661 jobs annually. Industries that support farming see the next largest set of job losses, with 1,616 jobs at risk each year from Mexico's proposed GM corn ban. Note that the labor impacts below are reported as the annual average across all 10 years in the study. This is done to avoid potential confusion[5] regarding the number of jobs lost per year or in total across the study period.

Figure 10: Annual Average Labor Impacts by Top-5 Sectors

	Impact Type			
Industry	Direct	Indirect	Induced	Total
Grain farming	-1,140	-503	-18	-1,661
Ag support activities	0	-1,616	-14	-1,630
Other real estate	0	77	-147	-70
Nondurable goods wholesalers	0	-10	-26	-35
Full-service restaurants	0	1	-187	-187

Source: World Perspectives, Inc.

Costs of Grain Segregation and Identity Preservation

Mexico's GM ban will create a massive change in the U.S. grain handling industry as non-GM corn will have to be segregated and identity preservation (IP) strictly maintained. Currently in the U.S. grain system, non-GM corn/soybeans

[5] IMPLAN employment is reported on an "average annual job" basis, regardless of whether that worker is part-time or full-time or a proprietor. IMPLAN simply sums the total number of annual jobs across all years in the study and does not adjust employment estimates in subsequent year for jobs gained/lost in the first. For example, a worker employed in the first and second years of a study is considered as two annual jobs by IMPLAN, regardless of the fact only one position was filled.

are "segregated within bulk" – that is, the grain flows through typical GM crop processes but firms either have separate facilities, handle/process GM-free grain on separate days or have strict cleaning policies (Elbehri, 2007). WPI estimates that in the first two years of Mexico's GM ban, the U.S. grain handling industry will continue to adopt "segregation within bulk" strategies, after which point the system shifts to dedicate certain facilities to handling GM and non-GM corn.

The cost of "segregation within bulk" and the eventual dedication of certain facilities to certain corn types will be significant. Elbehri (2007) noted that there are two primary costs associated with IP grain markets:

- Added costs of segregation and IP in the grain supply channel (e.g., costs of physically separating and tracking grain),
- Costs to mitigate specific risks inherent to IP grain markets (e.g., the risk of shipments being rejected for exceeding GM tolerance levels[6]). Rejection risk insurance is available but its relative cost is subject to the regulatory standards, transaction history, calculated risk and other factors that are not yet fully defined

In 2007, Elbehri estimated the costs of physical segregation and IP ranged from 1 to 27 cents/bushel, depending on the type of grain and the volume handled at the facility. Further, Doshi and Eudes (2007) compile a list of estimates that found per-bushel cost of IP grain handling range from 1.6 to 50 cents/bushel. WPI uses that study to estimate the mean cost increase for corn segregation and IP at 18.5 cents/bushel in 2002 dollars, which equates to 27 cents/bushel in 2020 dollars. That means U.S. grain origination and handling firms will have to incur costs of 27 cents/bushel on every bushel of corn that enters their system, or about 5% of the purchase price of corn, assuming $5.50/bushel corn prices[7].

U.S. grain handling firms will incur costs of 27 cents/bushel to segregate non-GM corn and maintain IP traceability.

WPI estimates that **the 27-cent/bushel segregation and IP costs create an $11.1 billion added cost[8]** that must be borne by U.S. farmers, grain handling firms, consumers, or global trading partners in the first four years of Mexico's GM corn ban. WPI finds that the per-bushel costs decrease in the third- and fourth-years following Mexico's ban and eventually approach zero (i.e., no additional marginal cost) in the final five years of the forecast period. Even though the marginal costs fade over time, the initial costs impose a significant burden on U.S. grain handling system and firms must either absorb them (i.e., accept reduced profits) or pass them along to consumers (in the form of higher prices) or farmers (in the form of lower grain prices).

WPI estimates that the 27-cent-per-bushel cost for segregation and IP systems can be passed to Mexican importers for the volume of non-GM corn exported to Mexico. Over ten years, this means U.S. firms will pass on $1.0 billion in additional costs to Mexico, reducing the U.S.' burden to $10.08 billion. The impacts of the costs passed to Mexico are discussed in the report section *Impacts on Mexico's Economy*.

A bifurcated grain system adds $10.08 billion in costs to the U.S. economy, but it is unclear whether farmers, consumers, or other firms are "winners" or "losers" in the new system.

How the remaining $10.08 billion in segregation and IP costs are absorbed or passed on through the U.S. corn value chain, however, remains unclear. Desquilbet and Bullock (2009) found that "the economics of technological innovation leading to market bifurcation are complicated." (pp. 671) and that multiple market equilibria may exist in a bifurcated GM/non-GM grain market. They further note that different types of producers and

[6] Note that Mexico has not issued guidance on its expected tolerance levels for GE material in grain exports after the ban. This adds significant uncertainty to the market and will have profound impacts on supply chains and business planning as tactics needed to meet a 5 percent threshold are different than those for a 1 percent threshold.
[7] The approximate value of Midwest cash corn at the time of this writing.
[8] The sum of the per-bushel segregation and IP costs multiplied by yearly total U.S. corn production.

consumers are affected differently by the presence of GMOs, making determination of net winners and losers difficult.

WPI has been unable to find academic research examining the endogeneity of IP costs (i.e., the cost of reduced flexibility in the supply chain) or grain handling/processing firms' response to the forced adoption of a bifurcated system. Such analysis is beyond the purview of this research and, consequently, we cannot define how U.S. grain handling firms will respond to the increased segregation and IP costs. Because firm-level economic responses (reduced purchase volume, lower wages, fewer jobs, etc.) cannot be estimated, the complete "ripple effects" on the U.S. economy cannot be estimated[9].

While grain segregation and IP methods impose direct costs to the grain handling industry (costs that may be passed along to consumers or farmers), secondary impacts also result from the shift in grain handling procedures. Notably, the dedication of certain facilities strictly non-GM corn imposes additional costs on farmers, who if their local elevator shifts to non-GM corn handling, now must transport grain further to a GM-accepting facility. Moreover, this will likely impact local basis[10] levels as GM (non-GM) farmers near non-GM (GM) handling facilities will see reduced demand for their crop while non-GM (GM) farmers near non-GM (GM) facilities will see higher local demand. While these impacts cannot be quantified presently, they must be noted as near-certain outcomes of Mexico's GM policy.

The second classification of costs associated with segregation and IP in grain markets - costs to mitigate specific risks inherent to the system – are also significant. While the Mexican government has yet to issue specific rules on this fact, one must assume the government will require testing for GM events in imported corn, otherwise the GM ban, practically, cannot be enforced[11]. Consequently, exporting firms facing the risk of shipments being rejected at Mexican ports due to the potential for a shipment exceeding yet-unspecified GM tolerance levels. A certification system may also be contrived but either way, the most important factor is the threshold or tolerance chosen for any GMO content.

Due to the risks of exporting/importing non-GM grain shipments where the GM impurity level exceeds a yet-undefined threshold, both U.S. exporters and Mexican importers will pay for genetic testing on all corn shipments.

Both U.S. grain exporters, Mexican importers, and the Mexican government face risks associated with GM contamination of non-GM corn exports. U.S. exporters face the cost of having shipments rejected while Mexican importers face the risk and costs of non-compliance with the government's ban should they accept a contaminated shipment. Finally, the Mexican government faces the risk of being perceived as being unable to enforce its policies and the possible political/societal pushback from importing "contaminated" grain. Consequently, both exporting and importing firms (including the Mexican government) have strong incentives to test shipments to make sure GM presence is below some yet-to-be-determined threshold[12] and WPI estimates that *both* exporting and importing firms will pay for genetic testing on each shipment.

Bullock and Desquilbet (2002) estimate that tests for GM events in grain shipments ranged from $5 to $325 per test, and that the total cost of GM testing reached $222.60 per 1,200 MT of corn exported via ocean vessel. In 2021, WPI estimates the costs of GM testing at $0.47/MT for U.S. exporters and Mexican importers. For U.S. firms, these genetic testing costs total $93 million over the 10-year forecast horizon and Mexican importers (or the Mexican government,

[9] IMPLAN economic input-output models require firm-level responses and cannot estimate explicitly the impacts of changing prices or costs.

[10] Basis in grain markets is the difference between the local cash price and the Chicago Board of Trade futures price and represents differences in local supply, demand, and transaction costs.

[11] Because GM corn varieties are generally indistinguishable from non-GM varieties without the use of specific tests, such tests are required to prove that a shipment does/does not contain GM grain.

[12] Elbehri (2007) notes the U.S. commercially accepted GM impurity threshold in non-GM grain is 1-5% and <0.5% for grain transported/handled in 20-foto containers or silo bags. As of this writing, however, the Mexican government has not set impurity thresholds for its new policy.

via subsidies) must pay $99.5 million over the same period. Mexican firms pay a greater total cost because of non-U.S. imports in the first and second years of the GM ban.

Note that it is likely U.S. exporters will simply pass along their genetic testing costs to Mexican importers in the form of higher prices or transaction costs. Consequently, **Mexico will pay $189.7 million for testing non-GM imports**, a cost that would not exist if the GM ban were abandoned. Importantly, Mexico would be diverting scarce resources from real public health issues such as foodborne illness. Mexico, where the term Montezuma's revenge originated, suffers a foodborne illness rate that is 125 percent of the global average calculated by the World Health Organization.

Severe Contraction in the U.S. Rail Transportation Industry

The sudden decrease in U.S. corn exports to Mexico will have a profound impact on the U.S. rail transportation industry. In the first two years of Mexico's GM ban, this study finds U.S. corn exports to Mexico fall by 10.8 and 10.1 MMT, respectively, versus USDA's most recent baseline projections. Additionally, U.S. ethanol co-product exports to Mexico fall by 2.3 and 2.2 MMT in the first two years of the ban, compared to WPI's baseline export projections. Combined, total corn and ethanol co-product exports to Mexico fall by 13.1 and 12.3 MMT in the first two years of Mexico's ban.

Some of the lost co-product export freight volume will be filled by other feedstuffs exports from the U.S. (e.g., soymeal). Determining the exact volume and products that are likely to replace co-products, however, depends on prices and availability of global feedstuffs, as well as preferences and the specific least-cost feed ration formulations of Mexican livestock feeders. While a worthy exercise, determination of the exact changes to Mexican livestock rations is beyond the scope of this study. Consequently, WPI assumes that half the lost co-product rail exports to Mexico are filled by substitute products, such as soymeal, in the first year and that substitute feedstuff exports grow 5 percent annually thereafter.

Using USDA data for rail freight rates from western Corn Belt locations to Mexico[13], this net decrease in rail volume creates a $1.8 billion cumulative revenue loss for U.S. railroads in the first two years of the ban. For comparison, this is nearly three-quarters of the Kansas City Southern railroad's 2020 revenues, which totaled $2.6 billion[14]. The revenue decrease industry will create a pronounced contraction in the U.S. rail transportation sector, with some railroads seeing greater impacts than others.

As shown in Figure 11, the economic impacts of the railroad industry's contraction in the first two years of the ban will create the loss of $2.45 billion in U.S. GDP and a $4.5 billion loss in economic output. On average, the U.S. economy loses 8,180 jobs each year in the first two years of the ban and total tax revenue (federal, state, and local) falls by $470 million.

Figure 11: Cumulative Economic Impact of Initial 2-Year Contraction in U.S. Rail Industry

Impact	Annual Avg. Employment	Labor Income	US GDP	Output
	Full-time Equiv.		*Million USD*	
Direct	-1,875	-$502	-$961	-$1,822
Indirect	-2,653	-$421	-$725	-$1,372
Induced	-3,653	-$429	-$762	-$1,360
Total	**-8,181**	**-$1,353**	**-$2,448**	**-$4,554**

Source: World Perspectives, Inc.

[13] Available here: https://www.ams.usda.gov/services/transportation-analysis/gtr-datasets
[14] Kansas City Southern investor relations.

As U.S. corn exports begin to grow again in the 3rd forecast year and exports of other feedstuffs offset the loss of ethanol co-product exports, the U.S. rail industry recoups some of its initial losses. Crucially, however, **the industry does not fully recover even after 10 years**. Cumulatively across the 10-year forecast horizon, U.S. GDP falls by $1.67 billion and economic output is reduced by $3.1 billion. On average, the U.S. loses 1,119 jobs annually due to the sudden shock to the rail transportation industry.

Figure 12: Cumulative 10-Year U.S. Economic Impacts of Contraction in U.S. Rail Industry

Impact	Annual Avg. Employment	Labor Income	US GDP	Output
	Full-time Equiv.	*Million USD*		
Direct	-256	-$343	-$657	-$1,246
Indirect	-363	-$288	-$496	-$938
Induced	-500	-$294	-$521	-$930
Total	**-1,119**	**-$925**	**-$1,674**	**-$3,114**

Source: World Perspectives, Inc.

Impacts on the U.S. Corn Milling Industry

Finally, while corn grain has been the focus of this analysis, we note that Mexico has issued no guidance on whether milled products derived from GM corn will be permitted for import. For this study, we assume the ban will cover corn-derived products and feed ingredients, which creates a scenario where U.S. ethanol co-product demand falls and likely leaves surplus stocks in the American domestic market. Note, however, that if Mexico's ban *does not* apply to GM corn-derived products, then Mexican demand for these products will increase significantly as buyers replace corn with other higher cost products.

Assuming the ban applies to GM corn-derived products, then at risk are exports of dried distillers grains with solubles (DDGS), corn gluten meal (CGM), and corn gluten feed (CGF)[15]. Exports of these products to Mexico totaled $433 million and $393 million in 2019 and 2020, respectively. For the rest of this report, these three products – DDGS, CGM, and CGF – will be referred to as "ethanol co-products" or "co-products". Notably, Mexico has long been a major – if not the largest importer of U.S. DDGS – and accounted for 21 percent of all U.S. DDGS exports in 2021.

Conceptually, Mexico's ban will have two distinct impacts on the U.S. ethanol and corn milling industry. First, if GM-derived co-products are not permitted for import into Mexico, it will create a supply surplus on the U.S. market and lower prices. Second, as detailed earlier in this study, Mexico's direct ban on GM corn will cause lower prices in the U.S., Canadian, and broader global markets. For the ethanol industry, this effectively lowers the cost of inputs for ethanol and co-product production, creating a net benefit. This section examines each of those impacts separately and subsequently combines them to provide a complete understanding of how the ban will impact the U.S. corn milling and ethanol sector and the broader American economy.

To estimate the impact of Mexico's GM corn ban (with the presumption that it will also impact GM-corn derived products), WPI used proprietary supply and demand models to create 10-year baseline forecasts of ethanol production and prices, co-product production and prices, and U.S. co-product exports to Mexico and other countries. The U.S. Energy Information Agency's long-term forecasts for crude oil and natural gas were used as inputs to help formulate WPI's forecasts of ethanol prices and production margins.

Note that it is unlikely that U.S. ethanol producing firms will pay the 87-cent-per-bushel premium for procuring non-GM corn as their primary feedstock in order to achieve non-GM status for its products. Consequently, it is assumed that

[15] These three products, DDGS, CGM, and CGF are co-products from ethanol production and corn starch milling that are used in feed rations.

ethanol and co-products will be produced from GM corn and thus will be ineligible for export to Mexico (at least until Mexico offers clarifying guidance on its policies).

Given the significance of Mexico's imports from the U.S. of DDGS and co-products, one might expect a ban on U.S. co-products to have a large impact on the U.S. market for these products. Such expectations should be tempered, however, with the realization that Mexico's co-product imports (which totaled 2.18 MMT in 2020) account for just 5 percent of U.S. co-product production. Using data from the USDA's *Grain Crushings* report, WPI finds U.S. total co-product production exceeded 41.3 MMT in 2020, nearly 68 percent of which was consumed domestically (based on USDA FAS export data that shows total 2020 co-product exports of 13.18 MMT). Consequently, while Mexico's market is highly important and significant for U.S. co-product exports, it is small in comparison to the domestic American market.

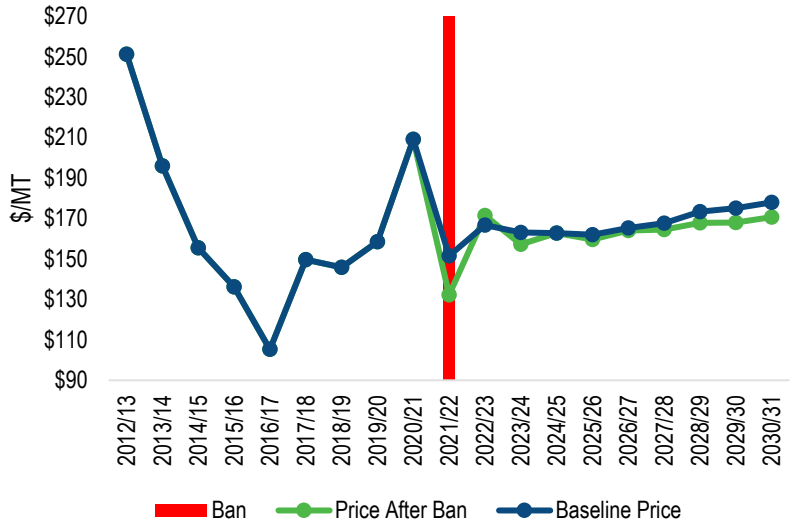
WPI estimates that in the first year of a Mexican ban on GM corn and GM corn-derived products, U.S. co-product exports to Mexico are eliminated, creating a supply surplus of 2.36 MMT. WPI estimates that the U.S. domestic market consumes 1 percent more co-products in the first year due to the resulting supply surplus and thus lower prices. The U.S. domestic market does not consume more co-products to absorb the additional supplies for two primary reasons: First, the DDGS inclusion rate in cattle rations has effectively reached its saturation point and greater use in the swine and poultry industries is not practical[16]. Additionally, the U.S. beef and dairy cattle industries are constrained by a multi-year biological time lag when responding to economic incentives (like lower feed prices).

The non-Mexico international market, however, does expand and import more co-products from the U.S. WPI's models predict a 9 percent increase in co-product exports to other countries during the first year of the ban as importers respond to lower prices. At the year's end, the Mexican ban leaves a surplus of 1.1 MMT of co-product supplies in the U.S. market. Based on supply and demand elasticities from Matthews and McConnell (2012), WPI estimates co-product prices fall 13 percent and U.S. DDGS prices average $132/MT. Holding corn prices constant (temporarily) as well as ethanol and natural gas prices, WPI estimates U.S. ethanol production margins fall $0.06/gallon in the first year of the ban versus the baseline forecast.

Over the 10-year forecast horizon, markets adjust to the loss of the Mexican co-product market and U.S. domestic and rest-of-the-world (ROW) consumption responds to price changes. Total co-product consumption, however, never fully recovers to its baseline forecast. On average, total co-product consumption (in the U.S. and from ROW exports) falls 0.4 MMT annually over the 10-year period and DDGS prices are, on average, 3 percent lower than would have otherwise occurred (Figure 13).

[16] Due to differences in ruminant (e.g., cattle), monogastric (e.g., swine), and poultry digestive systems, swine and poultry feed rations utilize less DDGS. Research from the U.S. Grains Council suggests poultry rations only include 5 percent DDGS and WPI's own research indicates a similar inclusion rate for swine.

Figure 13: U.S. DDGS Prices, FOB Central Illinois Ethanol Plant



Source: World Perspectives

The U.S. ethanol industry faces margins that, on average, are 1.5 percent lower than the baseline forecast due to the shocks in the co-product market created by Mexico's ban. Crucially, however, ethanol margins remain positive, which prevents a significant contraction in the industry. The price impacts, however, suggest that ethanol and co-product output will fall 3.8 percent in the first year of the ban as ethanol mills react to declining margins. The subsequent rally of co-product prices in the second year of the ban, however, pushes production 3.1 percent higher and largely offsets the losses of the first year. Thereafter, co-product prices and ethanol production margins experience much smaller shocks, and the ethanol industry's output stabilized. Cumulatively over the 10-year forecast horizon, ethanol and co-product output falls by $234 million. One key reason ethanol and co-product production does not experience a greater decline is that ethanol firms are known to have highly inelastic short-run supply elasticities[17]. Additionally, the blending mandates imposed by the U.S. Renewable Fuels Standard create an ethanol demand curve that is perfectly inelastic below the annual mandate (Irwin and Good, 2014).

Results from IMPLAN show that the change in ethanol output creates an annual loss of 353 jobs, on average, over the 10-year horizon and reduces labor income by $217 million. Additionally, U.S. GDP falls $374 million due to the ethanol industry's changes and economic output falls by $1.02 billion over 10 years.

Figure 14: Cumulative 10-Year Impacts of Mexico's Ban on U.S. Ethanol Co-Product Exports

Impact	Annual Avg. Employment	Labor Income	US GDP	Output
	Full-time Equiv.		***Million USD***	
Direct	-17	-$21.3	-$53.6	-$315.6
Indirect	-219	-$126.7	-$198.5	-$482.4
Induced	-117	-$68.8	-$122.1	-$217.8
Total	**-353**	**-$216.9**	**-$374.2**	**-$1,015.8**

Source: World Perspectives, Inc.

Readers will note that co-product prices are not the only variable impacting ethanol margins under a Mexican ban on GM corn and corn-products. Indeed, the industry will see a net benefit from the lower corn prices it uses as inputs in

[17] That is, production falls or increases by a smaller rate than does a change in price, due partly to high costs to enter or exit the industry.

the ethanol and co-product manufacturing process. As noted earlier in this study, U.S. GM corn prices fall $0.13/bushel, on average, in the 10 years following the ban, which will lower ethanol plants' input costs and boost margins.

WPI estimates the lower cost of corn will spark a mild expansion in the ethanol industry. The first year of the ban and its price-depressive effects on GM corn, U.S. ethanol and co-product output could expand by $347 million. The industry likely curbs output by $842 million in the second year as corn prices recover some of the prior year's losses. Over the 10-year forecast horizon, U.S. ethanol production expands by $152 million, cumulatively, due to the impacts of lower corn prices. This expansion sparks net job creation of 180 full-time position over each of the 10 years and increases labor income by $110 million. U.S. GDP and economic output increase by $191 million $518 million, respectively.

In total, the net economic losses created by Mexico's effective ban on GM corn-derived ethanol co-products outweigh the benefits to the ethanol sector afforded by lower corn prices. Annual U.S. employment decreases by a net 173 jobs annually over each of the 10 years following Mexico's ban and total labor income decreases $106 million. U.S. GDP shrinks by $183 million due to net contraction in the industry and economic output falls by $498 million.

Figure 15: Cumulative 10-Year Impacts of Lower GM Corn Prices on Ethanol Output

Impact	Annual Avg. Employment	Labor Income	US GDP	Output
	Full-time Equiv.		***Million USD***	
Direct	-8	-$10.5	-$26.3	-$154.7
Indirect	-107	-$62.1	-$97.3	-$236.4
Induced	-57	-$33.7	-$59.8	-$106.7
Total	**-173**	**-$106.3**	**-$183.4**	**-$497.8**

Source: World Perspectives, Inc.

Impacts on Canada's Economy

Due to strong linkages between the U.S. and Canadian farming and overall economies, the shock to the U.S. farm sector will ripple through to the Canadian farm economy as well. Historically, Canada has been an infrequent and minor supplier of corn to Mexico, but customs data may understate the volume of corn imported into the U.S. from Canada and re-exported to Mexico.

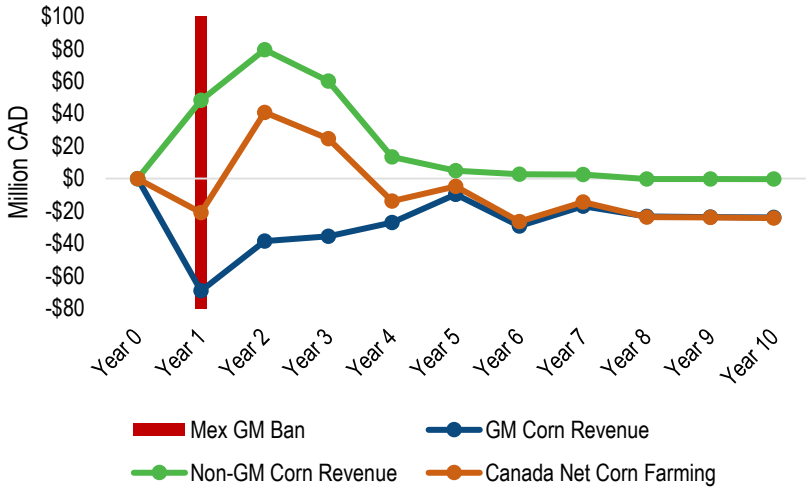
More importantly, however, the farming and grain handling systems of the U.S. and Canada are closely linked and prices in one market are transmitted to others (McKnight, et al 2021). This means that the price impacts hitting the U.S. farming industry due to the Mexican GM corn import ban will create similar impacts in Canada's market. Consequently, Mexico's new policy will adversely impact all three members of the U.S.-Mexico-Canada-Agreement on trade.

WPI uses historic relationships[18] between U.S. and Canadian corn prices to estimate the impact of the Mexico GM corn ban on Canadian corn prices and acreage. We find Canadian GM corn prices fall 3% in the first two years of the ban while non-GM corn prices in Canada rice 14 percent. Despite the larger increase in non-GM corn production[19] and prices, the losses faced by Canadian GM corn producers outweigh gains from non-GM production and higher prices. Over the 10-year forecast period, the **Canadian corn farming sector is projected to lose CAD$87.7 million in farm revenue versus what would have occurred without the ban** (Figure 16).

[18] We find U.S. and Canadian corn prices are correlated at the 0.88 level and time-series regression analysis shows U.S. corn price fluctuations explain 77% of the variation in Ontario, Canada prices.

[19] While not detailed in this paper, WPI's models show an increase in non-GM corn planted area and a decrease in GM corn area like what occurs in the U.S. The change in Canada's acreage composition, however, is not as great as in the U.S. and Canada's total corn acreage and production stay essentially constant.

Figure 16: Estimated Changes in Canadian Corn Farming Revenue Following Mexico's GM Corn Ban



Source: World Perspectives, Inc.

The net loss to Canada's corn farming sector cause total economic impacts of $72.8 million in lost GDP and $170 million in lower economic output over the next 10 years. Approximately 82 full-time jobs are lost each year as well due to the reduction in Canadian farm income.

Figure 17: 10-Year Cumulative Impacts on Canada's Economy from Changes in Corn Farming Revenue

Impact	Annual Avg. Employment	Labor Income	Canada GDP	Output
	Full-time Equiv.		*Million USD*	
Direct	-33	-$6.6	-$27.1	-$75.5
Indirect	-36	-$15.3	-$32.6	-$72.2
Induced	-13	-$6.1	-$13.1	-$22.4
Total	**-82**	**-$27.9**	**-$72.8**	**-$170.1**

Source: World Perspectives, Inc.

Lower prices for GM corn and acreage shifts are not the only impacts the Canadian economy will experience due to the Mexican GM corn ban. Like the U.S., the Canadian system will have to accommodate segregation of GM and non-GM corn at the grain origination, handling, and processing sectors. Given that Canada is a minor and infrequent exporter of corn to Mexico, it is unclear whether the Canadian grain industry will fully bifurcate into two streams (GM and non-GM) for grain handling. That is a possible outcome, but it is uncertain that it is a necessary one. What will be necessary, however, is for the Canadian grain industry to adopt sufficient identity preservation and testing to interface with the U.S. grain system. According to USDA FAS data, Canada is the largest exporter of corn to the U.S., shipping 228,000 MT in 2020 (41 percent of all U.S. corn imports).

The easiest way for Canada to identity-preserve non-GM corn will be to use a "segregation by channeling" approach, where certain facilities handle non-GM grain in certain days or alternate sites for receiving and shipping the crop (Elbheri, 2007). WPI estimates these costs at approximately $5.31/MT for 2021 but we estimate the cost of such approaches will decrease to $1.33/MT after three years as the industry's operations become more streamlined and efficient. Because these costs are imposed on all corn originated and handled in Canada, the 10-year direct costs to the grain industry exceed $325.9 million. Note that these are costs incurred by Canadian firms to simply retain efficient trade capabilities with the U.S. and that Canadian firms do not receive additional marketing opportunities to offset the cost increase.

As with the U.S. grain handling system, it is unclear how the $325.9 million in segregation and IP costs will be transmitted through the Canadian economy. Canadian farmers may face lower bids for their grain, or Canadian consumers may see higher food and fuel (in the form of ethanol) prices. Canadian corn exports may pass along some of the cost to U.S. importers, but determination of who bears these costs is complex and unclear (Desquilbet and Bullock, 2009).

Impacts on Mexico's Economy

The import ban will create a net negative economic impact for Mexico, the majority of which will be borne by Mexican consumers. Preliminary estimates find Mexico will pay $4.4 billion more over the next 10 years to secure non-GM corn to meet domestic consumption. Additionally, Mexico will see $1.0 billion in segregation and IP costs incurred by the U.S. grain industry passed onto importers, along with $189.7 million in genetic testing[20] to verify that non-GM corn imports meet yet-to-be-determined contamination thresholds. These additional costs create a total $5.6 billion burden the Mexican economy otherwise would not have to pay, were the GM corn ban not implemented (Figure 18).

Figure 18: Additional Costs Borne by Mexico Resulting from GM Corn Ban

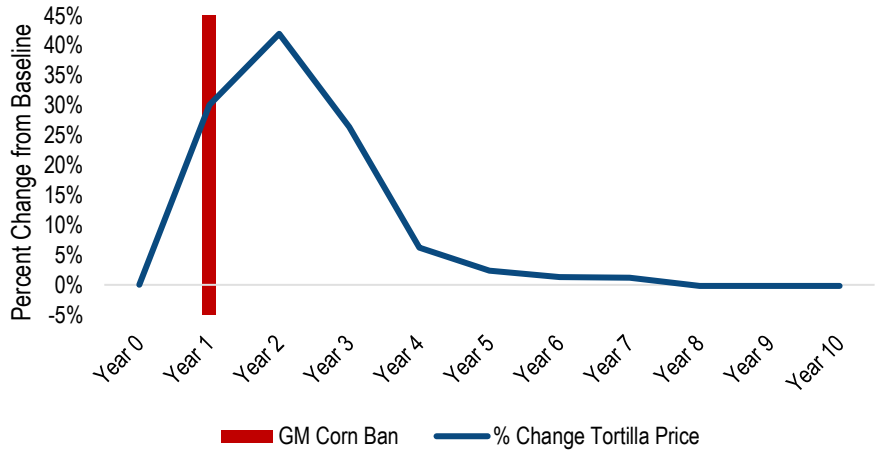
Added Cost	Million USD
Corn Import Cost, Change from Baseline	$4,403
Segregation & IP costs passed from U.S.	$1,005
Genetic Testing Costs	$190
Total	**$5,597**

Source: World Perspectives, Inc.

Mexican Tortilla Prices Under GM Corn Ban

Wise (2012) estimated that "a 20% increase in corn prices… transmitted to the Mexican market for white corn, raises tortilla costs by 14%" (pp. 10). WPI uses this formula to estimate the percentage change in Mexican tortilla prices that are likely to result from Mexico's GM corn ban, based on our estimates of changes in U.S. export prices. WPI finds that in the first year of the GM ban, **tortilla prices increased 30 percent and then by 42 percent in the second year of the ban, versus what would have occurred without the ban.** This is clearly a massive increase in the cost for a staple food item in Mexico and will contribute to Mexico's persistent food insecurity problems.

Figure 19: Estimated Changes in Mexican Tortilla Prices Resulting from GM Corn Ban



Source: World Perspectives, Inc.

[20] See discussion in the section *Costs of Grain Segregation and Identity Preservation* for more details.

WPI models the increase in tortilla prices as a net reduction in household income, since Mexican consumers will have to pay more to purchase the same quantity of goods (e.g., tortillas). While not a true reduction in household income, modeling it as such allows for the exploration of the economic impacts of household spending that would have otherwise occurred. We find **the 10-year total economic impacts of this decreased household income reduce Mexican employment by 108,000 jobs, reduce total labor income by $972 million, cause a contraction of $3.4 billion in GDP, and reduce Mexico's economic output by $5.4 billion.**

Impacts on Mexico's Livestock Operations

There will also be profound impacts on the Mexican livestock feeding sector as feed ingredient prices will rise and availability will decrease. While Mexico will likely be able to secure non-GM corn from Brazil and Ukraine (among other countries) to fill the immediate loss of U.S. exports, it will do so paying a sharply higher price to secure the grain. Moreover, **it is uncertain that Mexico will be able to fully replace the lost U.S. co-products used for feed**. The U.S. has historically been the world's largest DDGS producer and accounted for 77 percent[21] of global output in 2018 (Vasquez, et. al, 2018). Since then, however, Brazil has expanded its production significantly and WPI forecasts the country will produce 4.4 MMT of DDGS in 2022. While Brazil's rising DDGS production could potentially benefit Mexico, it will also be primarily GM corn-derived and, therefore, subject to the same restrictions or bans as U.S. co-products. Mexico could utilize non-corn derived feedstuffs, such as soymeal, cottonseed meal, etc., but these substitute products will require significant re-formulation of livestock feed rations and may ultimately not match the optimal energy and protein content combination provided by DDGS and other co-products.

Detailed forecasting of how Mexican livestock operations will address the dual impacts of rising corn costs and lower co-product (i.e., protein and energy feed components) availability is beyond the scope of this study. WPI can, however, note that these impacts will likely decrease the efficiency of livestock feed conversion and growth rates and, ultimately, reduce livestock operations' profits. Mexico is already a higher cost producer of pork and poultry than the U.S. In the long run, some of these operations will exit the industry due to declining profits, which will curb Mexico's meat and animal product output. In turn, Mexico's food security will suffer and the country will likely become more reliant on meat, dairy, and poultry imports. **Mexico's GM corn ban will increase food insecurity via two means: first by raising rising corn and tortilla prices and, second, destabilizing and causing an economic contraction in the livestock industry.**

Total Impacts on the Mexican Economy

How the Mexican economy absorbs these additional costs is difficult to model as multiple options exist for firms, the Mexican government, and consumers to react to the changes. WPI estimates the total economic impact by assuming these costs are passed on to the consumer level in the form of higher prices for food products. The impacts of grain segregation and IP costs and genetic testing costs combined over 10 years, lower Mexico's full-time employment by 29,750 jobs, reduce labor income by $268 million, cause a $946.99 million contraction in GDP, and lower Mexico's economic output by $1.493 billion. When these impacts are combined with those of reduced household spending due to higher tortilla prices, WPI estimates **138,000 jobs could be cut from Mexican economy and the country's GDP is likely to contract $4.3 billion and economic output will fall by $6.9 billion over the 10-year forecast period.**

Impacts on Future Innovation

The impact of GMO restrictions on future innovation has not been studied as robustly as needed. A brief report under the umbrella of the Council for Agricultural Science and Technology touched upon this topic in the context of the impacts of asynchronous approvals for biotech crops. It noted that most ex-ante impact analyses of such events have focused

[21] In 2018, U.S. production totaled roughly 44 MMT while the EU's output totaled 9 MMT, Canada produced 1 MMT, and China plus the rest of the world produced 2.5 MMT.

on the short-term direct economic losses from agricultural commodity shipments blocked due to low-level presence of unapproved traits.

Kalaitzandonakes, Zahringer, and Kruse (2015) modeled the cost of a three-year delay in introducing a new herbicide-tolerant crop. In addition to the near-term increased costs for weed control, they calculated that "the delayed commercialization of these new biotech events lessened the social benefits from their adoption by an estimated $20 billion over a ten-year period, roughly equally distributed between producers and consumers." **If extrapolated across the 19 traits still lacking approval in Mexico, the adverse impact could stretch to $380 billion dollars in the coming years**.

It is important to emphasize some nuanced but important factors in this analysis:

1) The convergence of low-cost genome sequencing with improved computational power and high-throughput molecular phenotyping technologies has accelerated the capacity to develop genetically improved cultivars. This means the opportunity costs increase over time.
2) The uncertainty can divert investment in biotechnology R&D away from crops, and it is estimated that the increase in asynchronous approvals increased regulatory costs by 50 percent during 2005 – 2015. (Cossey, 2016)
3) Higher regulatory costs disproportionately impact small market crops, and can effectively shut out small, innovative firms and producers, leading to increased industry concentration. (Phillips 2013; Sachs 2016; USDA-NIFA 2011)

See separate report on impacts on innovation.

VI. Conclusions

This study examines the economic impact of Mexico's proposed ban, to take effect in 2024, on GM corn imports for human consumption. While Mexican policy officials have stated the ban applies only to food imports, there is little documented confirmation of such intent and the nature of the U.S. and Canadian corn production systems and Mexico's import system make separating GM and non-GM corn difficult at best. Practically, this research finds limited potential for Mexico to adequately separate and identify-preserve GM versus non-GM corn imported for food or feed/fuel use, which means a ban on GM corn for food use is a ban on *all* GM corn.

Using USDA's long-run projections as a baseline, this study uses acreage, supply, and demand models to trace the impacts of Mexico's GM corn ban on the U.S. farm sector. The ban will create significant changes in the U.S. corn production system. In the short run, we find Mexico's GM ban increases the U.S. non-GM corn price by 49 percent the first year and 11 percent in the second year, with the price increase forcing a reduction in Mexico's corn imports. The first year the ban takes effect sees Mexico's net corn imports fall from 16.5 MMT in the baseline scenario to 13.07 MMT, with corresponding reductions in domestic use. U.S. GM corn export increase as non-Mexico buyers secure U.S. corn rather than from traditional supplies who are now exporting to Mexico.

In the long-run, this research finds the U.S. GM corn price remains under pressure from the shock of the export ban but generally stabilizes. Conversely, the non-GM corn price rallies sharply in the early years of the ban to encourage a sufficient production response from the U.S. and later declines to near parity with the GM corn price.

In total, the shock caused by Mexico's proposed ban will create a net negative impact for the U.S. corn farming industry and the entire U.S. economy. Using IMPLAN economic input-output models, this study finds U.S. economic output falls by $16.5 billion and GDP contracts by $7.95 billion as a direct result of Mexico's GM corn ban. Additionally, U.S. grain handling firms will realize $10.08 billion in additional costs to segregate, and identity-preserve non-GM corn destined for Mexico and it is unclear how these costs will be transmitted through U.S. economy. The U.S. rail transportation sector will suffer a significant contraction in the first two years of the ban with sales losses approximately equivalent to three-quarters the Kanas City Southern railroad's 2020 annual revenues.

The Mexican economy also experiences negative impacts as 138,000 jobs could be cut from the economy and the country's GDP is likely to contract $4.3 billion over the 10-year forecast period. Mexico's purchase price of corn rises $4.4 billion over ten years because of the ban and tortilla prices could rise 30 percent in the first year of the ban and by 42 percent in the second year. A stated goal of Mexico's' GM ban is to increase food security, but this study suggests the opposite effect is more likely.

Canada also experiences negative impacts from Mexico's policy, and the Canadian corn farming sector is projected to lose CAD$87.7 million in farm revenue versus the baseline outlook. Canada's total economic impacts of $72.8 million in lost GDP and $170 million in lower economic output over the next 10 years.

Finally, there are secondary and tertiary impacts of which economic consequences are significant but for which precise economic modeling is unavailable. These impacts include added "riskiness" and supply chain inflexibility stemming from a bifurcated grain handing system and changes in pricing and demand for ethanol co-products (e.g., distillers grains) and competing products (e.g., soybean meal). Importantly, innovation and development of future biotech crops are likely to be adversely impacted with Mexico's current hiatus in GM approvals alone likely costing $380 billion in the coming years.

VII. Sources

Bullock, D.S., and M. Desquilbet. 2002. *The economics of non-GMO segregation and identity preservation.* Food Policy. Vol. 27, Issue 1, pp. 81-99.

Desquilbet, M. and D. S. Bullock. 2009. *Who Pays the Costs of Non-GMO Segregation and Identity Preservation?* American Journal of Agricultural Economics. Vol. 91, No. 3 (Aug., 2009), pp 656-375. https://www.jstor.org/stable/20616226

Doshi, K. and F. Eudes. 2007. *Identity Preservation in Genetically Modified Crops*. In book: Recent Advances in Plant Biotechnology and its Application (pp. 229-256). Publisher: I.K. International Pvt. Ltd. New Delhi, India.

Elbehri, Aziz. 2007. *The Changing Face of the U.S. Grain System: Differentiation and Identity Preservation Trends*, ERR-35. U.S. Dept. of Agr., Econ. Res. Serv. Feb. 2007. Accessed at: https://www.ers.usda.gov/webdocs/publications/45729/11887_err35_1_.pdf?v=0

Fernandez-Cornejo, Jorge; Seth Wechsler; Mike Livingston; and Lorraine Mitchell. 2014. *Genetically Engineered Crops in the United States*, ERR-162 U.S. Department of Agriculture, Economic Research Service, February 2014. Accessed at: https://www.ers.usda.gov/webdocs/publications/45179/43668_err162.pdf

Irwin, S. and D. Good. 2014. *Why Are Ethanol Price and Production Profits So High?* Farmdoc Daily. 11 June 2014. Accessed at: https://farmdocdaily.illinois.edu/2014/06/why-are-ethanol-prices-and-production-profits-so-high.html

ISAAA 2019. *Global Status of Commercialized Biotech/GM Crops: 2019.* ISAAA Briefs. No. 55. Accessed at: https://www.isaaa.org/resources/publications/briefs/55/default.asp

Kalaitzandonakes, N., Giddings, V., McHughen, A., and Zahringer, K. 2016. *The Impact of Asynchronous Approvals for Biotech Crops on Agricultural Sustainability, Trade, and Innovation*. CAST Commentary QTA2016-2. Council for Agricultural Science and Technology. Access at: https://www.cast-science.org/wp-content/uploads/2018/12/QTA20162_Asynchronous_Approvals_Eng_1A2341477D0E2.pdf

Lusk, J.L., M. Jamal, L. Kurlander, M. Roucan, and L. Taulman. 2005. *A Meta Analysis of Genetically Modified Food Valuation Studies.* J. of Ag. and Resc. Econ 30(April):28-44.

Loureiro, M., and S. Hine. 2002. *Discovering Niche Markets: A Comparison of Consumer Willingness to Pay for Local (Colorado Grown), Organic, and GMO-Free Products*. J. of Ag. and Appl. Econ. 34.

Matthews, K. H. and M. J. McConnell. 2012. *The Market for U.S. Livestock Feed Proteins*. Applied Economic Perspectives and Policy, 34 (4), 555-569.

McKnight, C. F. Qui, M. Luckert, G. Hauer. 2021.*Prices for a second-generation biofuel industry in Canada: Market linkages between Canadian wheat and US energy and agricultural commodities.* Canadian J. of Ag. Econ. Vol. 69, Iss. 3, pp337-351. https://doi.org/10.1111/cjag.12295

Murray Wise Associates LLC. 2021. *Mexico to Go Non-GMO | Big Deal or Little Deal?* 26 Mar. 2021. Accessed at: https://murraywiseassociates.com/mexico-to-go-non-gmo-big-deal-or-little-deal/

Organization for Economic Cooperation and Development. 2014. *Freight Railway Development in Mexico.* International Transportation Forum. Accessed at: https://www.itf-oecd.org/sites/default/files/docs/14mexicorail.pdf

Prince Fosu & Thomas I. Wahl | Evan Lau (Reviewing editor) (2020) Empirical analysis of US bilateral corn trade: Evidence from Japan, Mexico, China, South Korea, and the European Union, Cogent Economics & Finance, 8:1, DOI: 10.1080/23322039.2020.1783128

Spalding, A., K. Kiesel. 2018. *Willingness to Pay for Local, Value-Added Goods*. Selected paper prepared for presentation at the 2018 Ag. & Appl. Econ. Assoc. Annual Meeting, Washington, D.C., 5-7 Aug.

Taheripour, F., H. Mahaffey, and W. E. Tyner. 2016. *Evaluation of Economic, Land Use, and Land-use Emission Impacts of Substituting Non-GMO Crops for GMO in the United States.* AgBioForum, 19 (2): 156-172.

U.S. Department of Agriculture, Foreign Agricultural Service. 2020. *Agricultural Biotechnology Annual: Brazil*. Report No. BR2019-0060. Accessed at: https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Agricultural%20Biotechnology%20Annual_Brasilia_Brazil_10-20-2019

Wise. T. A.. 2012. *The Cost to Mexico of U.S. Corn Ethanol Expansion*. Global Development and Environment Institute. Working Paper No. 12-01. Tufts University, Medford MA, USA. Accessed at: http://www.obela.org/system/files/WiseBiofuels.pdf

Vázquez, Y., H. Bernal Barragan, M. Valdivie, E. Gutierrez, L. Mora, C. Hernández Martínezt. 2018. *Nutritional value and application of dried distillery grains with solubles from different sources in rabbit feeding*. Cuban Journal of Agricultural Science. 51.

VIII. Appendix

Data Used in the Analysis

FOB price data for corn were obtained from WPI's proprietary datasets as well as DTN's ProphetX platform for the U.S. Gulf, Brazil, Argentina (Upriver terminals), Ukraine, and Romania. While not a major exporter, Romania is included in this list as reliable prices for non-GM corn were available, offering a key metric for possible price differences Mexico can expect under a GM-corn ban.

Forecasts of corn production, exports, and imports for the relevant countries (e.g., the USA, Mexico, Canada, Brazil, etc.) were obtained from the USDA's long-term projections datasets and are used as "baseline" scenarios. USDA's latest long-term projections data use the October 2020 WASDE report as the starting point and, as such, do not account for the large increase in U.S. corn exports and ending stocks decreases that occurred in 2020/21.

Notes on Interpreting IMPLAN Economic Input-Output Results

Readers should note there are caveats to interpreting these IMPLAN results. First, the IMPLAN system uses linear, unbounded models to estimate impacts from a shock in one industry to others. These models do not account for non-linear responses or relationships between industries, such as might exist, for example, in the case of diminishing marginal returns to increasing output, or efficiencies of scale or scope. Additionally, IMPLAN models assume wages and prices are fixed and do not adjust during the impact period. Consequently, results from IMPLAN should be viewed as the upper bound on expected impacts. Models that can incorporate non-linear responses and adjust wages and prices dynamically may offer results nearer to the mid-point or lower bound of expected results.