The Pollinator Penalty? EU Neonicotinoid Restrictions and Crop Yields

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Abstract

In 2018, the European Union banned outdoor use of three neonicotinoid insecticides to protect pollinators, yet eleven member states immediately granted emergency derogations for sugar beet—revealing genuine fear of yield losses. I exploit this variation in a triple-difference design: ban timing × crop pollinator dependence × emergency derogation status, using Eurostat yield data for 13 crops across 26 EU countries over 2000–2023. The DDD estimate is -0.097 (SE $= 0.117$) and statistically insignificant; no specification, subsample, or placebo test produces a detectable yield effect. The event study confirms clean pre-trends and no post-ban break. The design rules out yield losses exceeding 8% for rapeseed with 80% power but cannot exclude moderate effects in the 2–5% range. These results suggest that removing the most widely used insecticide class imposed, at most, modest yield costs—informing the EU's commitment to halving pesticide use by 2030.

JEL Codes: Q15, Q18, Q57
Keywords: neonicotinoids, pesticide regulation, crop yields, pollinator dependence, EU agricultural policy, triple-difference

1. Introduction

In December 2018, the European Union banned all outdoor uses of three neonicotinoid insecticides—clothianidin, imidacloprid, and thiamethoxam—affecting seed treatment and foliar application across every member state. The ban followed EFSA risk assessments documenting harm to wild bees (EFSA, 2018a,b,c), but the agricultural stakes were enormous: neonicotinoids were the world's most widely used insecticide class, protecting crops worth billions of euros annually in the EU alone. Within months of the ban, eleven member states invoked Article 53 emergency authorizations to continue using neonicotinoids on sugar beet—an implicit admission that they expected real yield losses without the pesticides.

This paper asks a direct question: did the ban actually reduce crop yields? And if so, does the yield cost vary systematically by how much each crop depends on pollinator services?

The answer to the first question matters urgently. The EU's Farm to Fork Strategy commits to halving pesticide use by 2030, yet ex ante simulations disagree sharply on the costs. Böcker and Finger (2016) estimate 4–16% yield losses for rapeseed and sugar beet from neonicotinoid withdrawal; Kathage et al. (2018) project 2.8–6.5% yield reductions for oilseeds. These forecasts drove the political fight over emergency derogations and continue to frame the debate over further restrictions. But they rely on agronomic trial data extrapolated to field conditions—no study has estimated the actual yield effects using the variation created by the ban itself.

The answer to the second question adjudicates between two competing channels. Neonicotinoids function primarily as systemic insecticides, killing crop pests (aphids, beetles, flea beetles) that damage yields. But a large body of evidence documents that they also harm pollinators—wild bees (Woodcock et al., 2017; Rundlöf et al., 2015), honeybees (Tsvetkov et al., 2017), and other insects critical for crop reproduction. These two channels predict opposite effects of banning neonicotinoids for pollinator-dependent crops: losing pest protection reduces yields, but recovering pollinators increases yields. For wind- and self-pollinated crops (wheat, barley, maize), only the pest-protection cost applies, making them a clean test of the insecticide channel.

I implement a triple-difference (DDD) design exploiting three sources of variation. First, the December 2018 ban creates a sharp temporal break in neonicotinoid availability. Second, pollinator dependence ratios (PDR) from Klein et al. (2007) provide a continuous gradient across crops: wheat and barley depend zero on pollinators, rapeseed depends 25%, and sunflower depends 65%. Third, eleven countries (Austria, Belgium, Croatia, Denmark, Spain, Finland, France, Lithuania, Poland, Romania, Slovakia) granted Article 53 emergency derogations for neonicotinoid use on sugar beet during 2019–2022, while the remaining fifteen

did not. The European Court of Justice ended derogations in January 2023 (Case C-162/21), providing a built-in reversal test.

The main specification includes country×crop, crop×year, and country×year fixed effects, absorbing all two-way interactions and isolating the triple interaction: the differential yield change for pollinator-dependent crops in derogation versus non-derogation countries after the ban. Standard errors are clustered at the country level.

The central finding is a null. The DDD coefficient is -0.097 (SE $= 0.117$, $p = 0.41$)—not only statistically insignificant but economically small. Alternative specifications tell the same story: the difference-in-differences across all countries yields 0.037 (SE $= 0.073$); the sugar beet-specific comparison shows a positive but insignificant derogation effect of 0.092 (SE $= 0.084$); and the binary PDR specification produces an estimate of 0.003 (SE $= 0.041$). A placebo test using 2014 as a fake ban date yields no effect. The event study shows no pre-trends and no post-ban break in the DDD interaction. The leave-one-country-out analysis confirms stability: the coefficient ranges from -0.129 to 0.002.

Power and minimum detectable effect. How large an effect could this design detect? At 80% power and a 5% two-sided significance level, the minimum detectable effect (MDE) on the DDD interaction is 0.327. For rapeseed (PDR $= 0.25$), this translates to a detectable yield change of $0.327 \times 0.25 = 0.082$ log points, or approximately 8.5%. For sunflower (PDR $= 0.65$), the detectable change is $0.327 \times 0.65 = 0.213$ log points, or approximately 24%. The design can therefore rule out yield losses exceeding 8.5% for rapeseed with 80% power, but not for sunflower, where only very large effects would be detected. The sugar beet DD (Column 4) has an MDE of approximately 16%, which rules out the upper end of the Böcker and Finger (2016) projection but not the lower end. The null should therefore be interpreted cautiously: the data are sufficiently powered to exclude catastrophic yield losses but cannot rule out moderate effects in the 2–10% range for some crops.

Area reallocation. One concern is that farmers may have adjusted crop composition rather than absorbing yield losses. I re-estimate the DDD with log harvested area as the outcome: the coefficient is -0.018 (SE $= 0.443$, $p = 0.97$), indicating no differential area reallocation by pollinator dependence in derogation versus non-derogation countries. The yield null does not reflect compensating area shifts.

This paper contributes to the literature on pesticide regulation and agricultural productivity. Jarvis (2021) reviews the projected costs of EU pesticide restrictions but emphasizes the absence of causal estimates from implemented bans. Garibaldi et al. (2013) document that wild pollinators enhance fruit set for 41 crops, but the economic magnitude of pollinator loss versus recovery remains debated (Aizen et al., 2019). Recent studies estimate the effects

of specific pesticide bans in controlled field trials (Pywell et al., 2015; Sterk et al., 2016), but these cannot capture the general-equilibrium responses—substitution to alternative pesticides, changes in crop choice, and adaptation in farming practices—that determine realized yield effects at scale. By estimating effects from national-level policy variation across multiple crops and countries, this paper fills that gap.

The paper also contributes to the broader literature on environmental regulation costs. A recurring theme in environmental economics is that ex ante cost projections overstate realized costs because they ignore adaptation and technological substitution (Harrington et al., 2000). The neonicotinoid ban provides a clean test: a major input restriction with well-defined predictions about yield losses, implemented simultaneously across an entire continent, with emergency derogations creating within-ban variation.

2. Institutional Background

The EU neonicotinoid ban. Neonicotinoids are systemic insecticides that protect crops by making the entire plant toxic to insects. Three active substances—clothianidin, imidacloprid, and thiamethoxam—dominated the global market, accounting for roughly 25% of world insecticide sales by value. They were primarily applied as seed treatments, coating seeds before planting so that the insecticide is distributed throughout the growing plant.

The European Commission restricted outdoor use of these three substances in Implementing Regulations 2018/783, 2018/784, and 2018/785, effective December 19, 2018. The restrictions followed three EFSA risk assessments published in February 2018, which concluded that most outdoor uses posed unacceptable risks to bees. The ban covered all outdoor uses including seed treatment, granular application, and foliar spraying; greenhouse use was permitted.

Emergency derogations. Article 53 of Regulation 1107/2009 permits member states to authorize otherwise banned pesticides for up to 120 days in response to "a danger which cannot be contained by any other reasonable means." Between 2019 and 2022, eleven member states repeatedly invoked Article 53 to authorize neonicotinoid seed treatment for sugar beet. The stated justification was protection against beet yellows virus, transmitted by aphids that neonicotinoids effectively control.

The geographic pattern of derogations was not random: it broadly tracked countries with large sugar beet sectors and strong farming lobbies. However, several major sugar beet producers—notably Germany, the Netherlands, and Italy—did *not* grant derogations, providing a control group within the high-production stratum.

The ECJ ruling. In January 2023, the European Court of Justice ruled in Case C-162/21 that Article 53 emergency authorizations could not be used to circumvent restrictions imposed after a full risk assessment. This ruling effectively ended all neonicotinoid derogations, creating a natural reversal: from 2023 onward, derogation countries were forced to comply fully with the ban.

Pollinator dependence gradient. Crops vary enormously in their dependence on animal pollination. Klein et al. (2007) classify 115 major world crops by the proportion of production attributable to animal pollinators. At one extreme, cereals (wheat, barley, maize, rice, oats, rye) and root crops (sugar beet, potatoes) depend zero on pollinators—they are wind- or self-pollinated. At the other extreme, sunflower seed depends 65% on pollinators, while rapeseed and soybeans depend approximately 25%.

This gradient creates a natural mechanism test. If removing neonicotinoids harms yields through lost pest protection alone, all crops should suffer equally. If there is an offsetting pollinator recovery channel, it should manifest differentially: pollinator-dependent crops should be partially buffered, while pollinator-independent crops bear the full pest-protection cost.

3. Data

The primary data come from Eurostat's crop production dataset (`apro_cpsh1`), which reports crop yield (100 kg/ha in EU standard humidity), harvested area (1,000 hectares), and production (1,000 tonnes) for all EU member states, annually. I construct a balanced-ish panel of 13 crops across 26 EU countries for 2000–2023, yielding 4,257 country-crop-year observations.

Crop selection. I include all crops in the dataset for which Klein et al. (2007) provide a pollinator dependence classification: seven cereals (wheat, barley, maize, oats, rye, triticale, rice), two root crops (sugar beet, potatoes), and four oilseeds (rapeseed, sunflower, soybeans, linseed). These 13 crops span the full PDR range from 0 (cereals and roots) through 0.25 (rapeseed, soybeans, linseed) to 0.65 (sunflower).

Country coverage. Of the EU-27, 26 appear in the analysis panel (Malta is excluded due to sparse crop reporting). Eleven countries are classified as derogation countries; fifteen as non-derogation.

Derogation classification. I code derogation status from EFSA's emergency authorization records and European Commission tracking of Article 53 notifications. Countries are classified

as "derogation" if they granted at least one emergency authorization for neonicotinoid use on any crop during 2019–2022.

3.1 Summary Statistics

Table 1: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Yield (100 kg/ha)	10.3	16.8	0.1	95.9
Log yield	1.6	1.1	−2.1	4.6
PDR (pollinator dependence)	0.09	0.17	0.00	0.65
Harvested area (1000 ha)	222.9	510.0	0.0	5,542.2
Post-ban (2019+)	0.32	0.46	0	1
Derogation country	0.46	0.50	0	1

Notes: N = 4,257 observations across 26 EU countries, 13 crops, and years 2000–2023. Yield is measured in 100 kg per hectare (Eurostat `apro_cpsh1`). Pollinator dependence ratio (PDR) from Klein et al. (2007): 0 for wind/self-pollinated crops (wheat, barley, maize), 0.05–0.25 for moderately dependent crops (rapeseed, soybeans, tomatoes), 0.65 for highly dependent crops (sunflower, apples, pears, cherries). Derogation country indicates the 11 EU member states that granted Article 53 emergency authorizations for neonicotinoid use on sugar beet during 2019–2022.

Table 1 reports descriptive statistics. Mean yield is approximately 10 (in units of 100 kg/ha, or roughly 1 tonne/ha), though this masks enormous variation across crops: sugar beet yields exceed 500 (i.e., 50 tonnes/ha) while oilseed yields are typically 2–3. The mean PDR is 0.07, reflecting the dominance of cereals in the sample. About 46% of observations come from derogation countries.

4. Empirical Strategy

4.1 Identification

The main specification is a triple-difference design:

$$\ln Y_{ckt} = \beta_1 \cdot \text{Post}_t \times \text{PDR}_k \times \text{Derog}_c + \alpha_{ck} + \alpha_{kt} + \alpha_{ct} + \varepsilon_{ckt} \tag{1}$$

where c indexes countries, k indexes crops, and t indexes years. Y_{ckt} is yield in 100 kg/ha. $\text{Post}_t = \mathbb{I}[t \geq 2019]$ indicates the post-ban period. $\text{PDR}_k \in [0, 0.65]$ is the pollinator dependence ratio from Klein et al. (2007). $\text{Derog}_c \in \{0, 1\}$ indicates whether country c granted emergency neonicotinoid derogations.

The fixed effects α_{ck} (country×crop), α_{kt} (crop×year), and α_{ct} (country×year) absorb all lower-order interactions. Country×crop effects absorb permanent differences in yields across country-crop pairs. Crop×year effects absorb common shocks to each crop (weather, global prices, technology). Country×year effects absorb common shocks within each country (macroeconomic conditions, other agricultural policies). Standard errors are clustered at the country level.

The coefficient β_1 captures the differential yield change for pollinator-dependent crops in derogation versus non-derogation countries after the ban. A negative β_1 would indicate that derogation countries' continued neonicotinoid use differentially harmed pollinator-dependent crops (through ongoing pollinator damage). A positive β_1 would indicate that derogation countries' maintained pest protection differentially helped pollinator-dependent crops.

Scope of derogations. A key limitation of the DDD is that emergency derogations were granted almost exclusively for sugar beet, not for all crops. The DDD interaction therefore tests whether *countries that maintained any neonicotinoid use* experienced differential yield trajectories for pollinator-dependent crops—not whether derogations directly protected those specific crops. If neonicotinoid use on sugar beet generated broader environmental spillovers (e.g., sustained pollinator exposure reducing pollination services for neighboring rapeseed or sunflower fields), the interaction could still capture a meaningful effect. However, if derogation countries' continued neonicotinoid use was truly confined to sugar beet fields with no spillovers, then the DDD coefficient may be attenuated toward zero. I therefore supplement the DDD with a direct sugar beet DD (Column 4 of Table 2) that estimates the derogation effect precisely where the policy variation binds.

4.2 Threats to Validity

The identifying assumption is that, absent the differential derogation status, pollinator-dependent crops in derogation and non-derogation countries would have followed parallel yield trends. Three features of the design support this assumption.

First, the event study (Table 2, Model 6) shows no significant pre-trends in the DDD interaction for 2010–2018. All eight pre-period coefficients are statistically insignificant and centered near zero, with no systematic pattern.

Second, the derogation classification is plausibly exogenous to crop-specific yield trends

conditional on country×year effects. Derogations were motivated by concerns about sugar beet—not by differential trends in oilseed or cereal yields. The country×year effects absorb any country-level confounders (political orientation, agricultural policy, weather) that might correlate with both derogation status and yield trends.

Third, the placebo test using a fake 2014 ban date on pre-ban data produces no significant effect (-0.173, SE $= 0.152$), confirming that the identifying variation does not appear in periods without treatment.

5. Results

5.1 Main Results

Table 2: Effect of the Neonicotinoid Ban on Crop Yields

	(1) DDD	(2) DD	(3) DDD Binary	(4) Sugar Beet
Post × PDR × Derog	-0.0974 (0.1166)			
Post × PDR		0.0366 (0.0728)		
Post × High PDR × Derog			0.0025 (0.0411)	
Post × Derog				0.0919 (0.0838)
Country × Crop FE	Yes	Yes	Yes	Yes
Crop × Year FE	Yes		Yes	
Country × Year FE	Yes	Yes	Yes	
Country FE				Yes
Year FE				Yes
Observations	4,253	4,253	4,253	317

 Notes: Standard errors clustered at the country level in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Dependent variable is log yield (100 kg/ha). Column (1): triple-difference with continuous PDR (Klein et al. 2007). Column (2): difference-in-differences with continuous PDR across all 27 EU countries. Column (3): DDD with binary PDR indicator (PDR > 0). Column (4): sugar beet only, comparing derogation vs. non-derogation countries. All specifications include country×crop fixed effects. Columns (1) and (3) additionally include crop×year and country×year fixed effects, which absorb all two-way interactions.

Table 2 reports the main results. Column (1) presents the full DDD specification from Equation (1). The coefficient on Post × PDR × Derog is -0.097 with a standard error

of 0.117 ($p = 0.41$). The point estimate is negative—suggesting that derogation countries' continued neonicotinoid use slightly harmed pollinator-dependent crops—but it is far from statistically significant.

Column (2) drops the derogation dimension and estimates a simple difference-in-differences of post-ban yields by pollinator dependence across all countries. The coefficient is 0.037 (SE = 0.073, $p = 0.62$), suggesting a trivially positive but insignificant differential yield gain for pollinator-dependent crops. This is consistent with a modest pollinator recovery channel, but the effect is indistinguishable from zero.

Column (3) replaces the continuous PDR with a binary indicator for any pollinator dependence (PDR > 0). The DDD estimate collapses to 0.003 (SE = 0.041), effectively zero.

Column (4) restricts the sample to sugar beet and estimates the derogation effect directly. The coefficient is 0.092 (SE = 0.084, $p = 0.29$)—derogation countries' sugar beet yields were 9.2% higher than non-derogation countries after the ban, but this difference is not statistically significant. The ex ante prediction of 4–16% yield losses from neonicotinoid withdrawal finds some directional support here, but the magnitude is at the low end and imprecisely estimated.

5.2 Event Study

The event study (Model 6) interacts year dummies (relative to 2018) with the PDR × Derog product. All eight pre-period coefficients (2010–2017) are statistically insignificant, ranging from −0.146 to 0.176. The post-period coefficients (2019–2023) are also insignificant, ranging from −0.068 to 0.108, with no systematic trend. The absence of pre-trends validates the parallel trends assumption; the absence of post-ban effects confirms the null.

5.3 Derogation Period versus Post-ECJ

Model 5 separates the post-ban period into the derogation era (2019–2022, when emergency authorizations were active) and the post-ECJ era (2023, after the Court struck down derogations). The DDD interaction during the derogation period is −0.124 (SE = 0.108, $p = 0.26$); the post-ECJ interaction is 0.005 (SE = 0.189, $p = 0.98$). Neither is significant, and the near-zero post-ECJ estimate is consistent with the reversal prediction: once derogations ended, any differential effect should disappear.

5.4 Mechanisms

Table 3: Mechanism: Derogation Effect by Crop Group

	(1) Cereals (PDR = 0)	(2) Oilseeds (PDR = 0.25–0.65)	(3) Fruit (PDR = 0.65)	(4) Root Crops (PDR = 0)
Post × Derog	-0.0190	-0.0358		-0.0108
	(0.0387)	(0.0658)	()	(0.0785)
Mean PDR	0.00	0.35	0.65	0.00
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	2,444	1,063	0	750

Notes: Standard errors clustered at the country level in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Each column estimates the derogation effect (Post × Derog) within a single crop group. Cereals (column 1) and root crops (column 4) have zero pollinator dependence and serve as mechanism tests: any derogation effect on these crops operates exclusively through pest protection. Oilseeds (column 2) and fruit (column 3) are pollinator-dependent, so the derogation effect conflates pest protection and pollinator harm.

Table 3 decomposes the derogation effect by crop group. For cereals (PDR = 0), the Post × Derog coefficient is -0.019 (SE = 0.039): essentially zero, suggesting that the pest-protection channel alone produced no detectable yield difference between derogation and non-derogation countries. For oilseeds (PDR = 0.25–0.65), the coefficient is -0.036 (SE = 0.066): also insignificant. Neither channel—pest protection nor pollinator recovery—produces a detectable yield effect in isolation.

5.5 Robustness

Table 4: Robustness Checks

	(1) Placebo 2014	(2) Alt. Cluster	(3) Excl. Sugar Beet	(4) Area-Weighted
Post × PDR × Derog	-0.1729	-0.0974	-0.0862	0.0320
	(0.1523)	(0.1204)	(0.1181)	(0.0376)
Country × Crop FE	Yes	Yes	Yes	Yes
Crop × Year FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Observations	2,490	4,253	3,936	4,240

Notes: Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Column (1): placebo test using 2014 as fake treatment year on pre-ban data (2006–2018). Column (2): standard errors clustered at country×crop level. Column (3): excludes sugar beet (the primary derogation crop). Column (4): observations weighted by harvested area.

Table 4 confirms the null across four robustness checks. The placebo test (column 1) applies the DDD to a fake 2014 ban on pre-treatment data: the coefficient is -0.173 (SE = 0.152), confirming no spurious effect in the pre-period. Alternative clustering at the country×crop level (column 2) barely changes the standard error (0.120 versus 0.117). Excluding sugar beet (column 3)—the directly derogated crop—yields -0.086 (SE = 0.118), nearly identical to the main result. Area-weighting (column 4) shifts the coefficient to 0.032 (SE = 0.038), which is positive but even smaller in magnitude and still insignificant.

The leave-one-country-out analysis produces a tight range: the DDD coefficient varies from -0.129 (excluding Italy) to 0.002 (excluding Portugal). No single country drives the result—or the null.

6. Discussion

The consistent null across all specifications, subsamples, and placebo tests invites two interpretations.

The first is that farmers successfully substituted away from neonicotinoids. The ban did not eliminate pest control; it shifted farmers toward alternative insecticides (pyrethroids, organophosphates), cultural practices (crop rotation, later sowing dates), and biological control. If substitution was effective and rapid, the ban's yield cost would be absorbed by

increased spending on alternatives rather than manifested in lower output. This interpretation is consistent with industry data showing a sharp increase in pyrethroid sales across the EU after 2018.

The second is that neonicotinoids were less essential than believed. They were widely used because they were cheap and convenient (as seed treatments), not because they were the only effective pest control option. In this view, the ban removed a convenient technology, imposed transition costs, but did not fundamentally compromise pest management. The non-significant sugar beet result is particularly telling: this was the crop for which derogations were explicitly justified, yet derogation countries' yields were only marginally (and insignificantly) higher.

Neither interpretation implies that neonicotinoids were ineffective pesticides. They clearly killed pests. The question is whether, at the *margin*, their removal was compensated by other pest management strategies. The evidence suggests it was.

Implications for Farm to Fork. The EU's Farm to Fork Strategy proposes halving pesticide use by 2030. Critics argue this would devastate yields; proponents argue farmers will adapt. The neonicotinoid ban—the first completed restriction under this framework—provides a data point: removing the most widely used insecticide class had no detectable yield effect at the country level. This does not guarantee that further restrictions will be similarly costless, but it challenges the assumption that pesticide reductions mechanically translate into yield losses.

Limitations. Three caveats apply. First, the analysis uses country-level yield data, which cannot capture within-country heterogeneity in neonicotinoid dependence. Regions specializing in crops historically reliant on neonicotinoid seed treatment may have experienced larger yield effects that are averaged away. Second, five post-ban years may be insufficient to capture long-run effects if pest resistance to alternative insecticides develops slowly. Third, the derogation classification treats countries as either fully derogation or non-derogation; in reality, the scope and duration of emergency authorizations varied.

7. Conclusion

Eleven EU countries were sufficiently afraid of crop losses from the 2018 neonicotinoid ban that they invoked emergency procedures to keep using the pesticides. Five years later, no specification or subsample reveals a statistically significant yield effect—but the design's power constrains what we can conclude. The data can rule out catastrophic yield losses exceeding 8–10% for key oilseeds like rapeseed, but cannot exclude moderate losses in the 2–5% range. Even so, the point estimates are consistently small and centered near zero,

and the event study shows no structural break at the ban date. The first major pesticide restriction under the EU's environmental agenda appears to have imposed, at most, modest yield costs—a finding that, while not definitive, reframes the cost-benefit calculus for the next round of restrictions under Farm to Fork.

Acknowledgements

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A. Data Appendix

Eurostat crop production. Crop yield, harvested area, and production data come from Eurostat dataset `apro_cpsh1` ("Crop production in EU standard humidity"), accessed via the `eurostat` R package. The dataset reports yield in units of 100 kg/ha at EU standard humidity. I use the `YI_HU_EU` structural variable for yields and `AR` for harvested area. The sample spans 2000–2023 and covers all 26 EU member states with data for at least one crop (Malta is excluded). Data were downloaded on March 14, 2026.

Pollinator dependence ratios. PDR values come from Klein et al. (2007), Table 1 and supplementary classification. For Eurostat crop categories not directly listed in Klein et al., I use the most closely matching crop species. PDR values used: wheat (0.00), barley (0.00), maize (0.00), oats (0.00), rye (0.00), triticale (0.00), rice (0.00), sugar beet (0.00), potatoes (0.00), rapeseed (0.25), soybeans (0.25), linseed (0.25), sunflower (0.65).

Derogation classification. Derogation status comes from EFSA's registry of emergency authorizations under Article 53 of Regulation 1107/2009, supplemented by European Commission tracking of national notifications. The 11 derogation countries are: Austria, Belgium, Croatia, Denmark, Finland, France, Lithuania, Poland, Romania, Slovakia, Spain. The 15 non-derogation countries are: Bulgaria, Cyprus, Czech Republic, Estonia, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Portugal, Slovenia, Sweden.

Sample restrictions. Observations with missing or zero yield are dropped (less than 3% of the raw sample). The panel is unbalanced: some country-crop combinations enter late (e.g., Croatia joins the EU in 2013) or have intermittent reporting. The mean number of years per country-crop pair is 15.1.

B. Identification Appendix

Event study coefficients. The event study interacts year dummies (relative to 2018) with the product PDR $\times$ Derog, including country$\times$crop, crop$\times$year, and country$\times$year fixed effects. Coefficients and 95% confidence intervals (country-clustered) for the 13 relative years:

Relative Year	Coefficient	SE	95% CI
−8 (2010)	0.176	0.207	[−0.245, 0.597]
−7 (2011)	−0.018	0.170	[−0.365, 0.329]
−6 (2012)	−0.146	0.200	[−0.554, 0.261]
−5 (2013)	0.031	0.200	[−0.377, 0.440]
−4 (2014)	−0.075	0.150	[−0.381, 0.231]
−3 (2015)	−0.043	0.102	[−0.250, 0.165]
−2 (2016)	−0.064	0.086	[−0.240, 0.111]
−1 (2017)	0.121	0.090	[−0.063, 0.304]
0 (2018)		[Reference year]	
1 (2019)	−0.068	0.086	[−0.244, 0.107]
2 (2020)	−0.045	0.112	[−0.273, 0.182]
3 (2021)	0.001	0.126	[−0.255, 0.257]
4 (2022)	−0.001	0.139	[−0.284, 0.282]
5 (2023)	0.108	0.189	[−0.279, 0.495]

No pre-period coefficient is individually significant at conventional levels, and there is no systematic pre-trend. The post-period coefficients are similarly insignificant and show no persistent shift.

Leave-one-country-out. The DDD coefficient from the main specification (Equation (1)) ranges from −0.129 (excluding Italy) to 0.002 (excluding Portugal) across all 26 leave-one-out iterations, confirming that no single country drives the result.

C. Robustness Appendix

Zero-PDR placebo. Restricting the sample to the nine crops with PDR = 0, I estimate a simple DD of Post × Derog. The coefficient is −0.009 (SE = 0.034, $p = 0.80$). This confirms that derogation status per se does not predict differential yield trends for crops unaffected by pollinators.

D. Standardized Effect Sizes

Table 5: Standardized Effect Sizes for Main Outcomes

Outcome	Specification	$\hat{\beta}$	SD(X)	SD(Y)	SDE	SE(SDE)	Classification
Log yield	DDD (cont. PDR)	-0.0974	0.126	1.106	-0.0111	0.0133	Small negative
Log yield	DD (Post × PDR)	0.0366	0.171	1.106	0.0057	0.0112	Small positive
Log yield	Sugar beet DD	0.0919	—	0.365	0.2519	0.2297	Large positive

Notes: This table reports standardized effect sizes (SDE) to facilitate cross-study comparison of treatment effect magnitudes. For the DDD and DD specifications, the treatment is continuous: SDE $= \hat{\beta} \times \text{SD}(X)/\text{SD}(Y)$, giving the effect of a one-standard-deviation change in the treatment interaction, measured in standard deviations of the outcome. For the sugar beet DD, treatment is binary (derogation $= 0/1$): SDE $= \hat{\beta}/\text{SD}(Y)$. SD($Y$) and SD($X$) are unconditional standard deviations from the full sample. **Research question:** What is the yield cost of the EU's 2018 neonicotinoid ban, and does it vary by pollinator dependence? **Treatment:** DDD interaction of post-ban period, pollinator dependence ratio, and derogation status. **Data:** Eurostat apro_cpsh1, 26 EU countries, 13 crops, 2000–2023, 4,257 observations. **Method:** OLS with country×crop, crop×year, and country×year FE; SEs clustered at country level. Classification labels refer to the magnitude of the standardized point estimate, not to statistical significance. "Null" denotes a near-zero effect size ($|\text{SDE}| < 0.005$), not a failure to reject a null hypothesis.