

HOW WILL CHINA'S ADOPTION OF GENETICALLY MODIFIED SOYBEANS AFFECT GLOBAL SOYBEAN MARKETS?

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Abstract: China began commercial planting of genetically modified (GM) soybeans in 2024 after two decades of regulatory caution. Because China buys about two-thirds of the soybeans traded worldwide, exporters ask whether higher domestic yields will cut its imports and depress world prices. This paper works through three channels: yield gains on existing soybean land, land reallocation between corn and soybeans, and slower structural change in the countryside. Three results follow from official statistics, variety-trial data, and the U.S. adoption record. First, trial yield gains of 5–10 percent applied to China's 10 million hectares of soybeans add 1–2 million tons, one to two percent of the 105 million tons imported in 2024, and would lower world prices by about one percent. Second, Heilongjiang cost-and-return data show that soybeans would need a 32 percent yield gain to match corn's per-hectare return without subsidies, three times the largest trial gain reported for an approved GM soybean variety; and because GM corn is being commercialized on the same timetable, the yield channel leaves relative profitability almost unchanged. Third, in the United States, where adoption became near-universal, GM adoption is not associated with higher average yields once the common breeding trend is absorbed by year fixed effects. GM adoption will not cut China's imports in the short run. Any larger effect would come from land consolidation, rural aging, and the subsidies that already carry the soybean sector, not from the seed itself.

Keywords: Genetically modified crops; Soybean trade; China agriculture; Crop rotation; Global commodity markets

1 INTRODUCTION

China's decision to commercialize genetically modified (GM) soybeans marks a turn in its agricultural biotechnology policy. For more than two decades GM soybeans could be imported for crushing but not planted. The government approved GM soybean and corn varieties for pilot cultivation in 2021 and moved to commercial planting from 2024 [1-2]. Because China takes roughly two-thirds of world soybean imports, the change has drawn attention in exporting countries, above all the United States, where the question is whether higher Chinese yields will mean smaller Chinese purchases and lower world prices.

The worry has a simple logic. If GM seed raises yields and lowers costs, China can grow more soybeans at home and buy fewer abroad. This paper takes that logic seriously and asks how far it carries once it meets the constraints that have shaped China's soybean sector for decades. Despite repeated policy pushes for self-sufficiency, domestic output covers about one-sixth of consumption. The reason is not seed technology. Soybeans compete for scarce cropland with grains whose self-sufficiency the state treats as non-negotiable, and on the land where both can grow, soybeans earn less per hectare than corn. The United States and Brazil expanded soybean output on abundant land; China cannot.

The argument of the paper is that GM adoption operates within these constraints rather than overturning them. In the short run, GM yield gains on existing soybean land are too small to change China's import bill or world prices. Over the medium and long run, the question is whether the technology can interact with land consolidation, rotation policy, and rural demographic change to move land toward soybeans, and here the decisive comparison is with GM corn, which is being commercialized at the same time.

The paper is a policy analysis, not an econometric one. It uses official Chinese and U.S. statistics and variety-trial results to put numbers on each channel, works the arithmetic in the open so that a reader can check it, and says what the numbers cannot show. Three calculations carry the argument: the yield gain soybeans would need to match corn's return in Heilongjiang (Section 2.2); a comparison of GM soybeans with GM corn in yuan per hectare rather than in percentages (Section 6); and a panel regression on the U.S. adoption record that separates the adoption effect from the breeding trend (Section 5.4).

2 INSTITUTIONAL BACKGROUND AND POLICY CONTEXT

2.1 Soybeans in China's Food Security Strategy

China's soybean deficit is best understood as a land problem. In 2024 the country sowed 10.33 million hectares of soybeans and harvested 20.65 million tons, an average yield of 2.0 tons per hectare [3]. Sown area has grown by about a quarter since 2021 under the government's soybean expansion program and is at its highest level in decades. Even at this historically high acreage, domestic production covers less than one-sixth of consumption: imports reached 105.03 million tons in 2024 [4].

The arithmetic of replacing those imports shows why. At two tons per hectare, growing 105 million tons at home would take about 52 million additional hectares, five times the current soybean area. That is more than the 44.74 million hectares China planted to corn in 2024, and about two-fifths of the country's entire cropland of 127.86 million hectares recorded by the Third National Land Survey [3, 5]. The other staples occupy the rest: 23.59 million hectares of wheat and 29.01 million hectares of rice in 2024. Because the state's declared priority is "absolute" self-sufficiency in these grains, large soybean imports are not a policy failure but a deliberate part of the food security strategy: China imports the crop that needs the most land per ton harvested.

Within this framework, GM soybeans do not relax the land constraint. They raise output somewhat on the land already allocated to soybeans, and they can change how much land soybeans receive only by changing how soybeans compare with corn.

2.2 Corn–Soybean Rotation Policy and the Profitability Gap

To lift soybean output without touching grain area, China has promoted corn–soybean rotation and strip intercropping, mainly in the Northeast. Since the 2016 reform that ended the corn temporary reserve program, the main instruments have been producer subsidies that pay far more per mu for soybeans than for corn, and rotation payments for land switched out of continuous corn. The response has been real but expensive. Soybean area rose from 8.4 million hectares in 2021 to about 10.5 million in 2023 as Heilongjiang raised its soybean subsidy, and slipped in 2024 when prices fell [3]. Intercropping reached about 1.3 million hectares in 2023, a small share of grain area. Studies of the 2017–2021 period find that the producer subsidy stabilized soybean area in the Northeast rather than expanding it, because corn remained the more profitable crop [6].

How large is the gap? Table 1 assembles the Heilongjiang budgets for corn and soybeans in the 2023 crop year from the 2024 edition of the National Compilation of Agricultural Product Cost and Return Data, the survey published each year by the National Development and Reform Commission that reports per-mu costs and returns by province and crop [7], together with the 2023 provincial producer subsidies [8–9]. The compilation's total cost is the sum of material and service cost, labor cost, and land cost, where labor includes an imputed wage for family labor and land includes imputed rent on the farmer's own land. Its net profit is gross output value less total cost and excludes subsidies; the subsidies are added in the last two rows.

Table 1 Cost and Return of Corn and Soybeans in Heilongjiang, 2023

	Corn	Soybeans	Corn – Soybeans
A. Per mu (yuan)			
Gross output value	1,218.87	724.93	493.94
Material and service cost	439.52	255.53	183.99
Labor cost (hired and family)	226.06	179.44	46.62
Land cost (rent paid and imputed)	675.68	646.55	29.13
Total cost	1,341.26	1,081.52	259.74
Net profit before subsidies	–122.39	–356.59	234.20
Producer subsidy, 2023	14.00	366.00	–352.00
Net profit after subsidies	–108.39	9.41	–117.80
B. Per hectare (yuan)			
Gross output value	18,283.05	10,873.95	7,409.10
Material and service cost	6,592.80	3,832.95	2,759.85
Labor cost (hired and family)	3,390.90	2,691.60	699.30
Land cost (rent paid and imputed)	10,135.20	9,698.25	436.95
Total cost	20,118.90	16,222.80	3,896.10
Net profit before subsidies	–1,835.85	–5,348.85	3,513.00
Producer subsidy, 2023	210.00	5,490.00	–5,280.00
Net profit after subsidies	–1,625.85	141.15	–1,767.00

Notes: One hectare equals 15 mu. Costs and returns are Heilongjiang figures for the 2023 crop year from the 2024 edition of the NDRC cost-and-return compilation [7]. Total cost is material and service cost plus labor cost plus land cost; labor cost includes an imputed wage for family labor and land cost includes imputed rent on the farmer's own land. Net profit before subsidies is gross output value less total cost. Producer subsidies are the 2023 Heilongjiang standards of 14 yuan per mu for corn and 366 yuan per mu for soybeans [8]. The rotation payment of 150 yuan per mu [10] is paid only on plots rotated into soybeans in a given year and is excluded. The last row is net profit before subsidies plus the producer subsidy.

Three things stand out. First, on this full-cost basis neither crop covers its imputed costs: a farmer who charged himself market rent for his own land and a wage for his own labor would lose money on both. Second, before subsidies corn's loss is 234 yuan per mu, or 3,513 yuan per hectare, smaller than the loss on soybeans. This is the gap, written *G* below, that farmers weigh when they choose between the two crops. Third, the 2023 producer subsidy of 366 yuan per mu for soybeans against 14 for corn is larger than the gap. It lifts soybeans to roughly break-even and about 118 yuan per mu ahead of corn. That is what a subsidy equal to half the soybean crop's gross value buys, and it explains both the rise in soybean area since 2022 and the difficulty of going further: every hectare held in soybeans costs the treasury roughly the size of the gap, every year.

The question for this paper is whether GM technology could do the subsidy's job. Let G be the pre-subsidy gap in net profit per hectare, p the soybean price, and y the soybean yield, so that $p \times y$ is soybean output value per hectare. Holding costs and prices fixed, soybeans match corn when the yield rises by

$$\frac{\Delta y}{y} = \frac{G}{p \times y} = \frac{3,513}{10,874} = 0.323. \quad (1)$$

Soybean yields in Heilongjiang would have to rise by 32 percent. The trial gains reported for GM varieties, discussed in Section 5.1, are 5–10 percent, and the largest figure for a GM soybean variety approved in 2025 is 10.2 percent (Section 6). The seed on its own closes at most one-third of the gap. GM soybeans will therefore change land use only if something else, the subsidy or a fall in corn's return, closes the rest.

3 RELATED LITERATURE

This paper draws on three strands of work. The first documents the agronomic effects of GM crops. The meta-analysis by Klümper and Qaim [11] finds average yield gains of about 9 percent for herbicide-tolerant crops, larger gains for insect-resistant ones, and pesticide cost reductions of roughly 40 percent. The gains reported in China's variety trials fall in the same range [12–13].

The second strand studies China's soybean policies. Di et al. [6] map crops at ten-meter resolution across the Northeast for 2017–2021 and find that the producer subsidy stabilized soybean area without expanding it, and that area fell by more than a quarter in 2020–2021 as corn's comparative return rose. The lesson is that farmers respond to the difference in returns between the two crops, and that subsidies have worked by raising the absolute return on soybeans rather than by closing that difference.

The third strand concerns world soybean markets, where demand is price-inelastic and prices are driven mainly by weather, energy markets, exchange rates, and trade policy [14–16]. A moderate supply shift from one country therefore moves prices little.

The three strands fit together. The agronomic work says how much GM traits change yields and costs; the policy work says how farmers turn those changes into planting decisions; the market work says how any change in supply feeds through to world prices. The paper follows that path from field to farm to market.

4 DATA AND METHODOLOGY

The analysis uses descriptive data from China's National Bureau of Statistics, the General Administration of Customs, the NDRC cost-and-return compilation, provincial subsidy notices, the Ministry of Agriculture and Rural Affairs' variety approval lists, USDA Foreign Agricultural Service reports, and international yield comparisons from the USDA IPAD database. No causal identification strategy is used. The paper relies instead on partial-equilibrium reasoning and back-of-the-envelope calculations to gauge the size of plausible supply shifts.

Yield effects are calculated by applying trial yield gains to current soybean area. Price effects are inferred from published ranges for the elasticity of world soybean demand. Profitability effects are calculated in yuan per hectare from the Heilongjiang budgets in Table 1. None of this establishes causal effects; it gives transparent bounds on likely magnitudes.

To benchmark the yield effect of GM adoption against the experience of a mature adopter, I assemble a state-level panel of U.S. corn and soybeans for 2000–2025. Adoption shares come from the USDA Economic Research Service [17], planted area and yields from USDA National Agricultural Statistics Service survey data [18], and growing-season precipitation and temperature from the NOAA climate division dataset [19]. The panel regressions that use these data are descriptive. They summarize how yields co-vary with adoption once weather, prices, and state and year fixed effects are held constant, and they do not identify a causal effect of adoption.

Two limits should be stated at the outset. The paper does not model the feedback among the soybean, corn, livestock, cooking-oil, and land markets, and it does not measure gains and losses to farmers, consumers, or trading partners. Its aim is narrower: to establish the direction and rough size of the most direct supply effects, and to leave the fuller modeling to later work.

5 RESULTS

5.1 Short-Run Production Effects

Variety trials report yield gains of roughly 5–10 percent for GM soybeans relative to leading conventional varieties [12–13]. Applied to China's 10.33 million hectares of soybeans at a yield of 2.0 tons per hectare, this adds 1–2 million tons a year with acreage held constant.

Against imports of 105 million tons, the addition displaces one to two percent of what China buys abroad. The short-run effect on import demand is therefore small: the extra home-grown supply is tiny next to the trade it would have to replace, and China remains the world's dominant soybean importer.

5.2 Global Price Implications

A 1–2 million ton rise in Chinese output is a supply shift of roughly 0.25–0.5 percent of world soybean production. With the elasticity of world demand in the range -0.3 to -0.6 [14–15], the implied price decline is about 0.5–1.5 percent.

The intuition is simple. Buyers change their purchases little when the price moves, so the market absorbs the extra beans only if the price falls by more, in percentage terms, than supply rose. Because the supply increase is a fraction of one percent, the price still falls by only about one percent.

That is not nothing, but it is small next to the year-to-year swings produced by weather, exchange rates, energy markets, and trade disputes [16]. Under current land allocation, GM soybean adoption does not pose a significant short-run threat to exporters.

5.3 International Yield Comparisons

China's soybean yields remain well below those of the major exporters. In crop year 2024/25, average yields were about 3.41 tons per hectare in the United States, 3.62 in Brazil, and 2.94 in Argentina, against about 1.95 in China [20]. Even a 10 percent gain would leave China far from the frontier. Early GM adoption improves domestic efficiency; it does not reshape trade flows.

What decides how land is used, though, is not whether Chinese yields catch up with the world's best but whether soybeans can earn as much per hectare as corn. Section 6 takes up that comparison.

5.4 Evidence from the U.S. Adoption Experience

The United States offers a natural benchmark for what GM adoption does to yields, because its farmers moved from limited to near-universal adoption of genetically engineered corn and soybeans between 2000 and 2025. If the technology raised average yields by a large margin, the effect should be visible in the aggregate record of the world's largest adopter. Figure 1 plots adoption shares and yields together for U.S. corn and soybeans. Both series rise over the period, which is the pattern behind the common intuition that GM technology drove the yield gains.

That intuition weakens under closer inspection, because yields were rising for reasons unrelated to the GM trait, principally conventional breeding progress, over the same years that adoption climbed. To separate the two forces, I regress log state yield on the adoption share while progressively adding controls and fixed effects. Table 2 reports the results. The adoption coefficient is statistically significant in each of columns (1) to (4), but its sign is not stable: it is negative in the simple correlation and with weather controls, and positive once price or state fixed effects are added. Once column (5) adds year fixed effects, which absorb the common national trend from breeding and technology, the coefficient falls to -0.0007 and loses significance, and clustering the standard errors in column (6) changes nothing. Figure 2 traces this path across the specifications.

Adoption and yield rose together over 2000–2025 (U.S. national)

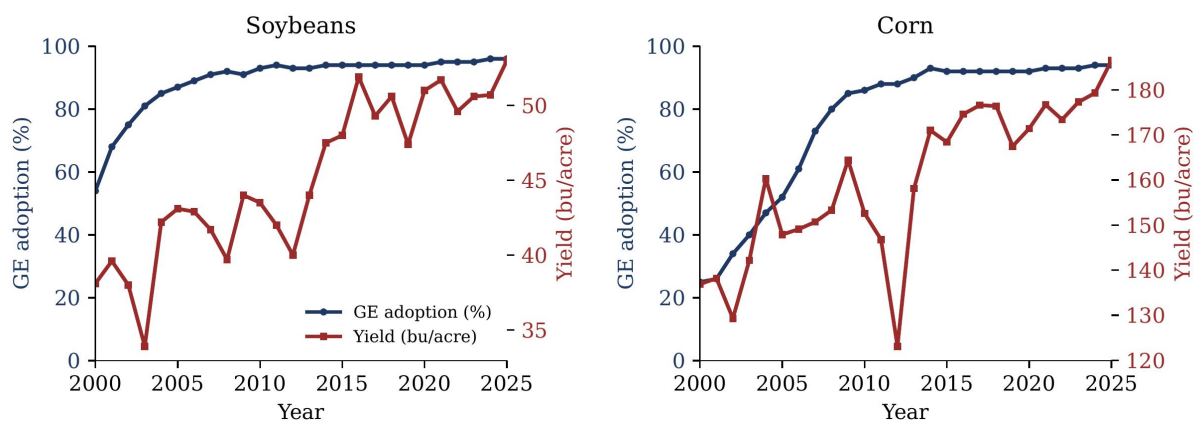


Figure 1 GE Adoption Shares and Yields Rose Together in the United States, 2000–2025. Adoption (left axis) and yield (right axis) for corn and soybeans at the national level.

Table 2 GE Adoption and Yield: From Simple Correlation to Two-Way Fixed Effects

	(1)	(2)	(3)	(4)	(5)	(6)
	Simple	+Weather	+Price	State FE	Two-way FE	Clustered
GE adoption (%)	−0.0072*** (0.0009)	−0.0070*** (0.0009)	0.0139*** (0.0010)	0.0040*** (0.0004)	−0.0007 (0.0004)	−0.0007 (0.0005)
Growing-season precip. (in.)		0.0053 (0.0046)	0.0131*** (0.0031)	0.0100*** (0.0018)	0.0074*** (0.0015)	0.0074*** (0.0020)
Growing-season temp. (°F)		−0.0082 (0.0052)	−0.0027 (0.0034)	−0.0013 (0.0048)	−0.0271*** (0.0071)	−0.0271*** (0.0083)

	(1)	(2)	(3)	(4)	(5)	(6)
ln(price)			-1.1200*** (0.0280)	0.0013 (0.0223)	-0.3332*** (0.0623)	-0.3332*** (0.0730)
State ($\times$ crop) FE	No	No	No	Yes	Yes	Yes
Year FE	No	No	No	No	Yes	Yes
<i>N</i>	692	692	692	692	692	692
<i>R</i> ²	0.045	0.049	0.591	0.285	0.160	0.160

Notes: Dependent variable is ln(yield) for corn and soybeans, major producing states, 2000–2025. Coefficients on the percentage regressors approximate semi-elasticities. Weather is growing-season (April–September) precipitation and mean temperature.

Standard errors in parentheses; column (6) clusters by state $\times$ crop. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

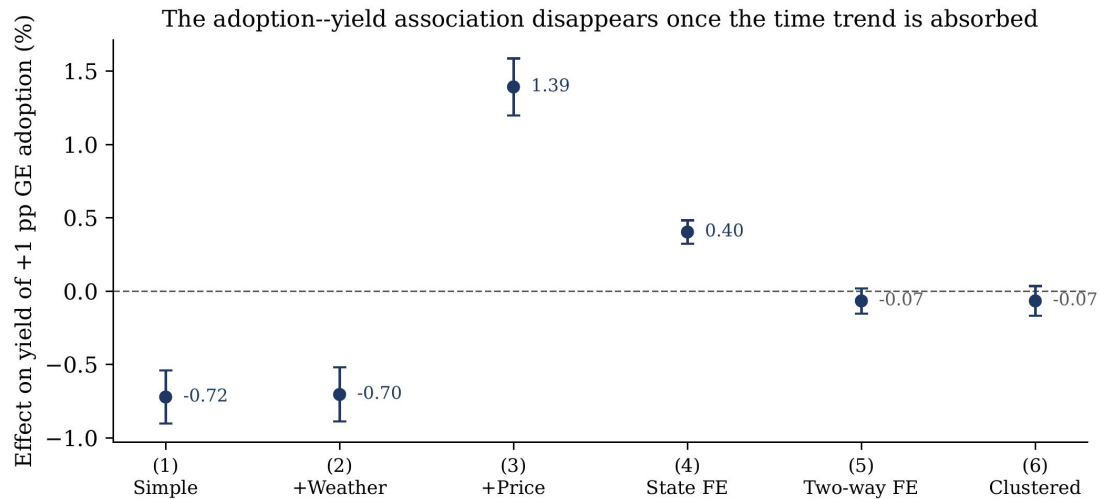


Figure 2 The Estimated Association Between GE Adoption and Yield, with 95 Percent Confidence Intervals, Across the Specifications in Table 2. The coefficient is statistically significant but changes sign across the specifications without year fixed effects; once two-way fixed effects absorb the common time trend it converges to zero and is no longer significant.

The sign changes are informative in their own right. Why does the coefficient jump from -0.0070 in column (2) to $+0.0139$ in column (3), when the only change is the addition of the log price? Two features of the data explain it. First, across states, adoption and yields are negatively related. The earliest and most complete adopters of GE corn were the drier, lower-yielding states of the western Corn Belt and Plains, such as Kansas, Texas, and the Dakotas, where insect pressure, drought, and large fields made the traits most valuable, while the highest-yielding states of the central Corn Belt adopted more slowly. In the sample the correlation between a state's average adoption share and its average corn yield is -0.53 . Without state fixed effects this cross-sectional pattern pulls the coefficient down; it says nothing about what adoption does to yields within a state. Second, the price variable is almost a national time series. Year effects explain 99 percent of its variance, so entering it acts as a crude control for time. Prices rose sharply in the 2000s along with adoption and yields, and the price term soaks up part of that common trend, which is why the R^2 jumps to 0.59 in column (3) and why the adoption coefficient turns positive. It is also why the price coefficient's standard error of 0.028 is implausibly small: the variable has essentially one distinct value per year. Columns (4) and (5) replace these makeshift controls with state and year fixed effects, and the adoption coefficient settles at zero. The instability of the sign, more than any single estimate, is the reason to distrust the specifications without fixed effects.

This finding does not contradict the trial-based estimates cited earlier. Field trials measure the agronomic gain from the trait with management held fixed, and they report positive effects near 9 percent for herbicide-tolerant varieties [11]. The aggregate state record measures a different quantity: the net change in observed yields after seeds, management, and land allocation all adjust. The two reconcile once we recognize that adoption in the United States was driven mainly by savings in cost, labor, and management rather than by large gains in average yield, and that most of the yield growth over the period came from breeding that would have occurred without the GM trait. Growing-season weather shows the expected and stable pattern, with more rainfall raising yields and higher temperatures lowering them, and the temperature effect is stronger for corn (Appendix Tables A1–A3).

The U.S. experience reinforces the central claim of this paper. Even after two decades of near-complete adoption, GM technology is not associated with a measurable lift in average yields beyond the ongoing breeding trend. China should not expect the seed technology alone to raise domestic soybean yields enough to displace a large share of imports. The value of GM adoption is more likely to appear in lower production costs and easier weed and pest management, which work through profitability and land allocation rather than through the average yield ceiling.

6 GM CORN AND RELATIVE PROFITABILITY

Land moves between crops in response to the difference in their returns, not the level of either. GM soybeans will pull land out of corn only if they raise the per-hectare return on soybeans by more than GM corn, which China approved in the same announcements, raises the return on corn:

$$\Delta\pi_s > \Delta\pi_c. \quad (2)$$

Each side decomposes into the gain in output value, which is the crop's output value per hectare V_i times its trial yield gain g_i , plus any saving in pesticide and labor costs ΔC_i :

$$\Delta\pi_i = V_i g_i + \Delta C_i, \quad i \in \{s, c\}. \quad (3)$$

The comparison must be made in yuan per hectare, not in percentages. Corn's output value in Heilongjiang is 1.68 times that of soybeans (Table 1), so the same percentage gain is worth 1.68 times as much money on corn.

Table 3 fills in the value terms with the Heilongjiang budgets of Table 1 and the trial gains reported in the 2025 national approval list [13, 21]. For corn I use Changcheng 338ZL, a stacked insect-resistant and herbicide-tolerant hybrid approved for the second accumulated-temperature zone of Heilongjiang, whose 2024 production trial yielded 831 kilograms per mu, 5.5 percent above its conventional recipient hybrid. The list contains only two GM soybean varieties, both herbicide-tolerant and both bred for the Yangtze valley rather than the Northeast. Jiaoyu 1 GS averaged 206.9 kilograms per mu over two regional trial years, 10.2 percent above the check variety Zhongdou 41, and 4.5 percent above it in the 2023 production trial.

Table 3 Does GM Soybean Raise Soybean Returns by More than GM Corn Raises Corn Returns?

	Corn	Soybeans
Gross output value, V_i (yuan/ha)	18,283	10,874
Trial yield gain of approved GM variety, g_i (%)	5.5	10.2
Variety Comparison	Changcheng 338ZL recipient hybrid	Jiaoyu 1 GS check variety
Gain in output value, $V_i \times g_i$ (yuan/ha)	1,006	1,109
Sensitivity		
Range of trial gains in the 2025 list (%)	0.4–9.1	4.5–10.2
Implied range of $V_i \times g_i$ (yuan/ha)	73–1,664	489–1,109
For reference		
Pre-subsidy gap G in net profit (yuan/ha)		3,513
Soybean gain needed to close G if GM corn gains 5.5%		41.6%

Notes: Output values from Table 1. Trial gains from the variety descriptions in the 2025 approval list [13]. Corn gains are measured against the conventional hybrid into which the trait was introduced; the corn range covers the 97 varieties and 112 trial results in the list. Soybean gains are measured against a conventional check variety and therefore mix breeding progress with the trait effect; the soybean range covers the two-year regional averages and the production trials of the two listed varieties. The last row is $(G +$

$$V_c g_c)/V_s.$$

The value terms come out at 1,006 yuan per hectare for corn and 1,109 for soybeans. Taken at face value, condition (2) holds, but by a margin of 104 yuan per hectare, and three observations put that margin in perspective.

First, it is a narrow margin produced by a wide difference in percentages. A soybean gain almost twice as large as the corn gain in percentage terms yields about the same money, because corn starts from a much higher output value. For the soybean side to win, its percentage gain must exceed 1.68 times corn's; with corn at 5.5 percent, soybeans need 9.2 percent.

Second, the margin is fragile. Corn varieties in the same list report gains from 0.4 to 9.1 percent, which put the corn side anywhere between 73 and 1,664 yuan per hectare. The soybean variety's own production trial gave 4.5 percent, or 489 yuan, and its comparison against a check variety rather than an isoline means part of the 10.2 percent is breeding progress rather than the trait. Within the range of the government's own trial data, the sign of $\Delta\pi_s - \Delta\pi_c$ is not determined.

Third, even the favorable reading closes almost none of the gap. The 104 yuan per hectare by which soybeans lead is 3 percent of G . If GM corn were ignored altogether, the full soybean gain of 1,109 yuan would close less than a third of it, and with GM corn in the picture soybean yields would have to rise by 42 percent rather than the 32 percent of equation (1). The cost-saving terms ΔC_i in equation (3) cannot rescue the comparison: for cost savings to close the remaining gap, the saving on soybeans net of any saving on corn would have to reach about 3,400 yuan per hectare, which is more than the entire labor cost of 2,692 yuan per hectare and nearly nine-tenths of the material and service cost of 3,833 yuan in Table 1; herbicide and weeding labor are a small part of either.

The judgment is therefore simple. Because GM corn arrives alongside GM soybeans and starts from a higher value base, the yield channel of GM technology leaves relative profitability in Heilongjiang about where it was. On its own it will not move land from corn to soybeans.

7 DISCUSSION: MEDIUM- AND LONG-RUN ADJUSTMENT

It helps to separate two forces. The first is a technology effect: with the farming system held fixed, GM traits raise yields and cut input and labor costs on a given plot. The second is a structural adjustment effect: over time, changes in who farms, how large farms are, and how land is divided among crops decide how much land soybeans receive in the first place. The short-run analysis shows that the technology effect alone is small for trade. The larger channel works through structural adjustment, mainly the movement of land into soybeans, and Section 2.2 shows why this is slow. Before subsidies, soybeans in Heilongjiang earn 3,513 yuan per hectare less than corn; with the 2023 subsidy they roughly break even and edge ahead of corn. The land that has moved into soybeans since 2022 has moved because the state pays the gap, and Section 6 shows that GM technology cannot pay it instead.

Over a longer horizon, demographic change may alter these dynamics. Rural aging and continued off-farm migration are expected to accelerate land consolidation and mechanization [22]. Larger farms find it easier to adopt new seed, manage rotations, and respond to price incentives, and lower labor requirements raise the value of herbicide-tolerant varieties in particular. If these changes allow China to allocate more land to soybeans while closing part of the yield gap, import demand could grow more slowly or stabilize.

As a rough illustration rather than a forecast, suppose structural change eventually raised soybean area by 10 percent, about one million hectares, and yields on all soybean land rose by another 10 percent. Domestic output would rise by roughly 4 million tons, about 4 percent of current imports. Such adjustments would arrive gradually. Even a reduction of 5–10 million tons in annual imports over several years would matter to exporters, but it would be modest against imports above 100 million tons.

8 TWO FARMS IN SHANDONG: AN ILLUSTRATION

Interviews with two farmers in Shandong Province illustrate, though they cannot establish, the profitability logic above. The two farm in very different ways. The first is a smallholder who grows tomatoes, garlic, and wheat, and no soybeans. His choice follows the logic of this paper: soybeans earn much less than cash crops such as tomatoes, so a single farmer on a tight income has little reason to plant them. Smallholders also lack storage of their own and must sell to dealers at prices below the market rate, which lowers the return on low-value bulk crops such as soybeans still further.

The second farmer belongs to a cooperative, the main vehicle through which the government has promoted soybeans. Members pool land and labor, are paid from the cooperative's profits, and are asked to grow soybeans alongside other crops. Subsidies flow through the cooperative to keep members' incomes acceptable even though soybeans on their own barely pay. The two cases are consistent with the view that expanding soybean production in China depends less on individual farmers responding to prices than on cooperatives and subsidies that make up the missing return. Two interviews are an illustration, not evidence; they put faces on the budget in Table 1.

9 CONCLUSION

The evidence points to one conclusion: what holds back China's soybean sector is limited land and the profitability gap with corn, not seed technology. GM adoption works inside these limits rather than removing them, which is why its short-run effect on imports and world prices is small. The numbers are specific. Trial yield gains add one to two percent of imports and move world prices by about one percent. Soybeans in Heilongjiang would need a 32 percent yield gain to match corn without subsidies, three times the best trial result, and because GM corn is being rolled out at the same time, the yield channel leaves relative profitability essentially unchanged. The U.S. record, after two decades of near-universal adoption, shows no yield effect beyond the breeding trend.

For U.S. producers, the near-term threat is therefore modest. The lasting one lies in the gradual reshaping of China's land use, not in a yield breakthrough. If land constraints ease through larger farms and more machinery, and if the state continues to pay the gap between corn and soybeans, GM technology could make soybeans somewhat easier to grow on the land that moves their way and slowly reduce import demand. Without that structural shift, and without the subsidy, China's reliance on imported soybeans will continue.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

- [1] Sun M, Li S, Yang W, et al. Commercial Genetically Modified Corn and Soybean Are Poised Following Pilot Planting in China. *Molecular Plant*, 2024, 17(4): 519-21.
- [2] Ministry of Agriculture and Rural Affairs of China. List of Approved Agricultural GMO Biosafety Certificates, 2020-2024. 2024.
- [3] National Bureau of Statistics of China. Announcement on Grain Output Data for 2024. 2024.
- [4] General Administration of Customs of China. Customs Statistics: Imports of Major Commodities, January-December 2024. 2025.
- [5] Ministry of Natural Resources, National Bureau of Statistics, and Leading Group Office of the Third National Land Survey. Main Data Bulletin of the Third National Land Survey. 2021.

- [6] Di Y Y, You N S, Dong J W, et al. Recent Soybean Subsidy Policy Did Not Revitalize but Stabilize the Soybean Planting Areas in Northeast China. *European Journal of Agronomy*, 2023, 147: 126841.
- [7] National Development and Reform Commission, Department of Price. National Compilation of Agricultural Product Cost and Return Data. Beijing: China Statistics Press, 2024.
- [8] Hegang Municipal People's Government. Notice on the 2023 Subsidy Standards for Corn, Soybean, and Rice Producers. 2023.
- [9] Heilongjiang Provincial Department of Agriculture and Rural Affairs, Department of Finance, and Development and Reform Commission. Implementation Plan for Corn, Soybean, and Rice Producer Subsidies in Heilongjiang Province. 2024.
- [10] Heilongjiang Provincial Department of Agriculture and Rural Affairs and Department of Finance. Notice on the Implementation Plan for the 2024 Cropland Rotation Pilot in Heilongjiang Province. 2024.
- [11] Klümper W, Qaim M. A Meta-Analysis of the Impacts of Genetically Modified Crops. *PLoS ONE*, 2014, 9(11): e111629.
- [12] U.S. Department of Agriculture, Foreign Agricultural Service. New Genetically Modified Corn and Soybean Variety Registration List Published. 2025.
- [13] Office of the National Crop Variety Approval Committee. Public Notice on Varieties Passing Preliminary Review at the Ninth Meeting of the Fifth National Crop Variety Approval Committee: Attachment 2, Descriptions of Genetically Modified Corn and Soybean Varieties. 2025.
- [14] U.S. Department of Agriculture, Economic Research Service. How Does Structural Change in the Global Soybean Market Affect the U.S. Price? 2004.
- [15] Food and Agricultural Policy Research Institute. Reference Prices, Farm Income and Agricultural Land Markets. 2023.
- [16] Colussi J, Langemeier M. U.S.-China Soybean Deal: Comparing Past Export Levels and Global Market Impacts. *Farmdoc Daily*, 2025, 15(212).
- [17] U.S. Department of Agriculture, Economic Research Service. Adoption of Genetically Engineered Crops in the U.S. 2025.
- [18] U.S. Department of Agriculture, National Agricultural Statistics Service. Quick Stats Database (Survey Program): Corn and Soybean Area, Yield, and Prices Received. 2026.
- [19] National Oceanic and Atmospheric Administration, National Centers for Environmental Information. Climate Division Dataset (nClimDiv): Statewide Temperature and Precipitation. 2026.
- [20] U.S. Department of Agriculture, Foreign Agricultural Service. Country Summaries: Soybean Area, Yield, and Production (IPAD Database). 2025.
- [21] Ministry of Agriculture and Rural Affairs of China. Announcement No. 947: Approval of Huawan 763D and 96 Other Genetically Modified Corn Varieties and Jiaoyu 1 GS and One Other Genetically Modified Soybean Variety. 2025.
- [22] Zhang T, Huang X, Zhang L, et al. The Evolution of China's Rural Labor Market in the 21st Century: An Empirical Study Based on Nationally Representative Survey Data at the Household Level. *China Agricultural Economic Review*, 2021, 13(2): 349-66.

APPENDIX A. SUPPLEMENTARY REGRESSION RESULTS

This appendix reports the robustness of the benchmark in Table 2. Table A1 estimates the two-way fixed-effects model separately for corn and soybeans. Table A2 decomposes corn adoption into its insect-resistant, herbicide-tolerant, and stacked traits. Table A3 reports first-difference, random-effects, and quadratic-temperature specifications, together with a Mundlak test that favors fixed effects over random effects.

Table A1 Two-Way Fixed Effects, Estimated Separately by Crop

	Corn	Soybeans
GE adoption (%)	0.0008 (0.0013)	0.0000 (0.0024)
Growing-season precip. (in.)	0.0032* (0.0019)	0.0107*** (0.0025)
Growing-season temp. (°F)	-0.0318*** (0.0098)	-0.0192 (0.0138)
ln(price)	-0.6507** (0.2541)	-0.7755** (0.3821)
<i>N</i>	328	364
Within <i>R</i> ²	0.171	0.180

Notes: Two-way (state and year) fixed effects; standard errors clustered by state. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A2 Corn Trait Decomposition, Two-Way Fixed Effects

	Coefficient
Bt only (%)	-0.0011 (0.0014)

	Coefficient
HT only (%)	0.0036* (0.0018)
Stacked (%)	-0.0023 (0.0015)
Growing-season precip. (in.)	0.0043** (0.0017)
Growing-season temp. (°F)	-0.0232** (0.0109)
ln(price)	-0.6958*** (0.2399)
<i>N</i>	320
Within R^2	0.194

Notes: Corn only. Bt, HT, and stacked adoption shares entered jointly. Two-way fixed effects; standard errors clustered by state. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A3 Additional Specifications

	(D1) First diff.	(D2) Random eff.	(D4) Temp. quadratic
GE adoption (%)	0.0036*** (0.0010)	0.0056*** (0.0005)	-0.0008 (0.0005)
Growing-season precip. (in.)	0.0065*** (0.0013)	0.0083*** (0.0026)	0.0052** (0.0020)
Growing-season temp. (°F)	-0.0123** (0.0054)	-0.0035 (0.0113)	-0.0279*** (0.0079)
ln(price)	-0.1973*** (0.0280)	-0.1338*** (0.0358)	-0.3309*** (0.0601)
Growing-season temp. ²			-0.0019*** (0.0006)
<i>N</i>	665	692	692

Notes: Pooled corn and soybeans. Temperature turning point in (D4) is about 58°F. Mundlak test of random versus fixed effects: Wald $\chi^2(4) = 688.2$, $p < 0.001$. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.