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ORIGINAL ARTICLE

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Unconstrained trade: The impact of EU cage bans on exports of poultry-keeping equipment

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Abstract

This study evaluates the impact of conventional cage bans for laying hens in the EU on exports of poultry-keeping equipment. Using detailed data on international trade in poultry-keeping equipment combined with an event study regression approach yields several new findings. The results suggest that the cage bans were associated with an increase in intra-EU trade, and also an increase in exports of poultry equipment from EU member states to non-EU countries where conventional cages are still permitted. The results suggest that some banned cages were likely exported to countries outside the EU to be used in egg production.

KEYWORDS
animal welfare, international trade, policy leakage

JEL CLASSIFICATION
F14, F15, Q17

1 | INTRODUCTION

Consumers and citizens in many countries continue to demand higher standards for the welfare of farm animals (Eurobarometer, 2016). Governments have thus responded by passing legislation with the objective to improve farm animal welfare. In the case of laying hens, the banning of conventional cages has been implemented in many countries. A potential concern, however, is that more stringent rules in one jurisdiction will lead to higher costs, farm exits (Harvey & Hubbard, 2013), and also a shift in animal production to other jurisdictions where animal welfare regulations are less stringent. This phenomenon, known as policy leakage, is

important because it can partially undermine the intent of the regulations. It is thus important to understand the scope of policy leakage with respect to animal welfare regulations. The export of banned production equipment is one way that animal welfare policies in one region can lead to leakage to 'low animal welfare havens'.

This study presents the results of an ex-post evaluation of the impact of conventional cage bans for laying hens in the EU on exports of poultry-keeping equipment, which includes cages. The analysis focuses primarily on the impact of the 2012 EU conventional cage ban, but also includes EU countries that implemented bans before 2012. The analysis includes both intra-EU trade and exports of poultry cages from EU member states to non-EU countries where conventional cages are still permitted. Studying the impact of stricter animal welfare regulations on international trade in animal-keeping equipment is new in the literature. In contrast, other studies in this literature have focused on the impact on production and trade in animal-based food products.

This study builds on a small and recent empirical literature evaluating ex post the impact of stricter animal welfare regulations on economic outcomes in general, and trade in particular. The most relevant studies of the trade effects of animal welfare regulations are based on the 2015 California cage ban. Mullally and Lusk (2018) find that egg production and the number of egg-laying hens were about 35% lower due to the law, but imports from other US states compensated for this decrease in production. Carter et al. (2021) study the impact of inter-state trade in more detail, and find that imports to California were characterised by higher firm-level concentration. Carter et al. (2021) also find prices in other states rose in response to California's law, resulting in a loss of consumer surplus and retailer surplus at the national level.[1]

The potential for an increase in cage exports in response to a cage ban relates to the phenomenon of policy leakage via input markets, where the input in this case is cages. The leakage mechanism studied here is thus conceptually distinct from the earlier work by Malone and Lusk (2016), Mullally and Lusk (2018), and Carter et al. (2021), which focus on leakage via output markets (eggs). This study is the first to analyse international trade in animal-keeping equipment affecting farm animal welfare and its subsequent response to a ban.

The rest of the paper proceeds as follows. In Section 2, I characterise the market for poultry equipment in the EU and explain the historical details of conventional cage bans at the EU and national levels. Section 3 describes the international trade data used in the analysis. In Section 4, I specify the event study methodology used in the analysis, and in Section 5 the results of the event study are described and discussed. Conclusions follow in Section 6.

2 | THE EU CONVENTIONAL CAGE BAN

The EU Council Directive 1999/74/EC stipulated a ban of conventional laying hen cages starting in January 2012.[2] This directive was passed in 1999, which thus gave EU member states several years to comply. The directive forced egg producers to replace their conventional cages with so-called 'furnished' or 'enriched' cages. The directive also permitted cage-free systems, which includes production in barns, free-range and organic production. The directive stipulated that furnished cages must provide at least 750 cm^2 of area per hen, of which 600 cm^2 is at

[1]Malone and Lusk (2016) and Mullally and Lusk (2018) also evaluate the impact of the California cage ban on prices and consumer surplus, but their analysis is restricted to California.

[2]Cages for laying hens are also referred to as 'battery cages', as they are usually built in units with several cages in a row.

least 45 cm high. Furnished cages must also provide a nest, a littered area, a sufficiently large perch and food trough, and a claw shortening device.[3]

A few EU countries banned conventional cages prior to the EU-wide ban. The official date of these national bans usually did not correspond to the timing of full compliance, as phase-out periods were granted. In Sweden, for example, the final day of banning conventional cages according to the legislation was 1 January 1999, but extensions were granted for most producers until 2004 (Berg & Yngvesson, 2006). Austria originally banned conventional cages in 2005, but extensions were granted until 2009 (Scrinis et al., 2017). Germany originally banned conventional cages in 2007, but extensions were granted until 2010 (Scrinis et al., 2017).

Several member states did not fully comply with the EU conventional cage ban by January 2012. The European Commission thus began proceedings against Belgium, Bulgaria, Greece, Spain, France, Italy, Cyprus, Latvia, Hungary, the Netherlands, Poland, Portugal and Romania.[4] In April 2013 the European Commission decided to take Greece and Italy to the Court of Justice of the European Union over their failure to correctly implement Directive 1999/74/EC.[5] Greece and Italy were both found guilty and were ordered to pay all legal costs.[6] Interestingly, there was no scrappage policy for used conventional cages, and egg producers were free to sell them onward to whoever they chose.

Around the time of the bans there was interest in the used conventional cages from Africa and Asia. Sales of used cages were organised by importers in the destination countries.[7] The German government provided a debt guarantee (Hermes-Bürgschaft) for the export of conventional cages for a very large layer farm in the Ukraine, which was deemed controversial at the time (German Bundestag, 2012).

Outside of the EU, Switzerland is the only country to have imposed a national ban on conventional cages before the EU ban, which occurred in 1992. Norway imposed a conventional cage ban in 2012. Conventional cage bans have been implemented at the sub-national level during the study period. A prominent example is California's Prevention of Farm Animal Cruelty Act (Proposition 2), passed in 2008 and implemented in 2015 (Malone & Lusk, 2016). Non-government initiatives to eliminate the use of conventional cages have also been implemented in many countries by private actors in the egg supply chain. Moreover, certified organic egg production prohibits the use of conventional cages. The impact of sub-national and non-government initiatives is beyond the scope of this study.

There is presently no EU-wide ban on furnished cages for laying hens. However, some EU countries have formalised plans to ban furnished cages. Austria officially banned furnished cages in 2020. In 2020 there were large differences across EU countries in terms of the share of laying hens farmed using different methods.[8] Almost all laying hens in Scandinavia, Germany, Austria and the Netherlands are housed in cage-free systems, whereas the majority of laying hens in other EU countries are housed in enriched cages. The shift to cage-free production systems has occurred in several EU countries despite a lack of a formal ban on furnished cages.

[3]Council Directive 1999/74/EC is available at https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31999L0074

[4]See https://ec.europa.eu/commission/presscorner/detail/en/IP_12_47

[5]See https://ec.europa.eu/commission/presscorner/detail/en/IP_13_366

[6]Cases numbers C-351/13 and C-339/13 respectively, see https://curia.europa.eu/jcms/jcms/j_6/en/

[7]Personal communication with Werner Bessei, 20 June 2022.

[8]Source: European Commission Market situation for eggs, see https://agriculture.ec.europa.eu/farming/animal-products/eggs_en

Some industry stakeholders were initially concerned about the prospect of increased egg imports due to the EU cage ban.[9] The EU has not banned the import of eggs produced with conventional cage systems, although a majority of Members of the European Parliament supported a Resolution on the European Citizens' Initiative 'End the cage age' (2021/2633(RSP)) on 10 June 2021. Banning imports of eggs produced using conventional battery cages would constitute a barrier to trade, which could lead to a trade dispute at the World Trade Organisation (WTO). The EU-Mercosur Trade Agreement is expected to include a requirement that eggs imported from Mercosur countries must comply with EU standards for laying hen production (Hagemejer et al., 2021).

EU egg imports between 2004 and 2019 are illustrated in Figure A1 in the Online Appendix. The figure suggests that there was a temporary increase in egg imports in 2012, but egg imports then fell after 2012. The EU is generally self-sufficient in egg production, with the value of annual imports ranging between €20 million and €40 million most years since 2004, which corresponds to import volumes of between 20,000 and 40,000 tonnes of egg equivalent. In contrast, the EU produced a total of 7 million metric tonnes (mmt) of eggs in 2020, with the top five largest egg producers being France (979 mmt), Germany (967 mmt), Spain (918 mmt), Italy (806 mmt) and the Netherlands (703 mmt).

3 | DATA AND DESCRIPTIVE STATISTICS

The analysis uses bilateral trade flow data from EU member states to each export destination, both within and outside the EU. These data are available at the 6-digit Harmonised System (HS) level. The source of the international trade data is CEPII's BACI database (Gaulier & Zignago, 2010).[10] The data is converted from USD to EUR using exchange rate data from the Penn World Table (Feenstra et al., 2015).[11] Trade value data is converted to constant 2015 prices using data from the Organisation for Economic Cooperation and Development (OECD).[12]

The analysis uses bilateral trade flow data for the period 1995–2019, where 2019 is the latest available year for the international trade data. This timespan provides a long span of pre-treatment and post-treatment periods in the event study. Exports to Switzerland are excluded from the analysis since they had already banned conventional cages in 1992. Croatia, Romania, and Bulgaria are excluded from the analysis since these countries joined the EU in 2007 and 2013, very close to the timing of the EU ban. Exports from Sweden to the 10 countries that joined the EU in 2004 are also excluded from the study, since their accession to the EU was very close to the timing of Sweden's ban. The United Kingdom is included in the analysis, as it was an EU member throughout the study period. International trade data for 25 member states and up to 200 non-EU destinations is included in the analysis. Belgium and Luxembourg are treated as a single country in the analysis.

Cages for laying hens (both conventional and furnished) are captured in the trade data by HS product code 843629, 'Other poultry-keeping machinery'. This product code captures both trade in new and used machinery. The control group includes total exports of agricultural

[9]See https://www.fwi.co.uk/news/farm-policy/deluge-of-egg-imports-predicted-after-eu-cage-ban

[10]The most recent documentation of the data is available at http://www.cepii.fr/DATA_DOWNLOAD/baci/doc/DescriptionBACI.html

[11]Penn World Table version 10.0 is available at https://www.rug.nl/ggdc/productivity/pwt/

[12]Consumer Price Index, All Items for the Euro Area, Index 2015 = 100, Annual

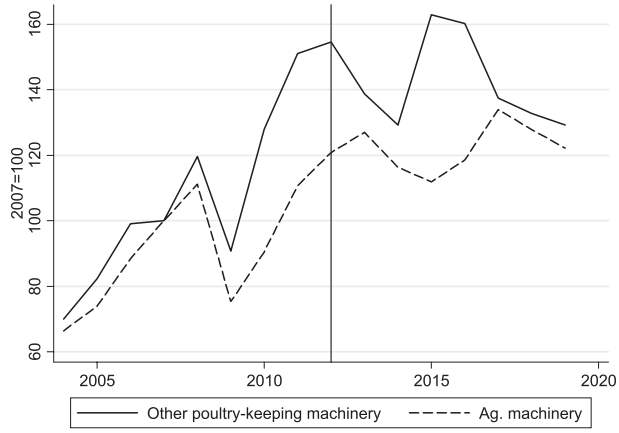

FIGURE 1 EU exports to the rest of the world, selected products, 2004–2019. Source: BACI database, author's calculations

machinery captured by the 4-digit HS codes 8432, 8433, 8434, 8435, and 8437.[13] Exports of other agricultural machinery not used in poultry production are subject to many of the same shocks to agricultural machinery demand and supply as poultry cages, making them a suitable control group. The control group product is referred to as 'Agricultural machinery' throughout the rest of the analysis. According to manufacturing production data available via the EU PRODCOM database, Germany, Italy, Spain and the Netherlands are the largest producers of 'Poultry-keeping machinery (excluding poultry incubators and brooders)' (PRODCOM code 28308500).[14] At the same time, several EU member states report that they do not produce any such products. Replacing conventional cages with enriched cages thus requires EU member states to import equipment in many cases.

Figure 1 shows that EU exports of 'Other poultry-keeping machinery' and 'Ag. machinery' increased at roughly the same rate throughout the 2000s, then diverged during the years between the Great Recession of 2007–2009 and the 2012 EU conventional cage ban. The decrease in agricultural machinery exports after 2012 was likely due to the Euro crisis, and affected the manufacturing sector more generally. However, exports of poultry-keeping equipment rose during this time.

The total export value of 'Other poultry-keeping machinery' to non-EU countries over the period 1995–2019, reported by EU member state, is provided in Table A1 in the Online Appendix. The largest producers of eggs and poultry-keeping equipment feature prominently among the EU exporters. Germany, Italy, Spain, and the Netherlands were the largest exporters of 'Other poultry-keeping machinery' to countries outside the EU. Figure 2 provides an illustration of exports for the top four exporting EU member states. Germany's exports reached their maximum in 2011. Many other countries' exports reached their peak around the 2012 deadline. Exports from Italy, which was one of the countries with the worst

[13]HS 8432: Agricultural, horticultural or forestry machinery for soil preparation or cultivation; lawn or sports-ground rollers. HS 8433: Harvesting or threshing machinery, including straw or fodder balers; Grass or hay mowers; Machines for cleaning, sorting or grading eggs, fruit or other agricultural produce, other than machinery of heading 8437. HS 8434: Milking machines and dairy machinery. HS 8435: Presses, crushers similar machinery used in the manufacture of wine, cider, fruit juices or similar beverages. HS 8437: Machines for cleaning, sorting or grading seed, grain or dried leguminous vegetables; Machinery used in the milling industry or for the working or cereals or dried leguminous vegetables, other than farm-type machinery.

[14]PRODCOM data is available at https://ec.europa.eu/eurostat/web/prodcom/data. Since HS and CN product classifications are identical at the 6-digit level, it is possible to find the corresponding PRODCOM product code using Eurostat's PRODCOM -CN concordances available at https://ec.europa.eu/eurostat/ramon/relations/index.cfm?TargetUrl=LST_REL.

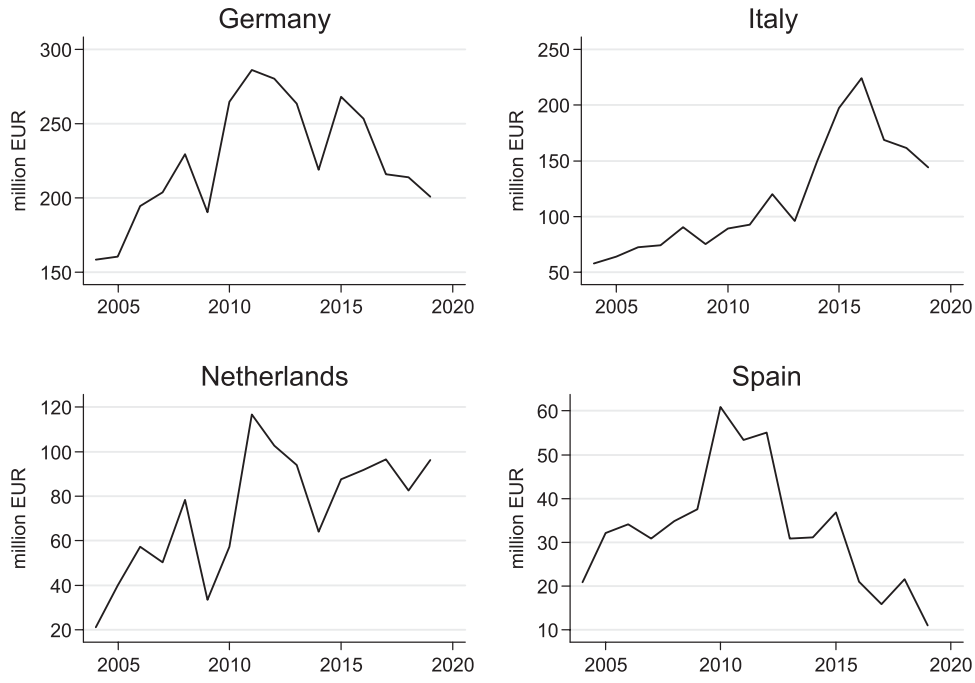

FIGURE 2 Top four exporters of 'Other poultry-keeping machinery' (HS 843629) to all non-EU destinations, 2004–2019. Source: BACI database, author's calculations

record of implementation, did not reach their peak until 2016. The late peak in exports from Italy is likely part of the reason why overall EU exports decreased in 2013 and 2014, only to rise again in 2015 and 2016. Compliance well in advance of the 2012 deadline as well as delays in compliance imply that sales of used cages could be detected several years before and after the 2012 deadline.

The top 20 destinations for EU exports of 'Other poultry-keeping machinery' over the period 1995–2019 are reported in Table A2 in the Online Appendix. Russia was the largest export destination during this period, followed by the United States, Japan and Ukraine. The pattern of imports over time by the top four destinations is illustrated in Figure 3. EU exports to Russia and Ukraine peaked in 2008, fell during the Great Recession, then peaked again around the time of the 2012 EU conventional cage ban. Exports to Russia fell in 2014 when its conflict with Ukraine began, only to rise again in 2015.[15] Exports to the United States exhibit a different pattern, with no response to the cage bans in EU states. US imports peaked in 2016, a year after the battery cage ban in California. Japan's imports peaked in 2006 and 2017.

4 | EVENT STUDY METHODOLOGY

The analysis applies an event study regression methodology to study the impact of conventional cage bans. As noted earlier, the timing of the ban was 2012 for all EU countries except for Sweden, Austria and Germany, which had national conventional cage bans in 2004, 2009

[15]Russia banned the import of many food products from the EU in response to EU sanctions stemming from the Russian annexation of Crimea, but eggs were not included, see https://food.ec.europa.eu/horizontal-topics/international-affairs/eu-russia-sps-issues/russian-import-ban-eu-products_en

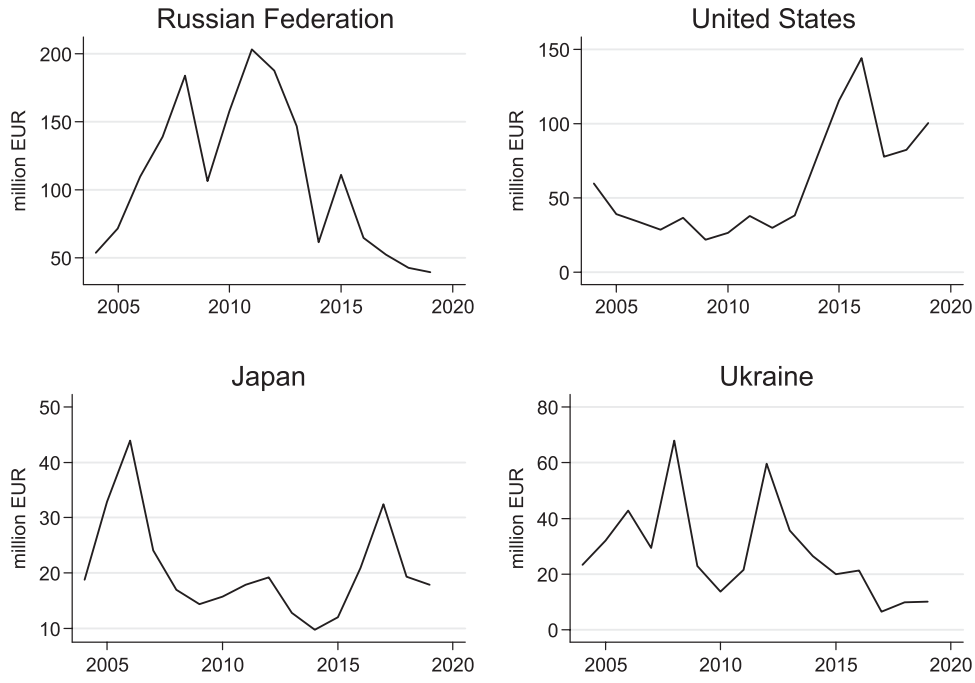

FIGURE 3 Top four importers of 'Other poultry-keeping machinery' (HS 843629) from the EU, 2004–2019. Source: BACI database, author's calculations

and 2010 respectively. As mentioned earlier, the treatment group product is 'Other poultry-keeping machinery', while the control group is 'Agricultural machinery'.

The event study regressions employ a Poisson pseudo-likelihood regression with multiple levels of fixed effects (Correia et al., 2019, 2020). Poisson regressions have the advantage of allowing for zeros in the trade flow data, and have recently gained popularity in the international trade literature, starting with work by Silva and Tenreyro (2006). The estimation follows the standard event study approach, and includes seven pre-treatment and post-treatment periods. Pre- and post-treatment effects greater than 7 years are included in the regression, but not reported.

The event study regression model is a special version of the difference-in-differences model, employing multiple time periods and including lag and lead treatment terms.[16] The event study model used in this analysis takes the following form:

$$Y_{ijkt} = \alpha_{ijk} + \alpha_{ijt} + \beta_e \sum_{e<-7} D^e_{ikt} + \sum_{e=-7}^{-6} \beta_e \bullet D^e_{ikt} + \sum_{e=-4}^{7} \beta_e \bullet D^e_{ikt} + \beta_e \sum_{e>7} D^e_{ikt} + \epsilon_{ijkt}, \quad (1)$$

where Y_{ijkt} is the value of exports from EU member state i to destination j of good k at time t. α_{ijk} and α_{ijt} are origin–destination-product and origin–destination-year fixed effects respectively. D^e is an indicator for member state i being e periods away from initial treatment at time t. D^e always takes a value of zero for the control good. ϵ_{ijkt} is the error term.

[16]The main advantage of an event study regression methodology is that it allows for estimation of pre- and post-treatment effects. In contrast, a simple difference-in-difference specification with a post-ban indicator would only allow for comparison for the period before versus after the ban in each country.

Indicators greater than 7 years before or after treatment are binned. $t-5$ is used as the baseline event-time, for reasons explained below.

Fixed effects are used to control for other factors that affect international trade in the treatment and control goods. Origin–destination-year fixed effects control for all explanatory factors such as trade agreements that affect both poultry-keeping machinery (the treatment group) and other agricultural machinery (the control group). Origin–destination-product fixed effects control for any time-constant explanatory factors that are specific to either poultry-keeping machinery or agricultural machinery. These fixed effects also control for the standard 'gravity model of trade' variables such as GDP, distance and the price indices. The point estimates are clustered at the origin country and destination country level, which is the most conservative clustering choice.

The event study analysis is divided into two parts: an analysis of intra-EU trade due to the cage bans, and an analysis of exports from EU member states to non-EU countries. Estimating the impact of the bans on intra-EU trade is interesting in its own right, but is also useful for detecting how many years before the ban and after the ban that egg producers began replacing their old conventional cages with furnished cages, or with cage-free systems. If the bans on conventional cages are associated with increases in exports from EU countries to non-EU countries, this could be indicative of sales of used cages, implying that policy leakage occurred.

Egg producers could begin adapting to the cage ban well in advance of the deadline, and some egg producers did not comply with the cage bans on time. One can thus expect that trade in cages will be affected several years before and after the formal cage ban. The base year used as the benchmark for determining statistically significant effects is thus ambiguous. A standard event study would set event-time $t-1$ as the base year, but since trade in cages may have preceded the ban by several years, $t-5$ is used as the baseline event-time. We use seven pre-treatment and post-treatment periods so that the event study results for cohorts affected by the 2012 EU-wide ban does not overlap with the 10 countries that joined the EU in 2004 or the withdrawal of the United Kingdom from the EU in 2020.

5 | EVENT STUDY RESULTS

5.1 | Intra-EU imports

The analysis begins with the event study results focusing on intra-EU imports around the time of the cage bans, including all 25 EU member states in the same regression. The point estimates and 95% confidence intervals estimating the impact of the cage bans on imports of 'Other poultry-keeping machinery' from other EU countries, relative to other agricultural machinery are illustrated in Figure 4. Using year $t-5$ as the baseline year is a reasonable choice, as intra-EU trade in 'Other poultry-keeping machinery' was steady 5 years before the ban and earlier.

The results suggest that imports of poultry equipment from other EU countries increased rapidly during the 3 years before the ban, reaching its peak in the year of the ban in each country. Intra-EU trade then declined and fell back to a statistically insignificant level 3 years after the bans. The regression coefficient on the treatment indicator at time $t=0$ is 1.01, which implies that intra-EU trade rose by $(exp(1.01)-1)\times 100 = 174\%$ compared to 5 years prior to the cage ban deadline.

In sum, the results presented in Figure 4 suggest that intra-EU imports of 'Other poultry-keeping machinery' clearly increased around the time of the ban. This trade likely included shipments of furnished cages meant to replace the banned conventional cages.

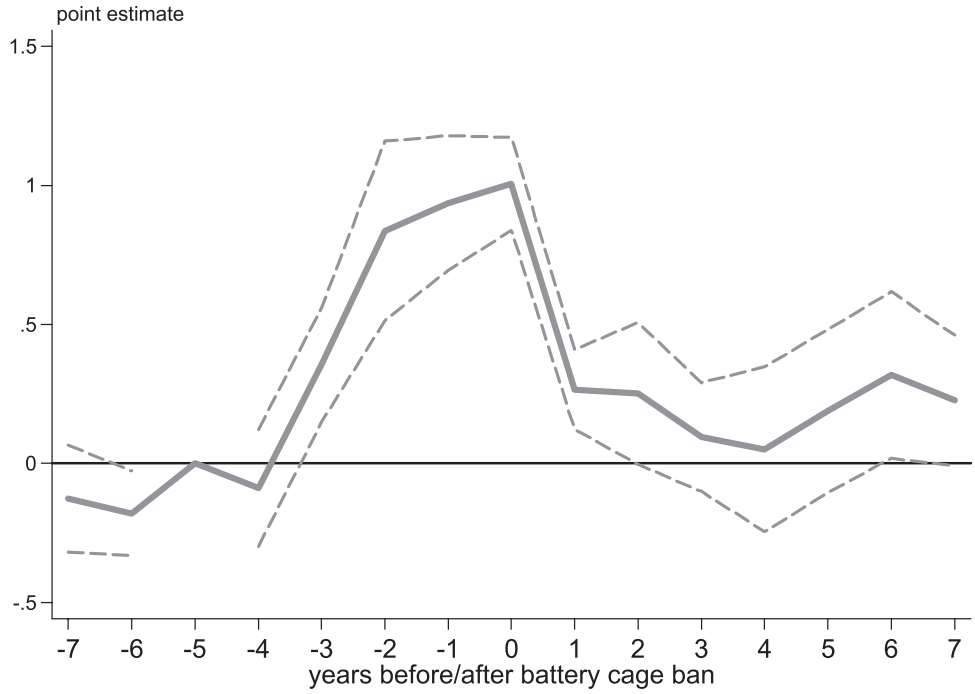

FIGURE 4 Event study results: Intra-EU imports, 'Other poultry-keeping machinery' versus 'Other agricultural machinery'. Source: Author's calculations

5.2 | Exports to non-EU destinations

The next part of the event study analysis focuses on exports from EU member states to non-EU destinations, again including all 25 EU member states in the same regression. The results of this analysis are illustrated in Figure 5. The results indicate that exports of 'Other poultry-keeping machinery' was arguably steady until 2 years before the ban in each country. The point estimate is positive and statistically significant 1 year before the ban and during the year of the ban. The regression coefficient on the treatment indicator at time $t = 0$ is 0.36, which implies that exports to non-EU countries rose by $(exp(0.36) - 1) \times 100 = 43\%$ compared to 5 years prior to the cage ban deadline. The banning of conventional cages thus corresponded to a large percentage increase in the exports of poultry-keeping machinery to non-EU destinations. The point estimate is also positive at time $t = 5$, which I explore in more detail when studying the results by treatment cohort.

It is important to note that one cannot rule out that the exports of 'Other poultry-keeping machinery' around the time of the conventional cage bans may be exports of furnished cages or other equipment used in cage-free systems. This limitation is due to the fact that data on international trade in used cages is not available. It is unlikely, however, that exports of poultry equipment would increase at exactly the same time because domestic demand for equipment to replace conventional cages is high due to the bans. The results are thus highly suggestive that such exports to destinations without conventional cage bans could indeed be used with conventional cages. Such trade may be replacing old cages in other non-EU countries, or it could be purchased by foreign egg producers that were aiming to increase egg production.

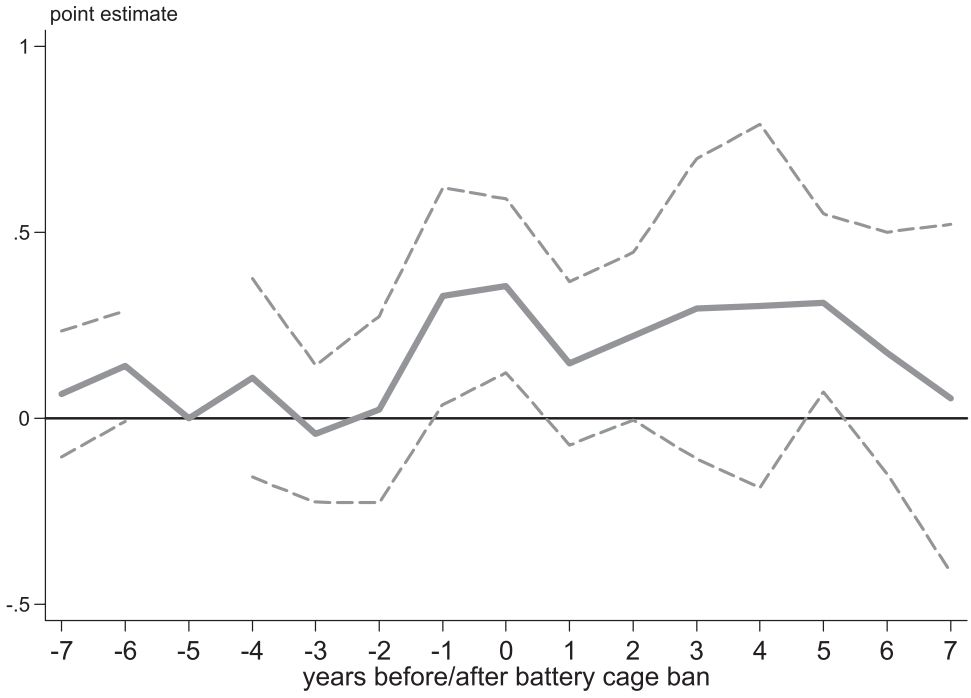

FIGURE 5 Event study results: Exports from EU countries to non-EU countries, 'Other poultry-keeping machinery' versus 'Other agricultural machinery'. Source: Author's calculations

5.3 | Additional robustness

One threat to identification is that exports may be affected by other confounders that occur at the country–pair–product–year level. The most obvious confounder is that countries export more poultry equipment to destinations that have a comparative advantage in egg production. I use the bilateral imports of eggs, interacted with the treatment product dummy variable, in order to control for the impact of egg production on imports of poultry equipment such as battery cages. I use both contemporaneous and lagged egg imports as an additional control in the event study. The point estimates for egg imports are not statistically significant, and the event study results, illustrated in Figure A2 in the Online Appendix, are robust to including these controls.

In the main analysis of exports from EU member states to non-EU countries I included the United States as an export destination. Even though the United States has not implemented a national conventional cage ban, including the United States may be slightly problematic since California implemented a cage ban during the study period. As a robustness check I drop exports to the United States from the analysis. The event study results for EU exports are presented in Figure A3 in the Online Appendix. The main effect of excluding the United States is that there is no longer a statistically significant point estimate in the year $t+5$.

As a final robustness check I drop exports from Greece and Italy from the analysis, since these two countries were the slowest to comply with the EU-wide ban. The event study results for EU exports are presented in Figure A4 in the Online Appendix. Again, the main effect of excluding Greece and Italy is that there is no longer a statistically significant point estimate in the year $t+5$.

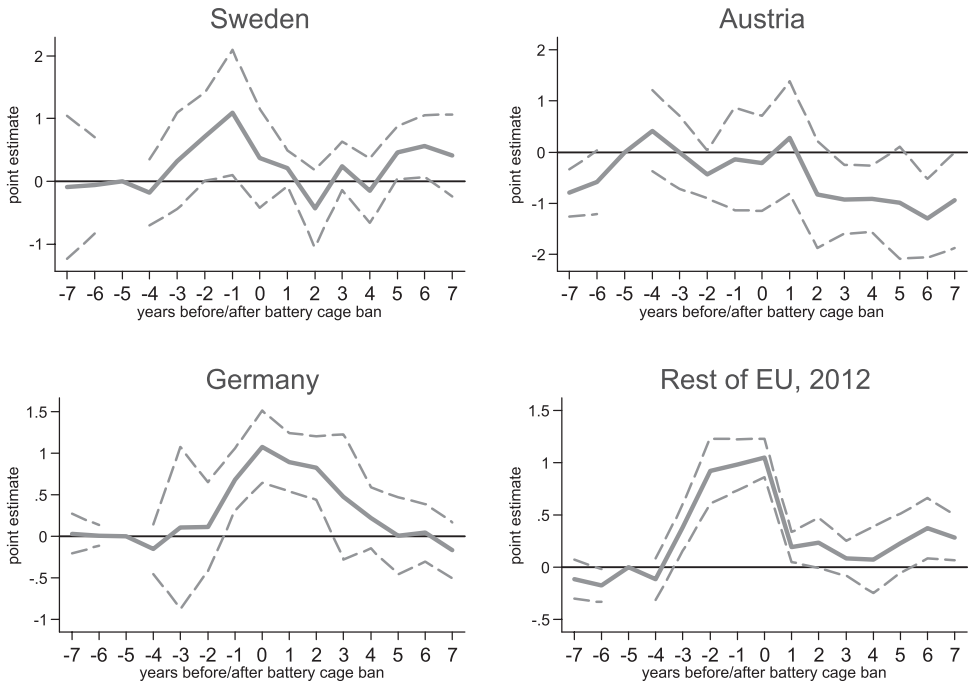

FIGURE 6 Results by treatment cohort: Intra-EU imports, 'Other poultry-keeping machinery' versus 'Other agricultural machinery'. Source: Author's calculations

5.4 | Results by treatment cohort and quantifying the effects

Recent studies have shown that the coefficient of interest in a two-way fixed effects specification is not guaranteed to recover an interpretable causal parameter if there are variations in treatment timing and heterogeneous treatment effects (Callaway & Sant'Anna, 2021; de Chaisemartin & D'Haultfœuille, 2020; Goodman-Bacon, 2021). In an effort to deal with this potential concern, I perform the event study analysis separately for each treatment cohort.

There are four treatment cohorts in this study: Sweden (2004), Austria (2009), Germany (2010) and the rest of the EU (2012). The regression model for the countries treated in 2012 is identical to Equation (1). The regression models for Sweden, Austria and Germany employ different fixed effects and clustering due to the fact that there are not multiple origin and destination countries in the regression. Destination-year and product-year fixed effects and clustering by destination are employed in the case of extra-EU exports. Origin-year and product-year fixed effects and clustering by origin are employed in the case of intra-EU imports. A potential drawback of performing event studies for individual EU member states is that fewer fixed effects can be employed.

The results of the event study estimation for intra-EU imports and exports from EU member states to non-EU countries for each treatment cohort are presented in Figures 6 and 7 respectively. The results in Figure 6 suggest that the imports of other poultry equipment to Austria from other EU member states were not affected by the Austrian conventional cage ban, but that imports of equipment to Sweden, Germany and other EU member states affected by the 2012 EU-wide ban did respond. The point estimates for the affected cohorts are at most around 1, which is nearly identical to the event study results including all cohorts in the same regression. Specifically, these point estimates imply that intra-EU imports rose by 199%, 194%, and 184% compared to 5 years prior to the cage ban deadline in Sweden, Germany and the 2012 cohort respectively.

FIGURE 7 Results by treatment cohort: Exports from EU countries to non-EU countries, 'Other poultry-keeping machinery' versus 'Other agricultural machinery'. Source: Author's calculations

In order to quantify the effects of the cage bans, I convert the point estimates to monetary values by using the value of exports 5 years prior to the bans as a baseline. In the case of Sweden, intra-EU imports 5 years prior to the ban were valued at €0.64 million, and the 199% change in trade implied by the point estimates imply a subsequent increase in trade by €1.27 million. Imports from EU countries totalled €5.9 million for Germany in 2005, and €128.6 million in 2007 for EU countries affected by the 2012 EU ban. These baseline values, combined with the percentage increases in trade, imply increases in intra-EU imports of €11.4 million for Germany and €237 million for the 2012 treatment cohort, all in constant 2015 EUR. The value of these effects on intra-industry trade are reasonable given the large cost of replacing conventional cages with furnished cages, which were sometimes sourced from other EU countries.

The results from Figure 7 reveal that the exports of other poultry equipment from Sweden or Austria to countries outside the EU were not affected by the Swedish and Austrian conventional cage bans. However, the results suggest that extra-EU exports from Germany and other EU member states affected by the 2012 EU-wide ban did respond. The point estimate for German exports at $t = 0$ was 0.50, with a p-value of 0.05. German exports to non-EU destinations 5 years prior to the ban totalled €160.5 million, and combining with the point estimate for time $t = 0$ implies an increase in exports of $(exp[0.50] - 1) \times 100 = 65\%$, or €104 million. Extra-EU exports among the 21 EU members affected by the 2012 ban totalled €196 million 5 years prior, and combining with the point estimate for $t = 0$ implies an increase in exports of $(exp[0.37] - 1) \times 100 = 44\%$, or €86 million. The impact of the bans on extra-EU trade are thus economically important.

The event study results for Germany in year $t+5$ and for the 2012 cohort in year $t+3$ also suggest that there was an increase in exports of 'Other poultry-keeping machinery' relative to the control group that occurred in 2015. As exports to the United States are already dropped from the analysis, further inspection suggests that this temporary increase is driven by exports to Russia. A comparison of EU exports of 'Other poultry-keeping machinery' and 'Ag.

machinery' to Russia is illustrated in Figure A5 in the Online Appendix. The pattern of trade in the figure suggests that EU exports of 'Other poultry-keeping machinery' temporarily diverged from the control group in 2015. This temporary divergence may have been driven by Russian import bans related to the conflict between Russia and Ukraine, which began in 2014.

5.5 | Poultry equipment exports and egg imports

Given that some industry stakeholders were initially concerned about the prospect of increased egg imports due to the EU cage ban, it is worth exploring whether exports of poultry equipment are correlated with imports of eggs. Table A3 in the Online Appendix reports the results of a simple panel regression using poultry equipment exports from the EU and its lag as the independent variables and egg imports to the EU as the dependent variable. This analysis is purely descriptive in nature, and the results should only be interpreted as correlation, not causation.

The estimations reported in Table A3 are performed at four levels of aggregation. Column (1) reports the results using annual bilateral trade flow data. Column (2) reports the results aggregating each EU country's total trade with the rest of the (non-EU) world. Column (3) reports the results aggregating over all EU trade with each non-EU country. Finally, column (4) reports the results aggregating total trade between the EU as a whole and the Rest of the World as a whole. Panel and year fixed effects are included in columns (1)–(3), and a time trend is included in column (4).

The results reported in column (1) of Table A3 suggest that there is no significant relationship between an EU country's bilateral exports of poultry equipment and its imports of eggs from the same country. Aggregating over all non-EU destinations does not change this result, and aggregating total EU trade implies a statistically significant negative relationship between the trade flows. Only when aggregating to total RoW–EU trade in column (4) is the point estimate for poultry equipment exports positive and statistically significant. Thus, there appears to be a positive relationship between poultry equipment exports and egg imports overall, but its effect cannot be attributed to a particular origin or destination.

6 | CONCLUSION

This study presents the results of an ex-post evaluation of the impact of conventional cage bans in the EU on international trade in poultry-keeping equipment. The results suggest that the cage bans were associated with an increase in intra-EU trade and exports of poultry equipment, such as cages, from EU member states to non-EU countries where conventional cages are still permitted. Although it is not possible to provide direct evidence that the increase in exports was in fact used conventional cages, the results are highly suggestive that some banned cages were exported to countries outside the EU to be used in egg production where conventional cages are still allowed.

The conventional cage bans implemented in EU countries did not include any policy to ensure that used cages were not sold to egg producers outside the EU. In order to avoid the risk of exporting banned cages in the future, the EU may want to implement measures to avoid such 'leakage' of cages to other countries. This issue may become important as EU countries consider banning furnished cages for laying hens, and as other countries implement bans on conventional cages.

One important potential limitation of the analysis is that it relies on trade data for a broader category of poultry-keeping equipment, as data focusing specifically on trade in cages, especially used cages, is not available. Although the goal of this study is to show that it is possible

to detect trade in cages using the data that is presently available, including new cages and used cages as a separate product codes in international trade data would greatly simplify the tracking of cross-border trade in cages. For example, including product codes for these items in new versions of the EU Combined Nomenclature (CN) system of classifying goods would ease future work in this topic in the European context.

This study does not analyse the animal welfare implications of an export ban for animal welfare in other countries, and it is important to emphasise that the welfare implications are potentially ambiguous. For example, exports of conventional cages from the EU may be displacing worse cage systems in other countries. I leave the study of the animal welfare implications of international trade in cages for future research. In sum, this study highlights that the complex issue of cage exports requires more attention from researchers and policy-makers.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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