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The impact of animal welfare regulations on pork trade: evidence from European countries☆

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ABSTRACT

We analyse the impact of stricter national animal welfare (AW) regulations on imports and exports of pork between 13 European countries during the period 1991–2020, a period in which EU directives and national actions related to AW regulations significantly affected pig farming practices. We exploit the fact that some countries have stronger AW regulations for pigs compared with EU's regulations and other countries' regulations. Our analyses utilize a new detailed dataset capturing the dynamics of pig AW regulations over time for several EU member states, taking into account multiple aspects of pig AW that can have significant cost impacts for pork producers. We focus on countries with relatively stringent AW legislation for pigs and countries that are major pork producers. Using panel regression, long-differenced IV, and event study approaches, we find that an increase in the relative stringency of pig AW regulations in a country is associated with a reduction in pork exports. We find mixed evidence suggesting that stricter AW regulations for pigs reduced pork imports. Our results have important implications for other jurisdictions that plan to mandate AW regulations for pigs in the near future.

1. Introduction

Modern industrialised agriculture with intensive animal production has led to ethical concerns regarding how livestock are managed and kept. In response to this, livestock producers in many countries are facing demands from both consumers of animal sourced products and from citizens in general for better welfare standards for farm animals (Eurobarometer, 2016; 2023). Consumers express increasing concern about how production animals are housed and managed (Thorslund et al., 2017; Ingenbleek and Immink, 2011). Consequently, governments have enacted legislation aimed at enhancing the conditions for these animals. Pork production in EU countries, which is the focus of this paper, has been particularly scrutinized, leading to the introduction of EU directives and national regulations to improve animal welfare (AW) standards for pigs.

However, while raising AW standards, there are also concerns about stricter regulations leading to increasing production costs (Harvey and Hubbard, 2013; Lee et al, 2023). Such production costs can lead to an erosion of countries' competitiveness in pork production, leading to a potential reduction in exports and/or increase in dependence on imports. More importantly, a decline in pork production in one country due to stricter AW regulations may simply encourage production to shift to other countries with more relaxed rules. Divergences in AW regulations could thus lead to "low AW havens" (Grethe, 2007) that reduce the overall effectiveness of the policy in improving AW. The extent to which more stringent AW rules for pigs erodes countries' comparative advantage in pork production is thus an important empirical question. National stakeholders in countries such as Sweden have long voiced a concern that stricter AW regulation negatively affects competitiveness (SOU 2015:15), and the question has been subject to governmental investigation, (SOU 2024:56) yet the question has never been analysed using rigorous empirical methods.

In this study, we evaluate the impact of stricter national AW regulations on the European pork sector, using international trade flows as an indicator of competitiveness. Using both a panel regression and event study analysis, we focus on bilateral trade flows of pork between 13

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European countries between 1991 and 2020, a period in which EU directives and national actions significantly affected pig farming practices. These 13 countries include those with relatively stringent animal welfare (AW) legislation for pigs or significant pork production. We exploit the fact that some countries have stronger AW-regulations for pigs compared to others, with some countries only meeting EU minimum standards and others having national regulations that extend beyond EU minimum standards. Our analysis utilizes a new dataset capturing the dynamics of pig AW-regulation stringency for the 13 countries in our study for the entire 1991–2020 period, which takes into account multiple aspects of pig AW that can have significant cost implications for pork producers.

Our work contributes to a new and growing literature assessing the economic impacts of stricter AW-regulations on the production and trade of animal-based food products. Ex-ante analysis suggest that pork production costs and competitiveness are particularly sensitive to AW regulations (Harvey et al., 2013; Grethe et al., 2017). Our work is the first ex-post analysis of the impact of pig AW regulations on competitiveness at the national level. It is also the first to study the impact of pig AW regulations using data on trade flows of pork, which allows us to explicitly test the "low AW havens" hypothesis (Grethe, 2007).

Our work also contributes to an empirical literature on the ex-post evaluation of stricter AW regulations' economic impacts. There are very few ex-post studies of the impact of AW regulations on trade in the literature, and the few studies that exist concern battery cage bans for laying hens. Mullally and Lusk (2018) found that imports from other states in the US compensated for this decrease in production due to the California battery cage ban. Carter et al. (2021) examined the inter-state trade effects in more detail and found that imports to California became more concentrated in a small number of firms. Ferguson (2023) did not detect any significant impact of cage bans in EU countries on egg imports. Battery cage bans have been relatively straightforward for economists to analyse, as laying hen AW is dominated by the single key issue of battery cages. In contrast, AW regulations governing pork production are more complex, as there are multiple key issues involved.

EU countries during the period 1991–2020 serve as an ideal setting to study the impact of AW regulations on countries' comparative advantage in pork production for several reasons. First, there is a great deal of variation in AW regulations for pigs in the EU during this period, both across countries and over time. Second, meat trade between countries within the EU single market is commonplace and economically important. Third, trade within the EU single market is not subject to tariffs or other trade restrictions that may otherwise confound an analysis of AW stringency on trade flows. Finally, the long timespan of the analysis allows us to observe the long-term effects of AW regulations. Analysis of the EU thus can provide important lessons for other jurisdictions that plan to mandate new AW regulations for pigs.

The rest of the analysis proceeds as follows. In Section 2 we provide a brief history of AW legislation for the EU and the 13 countries included in the analysis, describing the main changes over time at the EU-level and summarizing the substantial differences between countries. We then explain in Section 3 how changes in AW stringency relate to theories of international trade, allowing us to make theoretical predictions regarding the expected impact of AW stringency on exports and imports. A description of our empirical methodology follows in Section 4, including a description of our AW measures, and the panel, IV, and event study regression approaches. In Section 5 the data used in the analysis is described in detail, and the results are presented in Section 6. We then discuss the policy implications of our results in Section 7, followed by conclusions in Section 8.

2. A brief history of EU and national pig AW legislation

We now describe the changes in pig AW legislation at the EU-level and national-level used in the analysis.

2.1. AW legislation for pigs

Regulations on several aspects of pork production have been introduced in EU countries since 1991, as a result of both EU directives and national initiatives. We focus here on the following six AW key issues where more stringent rules can affect pork production costs:

1. Sow housing during gestation
2. Sow housing during lactation
3. Housing of growing/finishing pigs
4. Weaning age
5. Tail docking
6. Manipulable enrichment material

Regulations pertaining to these six AW key issues were not only important from an AW perspective (e.g. Veissier et al., 2008; Lundmark Hedman, 2020), but are likely to have affected production costs by e.g. reducing stocking densities, and by affecting construction costs in order to comply with the regulations. Provisions for larger unobstructed floor areas could be met by reducing stocking densities, but restrictions for slatted floors, group sow housing and loose farrowing systems sometimes required barns to be reconstructed or replaced. Providing manipulable enrichment material, such as straw, is in itself associated with a production cost, but also require suitable systems for handling manure and potentially increased costs for labour. Higher weaning ages increases the demand on farrowing housing and management. Moreover, the production flow (number of piglets delivered per sow per time unit) is decreased when the production time is increased, which may increase production costs per pig. Reducing tail biting (the reason for tail docking) could be handled in various ways, including the provision of manipulable enrichment material, reducing stocking densities, or other more labour intensive management. At the same time, compliance with new regulations related to these six AW key issues may be associated with reduced costs associated with improved animal health, due to decrease in veterinary treatments, drugs and labour costs associated with caring for sick animals and with increased incomes related to improved production performance (e.g. growth and reproduction performance).

EU legislation specific to pig animal welfare have existed for over 30 years. Council Directive 91/630/EC was the first directive to specify minimum standards for the protection of pigs. This directive, passed in 1991, required all farms to provide minimum unobstructed floor area for weaner and rearing pigs by 1998, and it also prohibited the construction of tethered sow stalls after 1995. Restrictions to tail-docking and a minimum weaning age of 28 days was required by 1994. Council Directive 2001/93/EC states that "piglets may be weaned up to seven days earlier (21 days) if they are moved into specialised housings which are emptied and thoroughly cleaned and disinfected before the introduction of a new group and which are separated from housings where sows are kept, in order to minimise the transmission of diseases to the piglets."

The 1991 EU directive was vague regarding specific requirements for sow housing and manipulable enrichment materials, and contained no restrictions on slatted floors. These issues were dealt with in 2001 via Council Directive 2001/93/EC, with further details given in 2008 via Council Directive 2008/120/EC. The more strict minimum requirements stipulated in the 2001 directive regarding sow housing, manipulable enrichment material, and slatted floors (often entailing construction costs for producers) came into force in 2013. See Wallenbeck et al. (2024) for more detail surrounding changes in EU AW legislation between 1991 and 2020.

Several EU member states have had national AW regulations that go beyond the EU minimum level, and national regulations were put in place many years before the EU rules came into force in some countries. Austria, the Netherlands, Sweden, and the UK (an EU member state until the end of 2019) require group sow housing during a longer part of the gestation period, compared with the 2013 EU minimum. Whereas the EU still allows farrowing crates, Sweden, for example, has required loose housed farrowing since 1988. The Netherlands and Sweden have substantially more far-reaching space and flooring requirements for weaner and rearing pigs than the EU minimum level. According to compliance audits (European Commission, various years), Sweden and Finland are the only countries to have fully complied with EU rules banning tail docking. Many countries were ahead of the EU in requiring manipulable enrichment material. See Wallenbeck et al. (2024) for more detail on differences between EU and national pig AW legislation.

3. The economics of AW stringency and international trade

A national regulator charged with the task of maximizing welfare would consider the market and non-market benefits accrued to citizens and consumers due to altruism (McInerney, 2004; Lusk and Norwood, 2011), as well as the additional fixed and variable production costs associated with more stringent AW. Variable and fixed production costs are critical determinants of trade patterns in gravity models, common in the agri-food trade literature (Hertel, 2002; Gaigné and Gouel, 2022).

If AW regulations increase the marginal cost of production, all else being equal, then gravity models of international trade predict that more stringent AW rules for pigs will reduce the value of the country's pork exports and increase the value of pork imports. Gravity models also predict that greater fixed production costs reduce entry and hence the size of the domestic industry by raising the average cost of production (Melitz, 2003), which indirectly affects imports and exports. These models also allow for the possibility that good AW may also increase the demand for pork, which can in theory increase exports and reduce imports.

Although we expect AW regulations to affect, and possibly be affected by, international trade in meat to some extent, a preference to consume domestically-produced goods (so-called "home bias") may reduce the sensitivity of trade to AW regulations. Non-tariff barriers, which capture home bias effects, have been shown empirically to reduce international trade for merchandise trade in general (Head and Mayer, 2000; Head and Ries, 2001; Anderson and van Wincoop, 2003) and agricultural trade in particular (Chevassus-Lozza et al., 2008; Olper and Raimondi, 2008; Ghazalian, 2012; Luckstead, 2024).

Differences in consumer preferences for AW in domestically produced versus imported pork may dampen the impact of higher domestic production costs, making imports less responsive to AW regulations than exports. Separate preference parameters for domestic and imported products (Head and Ries, 2001) or a separate elasticity of substitution for domestic products (Bergstrand, 1985) could predict such a pattern of home bias, but this has not been investigated in the literature.

4. Empirical methodology

4.1. Measures of pig AW stringency

As discussed earlier, rules regarding pig AW differ in many dimensions between countries and over time. It is thus difficult to find a single metric that adequately quantifies the stringency of AW regulations, even within a single key issue. We use a categorical variable for each of the six pig AW key issues in order to capture when a country's AW regulations are substantially more stringent than the EU minimum. The categorical variable is equal to 1 each year a country's AW regulations entail additions with potential impact on production costs compared to the EU minimum in that year, and zero otherwise. This measure of each country's AW stringency thus captures deviations in the level of AW relative to the EU minimum in each year of the data.

In the case of sow housing during gestation, we define an addition as requiring group housing at all times except for the last week of pregnancy. Four countries met this condition: Sweden (since 1988), the UK (since 1999), the Netherlands (since 2013) and Austria (since 2018). Such strict requirements for group housing during gestation go beyond the EU minimum standard that entered into force in 2013, requiring sows to be kept in group housing from four weeks after service until one week before expected farrowing (Council Directive 2008/120/EC).

In the case of sow housing during lactation, we define the banning of farrowing stalls as an addition. Sweden has required loose farrowing systems at all times since before 1991, and Austria began allowing farrowing stalls only for the first 10 days after farrowing since 2018. Farrowing stalls have not yet been banned at the EU level.

In the case of housing for growing/finishing pigs, an addition is defined as providing substantially more space compared to the EU minimum, which entered into force in 2013. For a finishing pig of 110 kg live weight, Sweden's space requirement since before 1991 is 1.02 m2, and the Netherlands requirement since 2013 is 1.00 m^2. In contrast, the space requirement for the same size pig in the EU since 2013 is 0.65 m2.

In the case of weaning age, we define an addition as a shorter weaning age than the EU minimum of 21 days if certain conditions are met, a rule that entered into force in 2001. Sweden was the only country to exceed this condition, requiring a minimum of 28 days with no exceptions during the period from before 1991 to 2017.

In the case of tail docking, EU restrictions have been in place since 1994 and routine taildocking has been prohibited since 2003. However, only Sweden (pre-1991) and Finland (since 2004) have fully complied with this rule, which we define as an addition for this key issue.

Finally, in the case of manipulable material, we define the provision of sow nesting material as an addition, which was undertaken by Sweden (pre-1991), Austria (since 2005) and Finland (since 2012). EU minimum requirement for manipulable material, which was roughly equivalent to the earlier requirements in Sweden, Austria and Finland, entered into force in 2013.

Using a categorical variable to capture divergences in AW regulations across jurisdictions has been commonly used in empirical studies of the economic impacts of AW regulations. The empirical literature evaluating the impact of battery cage bans, for example, has used categorical variables to identify the timing of bans (Mullally and Lusk, 2018; Carter et al., 2021; Ferguson, 2023). In the context of pig AW regulations, several of the AW key issues can be easily summarized as a discrete variable, such as whether farrowing crates are allowed or not, whether group sow housing is required or not, and whether the tail docking ban is effectively enforced. In other cases, such as minimum space and flooring types for growing/finishing pigs, there are so many different combinations of regulations that creating a single continuous measure is all but impossible.

4.2. Panel regression methodology

We begin the analysis using a panel regression approach, employing a Poisson pseudo-likelihood regression model with multiple levels of fixed effects (Correia et al., 2019; 2020). Compared to Ordinary Least Squares, which uses the logarithm of trade values as the dependent variable, Poisson regression models have the advantage of allowing for zeros in the bilateral trade flow data. Poisson regression models have gained popularity in the international trade literature, starting with work by Silva and Tenreyro (2006). We analyse bilateral trade flows at the product-origin–destination-year level.

When analysing bilateral trade flows of pork only, we estimate the following equation:

$$trade_{odt} = exp\left(\begin{array}{c}\alpha^o AW_{ot} + \alpha^d AW_{dt} + \beta^o Y_{ot} + \beta^d X_{dt} + \gamma \mathrm{T}_{odt} \\ + \delta_{od} + \delta_t + \varepsilon_{odt}\end{array}\right), \tag{1}$$

where $trade_{odt}$ is the value of bilateral trade in pork from origin country o to destination country d in year t. AW_{ot} and AW_{dt} are animal welfare relative stringency measures for pigs in the origin and destination countries respectively, compared to the EU minima. Y_{ot} and X_{dt} are covariates affecting pork export supply and import demand in the origin and destination countries respectively. T_{odt} is a vector of country-pair-year covariates, such as trade costs. δ_{od} and δ_t are country-pair and year fixed effects respectively.

The main coefficients of interest are α^o and α^d, which capture the impact of substantially more stringent national regulations on pork exports and imports respectively. It is important to include AW measures for both the origin country and destination country in the analysis, so that the effects can be interpreted while controlling for the trade partner's AW stringency. Trade theory predicts a negative impact of cost-increasing pig AW regulations on exports of pork ($\alpha^o < 0$), and a positive impact on imports of pork ($\alpha^d > 0$) if competitiveness is strictly driven by considerations of production costs. However, consumers' willingness to pay for higher AW standards or a prevalence of home bias may reduce the overall effects of higher costs.

An important caveat when analysing the impact of country-specific policies is that we cannot use fixed effects to control for product-destination-year and product-origin-year determinants of trade, known as "multilateral resistance terms" (Anderson and van Wincoop, 2003; Head and Mayer, 2014; Yotov et al., 2016). Our estimations thus do not yield a theoretically-consistent estimation of the gravity model. Instead, our empirical approach follows other studies that analyse country- or region-specific policies or shocks using trade data (Luo and Tian, 2018; Andersson, 2019; Fiankor et al., 2020, Raimondi et al., 2020, Dall'Erba et al., 2021; Ferguson, 2023).[1]

4.3. Threats to identification

It is important to consider potential concerns regarding endogeneity when regressing bilateral trade flows on AW stringency. Endogeneity may arise if changes in international trade over time lead countries to a change in national AW regulations. For example, increased international trade could lead to a convergence in AW regulations, as consumers in export markets demand that imported pork meets higher AW standards. Although the domestic market dominates exports in most cases, reverse causation via the convergence channel is impossible to completely rule out. Another possible source of reverse causation is the case where lower export competitiveness for reasons unrelated to AW lead to a national pork industry that caters primarily to domestic consumer concerns, which could encourage more strict domestic AW regulations.

Another potential concern is that changes over time in AW and intra-EU trade may be spuriously correlated if they are both driven by another underlying factor, such as the overall level of prosperity in a country. However, explanatory factors such as GDP and GDP per capita are controlled for by country-year fixed effects.

We employ several alternative approaches in response to the threats to identification described above. We propose an instrumental variable (IV) strategy to deal with concerns of endogeneity and spurious correlation. We also employ an event study approach, which allows us to check the parallel trends assumption. Several robustness checks are also performed.

Finally, a third potential concern is that of omitted variable bias. The fixed effects in equation (1) eliminate the problem of omitted variables at the country-pair and year level. At the country-year level, we control for the impact of within-EU export bans due to foot-and-mouth disease (FMD), African swine flu and Classical swine fever outbreaks using indicator variables. Although the vast majority of trade observations are between EU member states (thus having no tariffs or trade restrictions), we include an indicator variable controlling equal to one if the country is an EU member state in a given year, and zero otherwise. This controls for any omitted country-year-specific differences in trade that are driven by EU membership status.

Despite the controls described above, omitted variable bias may still occur if there are additional country-year covariates that can explain trade flows over time and are also correlated with changes in pig AW over time. We apply several alternative methods to reduce the problem of omitted country-year covariates, which we describe in the robustness section.

4.4. Long-differenced IV methodology

As a response to concerns regarding endogeneity and spurious correlation, we propose instrumenting for origin and destination country AW regulations, using survey data from the 1990 European Values Study (EVS 2011). We use data on the share of respondents saying that they belong to an animal rights organization.[2] This measure includes a wide variety of organizations, some of which may not deal with farm animals. However, we argue that this measure is informative about the size of the domestic lobby for AW, including farm AW, which could influence the stringency of national legislation.

This instrument has the desirable property that it is correlated with future AW regulations, but is exogenous to future growth in trade driven by costs of production. We also argue that this instrument reduces exports and increases imports exclusively via its influence on AW regulations, thus satisfying the exclusion restriction. It is difficult to argue that the strength of animal rights groups could reduce exports in any other meaningful way than via lobbing for tougher rules. Any direct effect of animal rights groups on imports, if any such effects are present, would influence imports in a direction that would bias our estimates toward zero. For example, any direct influence of animal rights groups would likely be to *reduce* imports if they discourage consumers from eating pork. In contrast, the impact of lobbying on producer costs would *increase* imports, as domestic pork production becomes less competitive. One potential concern with this instrument is that it could be correlated with broader social, political, or environmental attitudes. Reassuringly, however, our AW measure shows a low correlation (0.10) with the OECD Environmental Policy Stringency Index, which we include as a control variable. This is reported in Table A3 in the appendix.

The values of the instrumental variable for each country in the analysis are reported in Table A1 in the appendix. The survey includes all 13 countries in our analysis. The Netherlands reported the highest share of respondents being members of animal rights organizations in the 1990 survey wave, followed by Belgium and Sweden.

As our proposed instrumental variable does not contain any time variation, we implement a "long-difference" of equation (1) over the entire 1991–2020 period. This approach thus focuses on how long-run changes in AW stringency affect the long-run trade growth of pork within the 13-country study area. We estimate the following model by Two Stage Least Squares:

$$\begin{aligned}\Delta \ln(\text{trade})_{od} &\equiv \ln(\text{trade})_{od,2020} - \ln(\text{trade})_{od,1991} \\ &= \omega^o \widehat{\Delta AW}_o + \omega^d \widehat{\Delta AW}_d + \theta \Delta X_{o,d} + \eta_{od}, \qquad (4)\end{aligned}$$

where $\widehat{\Delta AW}_o$ and $\widehat{\Delta AW}_d$ are the fitted values resulting from estimating the following models in the first stage:

$$\Delta AW_o = \varpi^o share\_org_{o,1990} + \varpi^d share\_org_{d,1990} + \varphi \Delta X_{o,d} + \nu_{od},$$

$$\Delta AW_d = \rho^o share\_org_{o,1990} + \rho^d share\_org_{d,1990} + \chi \Delta X_{o,d} + \xi_{od}.$$

$\Delta X_{o,d}$ is a vector of origin-specific and destination-specific control variables.

[1] We are able to control for unobserved country-year and product-country-year in a robustness check to some extent, which we describe in the results section.

[2] Question 131 states: "Please look carefully at the following list of voluntary organisations and activities and say which, if any, do you belong to? One of the options is "Animal rights" (Q144A).

4.5. Event study regression methodology

We estimate a Difference-in-Differences (DiD) model with multiple periods, as introduced by de Chaisemartin and d'Haultfoeuille (2024). This method allows for panel units to move in and out of treatment status and also allows for time-varying, heterogeneous treatment effects, This method thus deals with the problems of bias in older two-way fixed effects (TWFE) estimations. In the event study, all 2x2 DiD estimates are first obtained by this approach including pre- and post-treatment effects, which takes the following form when estimating the impact of AW stringency in the origin country:

$$\ln(trade)_{odt} = \gamma_{od} + \gamma_t + \gamma_F^{-F} AW_{it}^{<-F} + \sum_{s=-F}^{-2} \gamma_s^{lead} \bullet AW_{ot}^{s} + \sum_{s=0}^{L} \gamma_s^{lag} \bullet AW_{ot}^{s} + \gamma_s^{-L} AW_{ot}^{>L} + \epsilon_{odt}, \quad (3)$$

where the notation closely follows the panel specification in equation (1). AW_{ot}^{s} is the AW stringency measure in origin country o being s periods away from initial treatment at time t, with the analogous term for the destination country. The approach provides an estimate of the average treatment effect on the treated (ATT), which reflects the change in trade (in log points) associated with a one-unit change in the AW stringency indicator in a given period.

The event study approach permits the graphical inspection of parallel trends pre-treatment, which is an important assumption for DiD designs. The analysis uses the year before the regulation entered into force (t-1) as the base year. However, it is possible that trade could respond in advance of the regulations, so it is plausible that anticipation effects may be present. The main drawback to the event study approach in this context is that it is not possible to include time-varying covariates.

5. Data and descriptive statistics

5.1. Bilateral trade data

The bilateral trade data is taken from the FAOstat detailed trade matrix. We focus on trade flows of pork between the 13 countries for which we have detailed AW regulation data 1991–2020 (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Poland, Spain, Sweden, and the United Kingdom). These countries were selected by Wallenbeck et al. (2024) because they represent a diversity of AW levels for pigs, and include the largest European meat exporters. 1991 is an ideal starting year because it was the year of the first EU directive pertaining specifically to pig AW (Council Directive 91/630/EC). 1991 also happens to be the earliest year that trade data for post-unification Germany is available in FAOstat.[3]

When preparing the data, we combine Luxembourg trade data with that of Belgium, which is customary in the trade literature, since they were not reported separately in the trade data until 1999. We use the value of trade in million US dollars in the analysis. We convert the nominal trade values to constant 2015 prices using the Euro Area consumer price index, taken from OECD.stat. FAOstat includes both importer-reported and exporter-reported bilateral trade data. We use importer-reported trade data whenever available, and fill in missing trade flows using the exporter-reported data whenever possible. This is mainly an issue for trade flows to and from Poland, which did not always report trade data during the 1990′s. Using importer-reported trade data likely introduces more measurement error on exporting decisions compared to importing decisions, but importer-reported trade data is commonly regarded as more trustworthy.

After combining the various data, we obtain a fully balanced panel of 4680 unique bilateral trade flow observations for each meat type. In the trade data, we include meat, edible offal, and processed meat for pork. In a robustness check we also include data on trade flows of beef and chicken. A complete list of FAO product codes and their descriptions is provided in Table A2 in the appendix.

Summary statistics for the trade value data are provided in Table 1. The average bilateral trade flow for pork during this period was 88 million USD (constant 2015 values). Trade zeros (trade flows reporting no trade in pork) are reported for 139 observations, about three percent of the data.

5.2. AW regulation data

We construct the pig AW-regulation stringency data based on several sources. We first gleaned as much information as possible from existing academic literature and government reports. A few studies provide detailed information about differences between pig AW regulations in a particular year, such as 2010 (Mul et al., 2010), but there is a dearth of

Table 1
Panel data summary statistics, $n = 4680$.

Description	Variable name	Mean	SD	Min	Max
Pork bilateral trade value, constant 2015 USD, millions	$trade_{odt}$	88.1	177	0	1,505
Indicator variables, additional pig AW regulations, by key issue:					
Housing during gestation	$gestAW_{okt}$, $gestAW_{dkt}$	0.16	0.37	0	1
Housing during lactation	$lactAW_{okt}$, $lactAW_{dkt}$	0.085	0.28	0	1
Housing for growing/finishing pigs	$finiAW_{okt}$, $finiAW_{dkt}$	0.097	0.30	0	1
Weaning age	$weanAW_{okt}$, $weanAW_{dkt}$	0.069	0.25	0	1
Tail docking	$tailAW_{okt}$, $tailAW_{dkt}$	0.12	0.33	0	1
Manipulable material	$manipAW_{okt}$, $manipAW_{dkt}$	0.038	0.19	0	1
Sum of pig AW indicators	$AWsum_{okt}$, $AWsum_{dkt}$	0.57	1.39	0	6
AW index	$AWindex_{okt}$, $AWindex_{dkt}$	0.35	1.19	−0.18	6.32
Other control variables:					
EU member indicator	$EUmember_{ot}$, $EUmember_{dt}$	0.93	0.25	0	1
Gross domestic product, constant 2015 USD, billions	GDP_{ot}, GDP_{dt}	1,031	968	82.1	3,599
Gross domestic product per capita, constant 2015 USD	$GDPpc_{ot}$, $GDPpc_{dt}$	36,473	11,753	4,771	79,464
Foot-and-mouth disease outbreak indicator	FMD_{okt}, FMD_{dkt}	0.013	0.11	0	1
African swine fever outbreak indicator	ASF_{okt}, ASF_{dkt}	0.028	0.17	0	1
Classical swine fever outbreak indicator	CSF_{okt}, CSF_{dkt}	0.018	0.13	0	1
Environmental policy stringency index	$EnvPol_{ot}$, $EnvPol_{dt}$	2.40	0.99	0.47	4.89

[3] We do not include domestic trade flows in the analysis because the FAOstat Value of Agricultural Production database contains too many missing country-year observations for pork production. However, in a robustness check reported in Table A.5 we include destination-product-year or destination-product-year fixed effects, which controls for domestic trade flows.

literature that describes the dynamics of additional rules at the national level. We compared the texts of EU directives with national laws in order to determine the years when countries' national AW requirements greatly exceeded the prevailing EU legislation for each key issue in our study. We complemented our review of official documents with a questionnaire sent to AW experts from governmental, academic and animal protection organisations in the countries we study. The details of the methodology and sources of information are summarized in Wallenbeck et al. (2024).

Inspection of the pairwise correlation coefficients for the six different AW indicator variables in Table 2 reveals that many of the AW measures are highly correlated. In order to avoid problems of collinearity, we construct an aggregate measure of pig AW-regulation that is the sum of the six indicator variables for each country and year. We construct a variable based on this aggregate AW measure for the origin country in each trade flow observation ($sumAW_{ot}$) and a corresponding variable for each destination country ($sumAW_{dt}$). These aggregate measures of pig AW-regulation take a value between zero and six. The evolution of the aggregate measure of AW regulation for each country in the analysis is illustrated in Fig. 1. Five countries (Austria, Finland, the Netherlands, Sweden and the UK) increased the stringency of their AW regulations beyond EU minima during the study period, while eight did not. We also construct an inverse covariance weighted index of the six AW indicators, as well as the first component of a principal component analysis, which we use in a robustness check.

A potential weakness of using an aggregate AW index is that it does not weight each component based on its impact on production costs. We do not have data on the costs to implement each AW key issue in each country. We tackle this problem by estimating the impacts of individual key issues separately, which allows us to estimate whether certain key issues have a larger effect on competitiveness than others, as reflected in the impact on exports and imports.

5.3. Other variables

We control for whether the origin country or destination country is an EU member, using a categorical variable. This variable takes a value of 0 for Sweden, Finland, and Austria 1991–1994, Poland 1991–2003, and the UK in 2020, and takes a value of 1 otherwise.

We include an indicator variable for FMD export bans takes a value of 1 trade flows to and from the United Kingdom, France, the Netherlands and Ireland for the year 2001, and also the United Kingdom in 2007, and takes a value of 0 otherwise (European Commission 2003, 2024). We also include indicator variables for outbreaks of African swine fever (EFSA 2021) and Classical swine fever (EFSA 2021).

We also include country-year controls for national environmental regulations that may have affected the competitiveness of animal farming in EU countries. The Nitrate Directive (91/676/EEC) is one example of an environmental regulation that directly affects animal production by limiting the amount of manure that can be applied to agricultural lands. This restriction forced some producers to transport their manure to spread on fields further away, which reduces the value of this by-product. Since nitrogen application levels are obviously endogenous to a trade, we instead use the OECD Environmental Policy Stringency Index, a broader measure of countries' environmental policy strictness.

In some specifications we use only panel and year fixed effects, which allows for the use of controls at the origin-year and destination-year level. In these specifications we control for countries' Gross Domestic Product (GDP) and GDP per capita, which are common controls in the empirical trade literature. The data on GDP and GDP per capita is taken from FAOstat.

The summary statistics reported in Table 1 indicate that there is large variation in the control variables. Reassuring, correlation coefficients between the AW index and the control variables are generally low, as reported in Table A3 in the appendix.

Global trade in pork between the EU member states included in our study, the rest of the EU28, and the rest of the world in 1991 (Panel A) and 2020 (Panel B) is illustrated in Fig. A1 in the appendix.[4] World trade in pork increased substantially between 1991 and 2020, from 22 billion to 55 billion constant 2015 USD. International trade in pork between the 13 countries included in the analysis grew modestly during this time, while exports to other EU-28 countries and the rest of the world grew substantially. The 13 countries included in the analysis have historically been self-sufficient in pork, with very limited imports from other countries. Fig. A1 also illustrates that the other EU28 countries not included in our analysis have much smaller trade flows compared to the countries that we study. Our sample of countries thus covers the vast majority of EU pork trade.

Total annual trade in pork between the 13 countries we study over the period 1991–2020 is illustrated in Fig. A2 in the appendix. Trade in pork among these countries declined slightly in the 1990′s, then grew rapidly in the 2000′s, only to fall again slightly during the 2010′s. Trade in live animals between these countries has been relatively small in comparison, valued at 780 million USD per year on average for pigs under 50 kg and 1.06 billion on average for pigs 50 kg and over. As indicated by Table A4 in the appendix, average annual imports and exports to partners within the study group vary by country, with Germany being the largest trade partner and Finland the smallest.

6. Results

6.1. Panel regression results

In Table 3 we report the regression results when estimating equation (1). Column 1 includes the AW index for the origin country and destination country, as well as controls for GDP and EU membership. Controls for disease are added in column (2), and the environmental policy control is added in column (3). All specifications include panel and year fixed effects and cluster at the panel (country-pair) level.

Across all columns of Table 3 we find that the stringency of AW regulations in the origin country has a negative and statistically significant relationship with the value of exports. The point estimate for $AWsum_{ot}$ in column (3) suggests that each key issue with substantially more stringent AW regulations is associated with a $(exp(-0.27)-1) \times 100 \cong 24$ percent decrease in pork exports.

The results in Table 3 suggest that the impact of more stringent AW regulations in the destination country is relatively small compared to those of the origin country, with weakly positive estimates. The point estimate for $AWsum_{dt}$ in column (3) suggest that each key issue with substantially more stringent AW regulations is associated with a $(exp(0.094)-1) \times 100 \cong 10$ percent increase in imports, although this estimate is imprecise.

Some control variables yield statistically significant point estimates with the expected sign in Table 3. EU membership has a positive and statistically significant effect on both the origin and destination country's value of pork trade. We find weak results with respect to origin and destination country GDP and GDP per capita. We do not detect any detrimental effects of disease outbreaks on pork trade. Surprisingly, outbreaks of Classical swine fever (CSF) in the origin country exhibit a positive relationship with pork trade. The estimates suggest that a country's overall environmental policy stringency is negatively associated with its exports, but we do not detect a statistically significant association between environmental policy and countries' imports.

[4] The EU28 consisted of the following countries: Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom.

Table 2
Pairwise correlation coefficients, AW-regulation indicator variables.

	$gestation_{ot/dt}$	$lactation_{ot/dt}$	$finishing_{ot/dt}$	$weaning_{ot/dt}$	$tail_{ot/dt}$
$lactation\_housing_{ot/dt}$	0.69				
$finishing\_housing_{ot/dt}$	0.75	0.83			
$weaning_{ot/dt}$	0.62	0.90	0.83		
$tail\_docking_{ot/dt}$	0.48	0.74	0.68	0.74	
$manip\_material_{ot/dt}$	0.13	0.23	0.20	0.26	0.21

Note: The panel is strongly balanced, implying that the correlation coefficients for the origin-year and destination-year variables are identical, hence the "ot/dt" notation after each variable name.

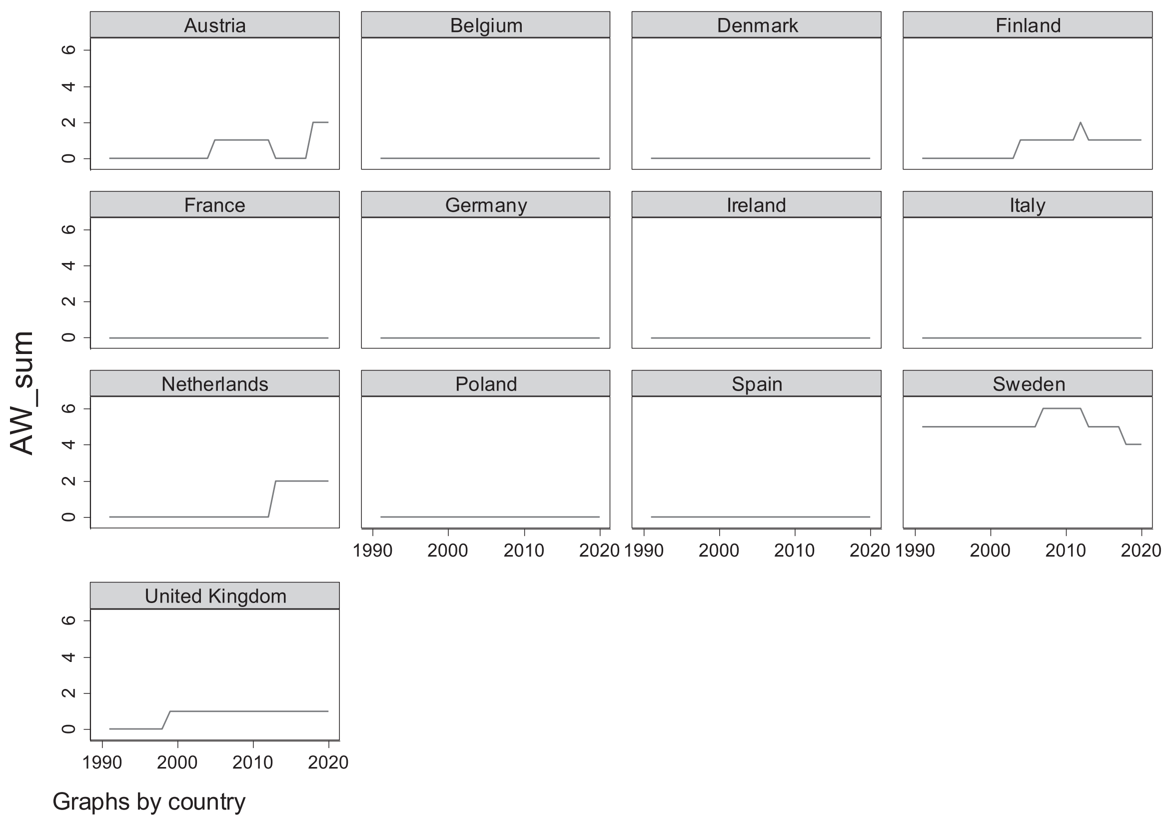

Fig. 1. Aggregate national AW index (stringency in AW regulation in relation to EU directives) by country and year, 1991–2020.
Source: Authors' calculations

6.2. Long-differenced IV results

The main results from the IV regression analysis using long-differenced pork trade are presented in Table 4, where we estimate equation (4) by TSLS, as well as the corresponding OLS estimate. The dependent variable in Table 4 is the log change in the bilateral trade value between 1991 and 2020. The estimates reflect the impact of a one unit change in the AW composite index on the growth of pork trade over the sample period.

Test statistics for underidentification and weak identification are also reported at the bottom of Table 4, which confirm that the instruments are valid. The point estimates and associated standard errors for the first stage results, reported in Table A5 in the appendix, provide further evidence supporting the validity of the instruments.

In the IV results reported in column (2) of Table 4 we find that the stringency of AW regulations in the origin country has a negative relationship with pork exports. The point estimates for $\Delta AWsum_o$ are considerably larger when estimated by TSLS compared to OLS. The point estimate for $\Delta AWsum_o$ in column (2) implies that a one-unit increase in the AW index leads to a 78 percent decrease in pork exports over the entire 29-year period. These are quantitatively large effects when considering that the mean of in the dependent variable is 1.49.[5] In the IV specification we do not detect a relationship between destination countries' pig AW regulations ($\Delta AWsum_d$) and pork imports. This estimate corresponds to a annualized decrease in export growth of around minus 5 percent.

The control variables included in Tables 4 and 5 share some similarities with the results from the panel regressions, with some key differences. The IV results do not detect an impact of EU membership effect for the country of origin. Furthermore, the IV specification finds a positive effect of origin country GDP, and a negative effect of destination country GDP. A negative effect of African Swine Fever is found when using the IV specification.[6]

[5] The mean of $\Delta AWsum_o$ is 0.38, with a minumum of -1 and a maximum of 2.

[6] There is no variation in in the Classical Swine Flu variable in the 1991–2020 long difference, resulting in no point estimates reported in the IV specification.

Table 3
Panel regression results, pork trade flows only.

	(1)	(2)	(3)
Dep. var: $trade_{odt}$			
$AWsum_{ot}$	−0.24***	−0.24***	−0.27***
	(0.071)	(0.069)	(0.063)
$AWsum_{dt}$	0.084	0.082	0.094
	(0.070)	(0.070)	(0.062)
$EUmember_{ot}$	1.67***	1.65***	1.79***
	(0.36)	(0.35)	(0.33)
$EUmember_{dt}$	0.87***	0.86***	0.77***
	(0.23)	(0.23)	(0.21)
ln_GDP_{ot}	−2.78	−2.81	−2.25
	(2.48)	(2.49)	(1.95)
ln_GDPpc_{ot}	3.41	3.48	2.51
	(2.72)	(2.74)	(2.11)
ln_GDP_{dt}	1.35	1.37	1.00
	(1.94)	(1.93)	(1.42)
ln_GDPpc_{dt}	0.54	0.50	1.08
	(2.01)	(2.02)	(1.47)
FMD_{ot}		0.081	−0.047
		(0.093)	(0.087)
FMD_{dt}		0.084	0.12**
		(0.060)	(0.051)
ASF_{ot}		−0.0056	0.072
		(0.13)	(0.13)
ASF_{dt}		0.018	0.011
		(0.12)	(0.13)
CSF_{ot}		0.16*	0.24***
		(0.086)	(0.070)
CSF_{dt}		0.022	0.031
		(0.082)	(0.080)
$EnvPol_{ot}$			−0.52***
			(0.11)
$EnvPol_{dt}$			0.10
			(0.089)
Fixed effects	Panel and year	Panel and year	Panel and year
Constant	−29.5*	−29.8*	−25.6**
	(16.8)	(17.0)	(12.6)
Observations	4,680	4,680	4,680
Pseudo R-squared	0.91	0.91	0.92

Notes: The dependent variable is the value of trade in constant 2015 USD millions. Estimates clustered at the panel-level in all specifications. ***p < 0.01, **p < 0.05, *p < 0.1.

6.3. Panel and long-differenced IV results by AW key issue

We explore the relationship between AW-regulation stringency and trade flows in Tables 5 and 6, where we regress each of the six AW key issues separately on the value of trade. The estimates in Table 5 are based on the panel regression specification in Table 3, column (3). The estimates in Table 6 are based on the IV specification based on Table 4, column (4).

In the panel regression analysis by AW key issue in Table 5, we find negative and statistically significant estimates for gestation housing, finishing housing, and tail docking in the origin country. Weaning age and manipulable material yield inconclusive results. Surprisingly, lactation housing yields a positive and statistically significant point estimate.

The results of the long-differenced IV regressions in Table 6 with respect to origin-country gestation housing and finishing housing are negative, which is agrees with the panel results in Table 5. The test statistics indicate that the instrument does not perform as well for sow housing during lactation, weaning age, and tail docking, so the IV estimates are not to be trusted for these specific outcomes. Manipulable material could not be included due to a lack of variation for the 1991–2020 first-difference. We do not detect effects of destination-country legislation on trade for any key issues except manipulable material in Table 5, with a positive point estimate.

Table 4
Long-differenced IV results, 1991–2020.

	(1)	(2)
Dep. var: $\Delta ln(trade)_{od,2020\text{-}1991}$	OLS	IV
$\Delta AWsum_{o}$	−0.43	−1.53***
	(0.27)	(0.37)
$\Delta AWsum_{d}$	0.79***	0.47
	(0.25)	(0.47)
$\Delta EUmember_{ot}$	0.35	0.20
	(0.40)	(0.43)
$\Delta EUmember_{dt}$	1.29***	1.25***
	(0.37)	(0.38)
Δln_GDP_{ot}	5.25	9.75**
	(3.86)	(3.94)
Δln_GDPpc_{ot}	1.11	2.82
	(3.99)	(4.44)
Δln_GDP_{dt}	−4.63	−8.52**
	(3.19)	(3.32)
Δln_GDPpc_{dt}	−0.23	−1.76
	(3.36)	(3.75)
ΔASF_{ot}	−0.30	−1.24**
	(0.45)	(0.57)
ΔASF_{dt}	−0.29	−0.54
	(0.62)	(0.76)
$\Delta EnvPol_{ot}$	−1.53***	−2.28***
	(0.35)	(0.42)
$\Delta EnvPol_{dt}$	0.025	−0.19
	(0.40)	(0.46)
Constant	4.84***	8.40***
	(1.60)	(2.12)
Observations	142	142
R-squared	0.23	0.15
Kleibergen-Paap rk LM stat		33.3
Kleibergen-Paap Wald rk F stat		76.1

Notes: The dependent variable in all columns is the log difference in the value of bilateral trade between 1991 and 2020. OLS and the second stage of the TSLS regression results are reported in columns (1) and (2) respectively. Heteroscedasticity-robust standard errors reported in all specifications. ***p < 0.01, **p < 0.05, *p < 0.1.

6.4. Event study regression results

The main results from the event study regression analysis are presented in Fig. 2, including point estimates and 95 percent confidence intervals. We report up to seven pre-and post-treatment periods. The aggregate AW measures in the origin country ($AWsum_{okt}$) is the treatment variable in Panel A of Fig. 2. Aggregate AW in the destination country ($AWsum_{dkt}$) is the treatment variable in Panel B of Fig. 2.

The results in Panel A of Fig. 2 suggest a decline in exports around the time that AW stringency increases in the origin country within a few years of the legislation coming into force. The point estimates suggest that annual exports fall by up to 0.69 log points four years after the index increases by one additional unit, which corresponds to a $(exp(-0.69)-1)\times 100 \cong 49$ percent decrease in pork exports. The negative effect on exports are the strongest for three to six years after a change in AW stringency, then subside over time.

The results in Panel B of Fig. 2 suggest a positive effect of AW stringency on imports from four years after a change in AW stringency and onwards. The estimates imply an impact of at most 0.65 log points, corresponding to a $(exp(-0.65)-1)\times 100 \cong 91$ percent increase in exports.

Overall, the event study results with respect to origin country AW in Fig. 2 are in line with the regression results in Tables 3 and 4, and suggest that exports respond to changes in overall AW stringency. The event study results with respect to destination country AW are suggest a stronger effect than the panel and long-differenced IV would suggest. These event study results also suggest that our earlier results with respect to impacts on exports in Tables 3 and 4 were not driven by

Table 5
Panel regression results by AW key issue.

	(1)	(2)	(3)	(4)	(5)	(6)
Dep.var: $\ln(\text{trade})_{odt}$	Gestation housing	Lactation housing	Finishing housing	Weaning age	Tail docking	Manipulable material
AW_{ot}	−0.51***	0.47***	−0.58***	0.14	−0.99**	−0.084
	(0.13)	(0.14)	(0.13)	(0.18)	(0.43)	(0.072)
AW_{dt}	0.091	0.048	0.088	0.33	0.26	0.16**
	(0.13)	(0.12)	(0.12)	(0.26)	(0.51)	(0.068)
Observations	4,680	4,680	4,680	4,680	4,680	4,680
Pseudo R-squared	0.92	0.91	0.92	0.91	0.91	0.91

Notes: The table reports the point estimates from six separate panel regressions, using each AW key issue for the origin and destination countries as the main explanatory variables. The dependent variable is the value of trade in constant 2015 USD millions. Estimates clustered at the panel-level in all specifications. The same control variables as Table 3 are included in each regression, but not reported. Heteroscedasticity-robust standard errors reported in all specifications. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 6
Long-differenced IV regression results by AW key issue.

	(1)	(2)	(3)	(4)	(5)
Dep.var: $\Delta\ln(\text{trade})_{od,2020\text{-}1991}$	Gestation housing	Lactation housing	Finishing housing	Weaning age	Tail docking
$\Delta AW_{o,2020\text{-}1991}$	−2.52***	25.4	−2.11***	11.3**	11.1*
	(0.66)	(29.0)	(0.61)	(5.39)	(5.80)
$\Delta AW_{d,2020\text{-}1991}$	0.77	−12.5	0.63	−3.16	−2.16
	(0.79)	(35.5)	(0.58)	(5.79)	(7.77)
Observations	142	142	142	142	142
R-squared	0.109		0.243		
Kleibergen-Paap rk LM stat	24.3	0.66	19.5	6.56	5.33
Kleibergen-Paap Wald rk F stat	103	0.31	433	3.14	2.71

Notes: The table reports the point estimates from 18 separate IV regressions (6 key issues × 3 timespans). The dependent variable in all columns is the log difference in the value of bilateral trade. The same control variables as Table 5 are included in each regression, but not reported. Estimates with respect to manipulable material are not reported due to a lack of variation in the explanatory variables. Negative R-squared values not reported. Heteroscedasticity-robust standard errors reported in all specifications. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

underlying trends or pre-treatment effects.

Event study results for each AW key issue in the origin country and destination country are reported in Figs. 3 and 4 respectively. The results suggest that the effects vary substantially across different AW key issues, which may in part be due to constraints in the number of pre- and post-treatment effects that can be estimated. Treatment effects could be estimated separately for all AW key issues except weaning age.

The results in Fig. 3 suggest that analysing the impact of single AW key issues in exports yields less precision for most key issues compared to the aggregate AW measures illustrated in Fig. 2. Sow housing during gestation yields the most precisely estimated effects, with a negative impact on exports in Panel A of Fig. 3 detected within three years. The results in Panel A of Fig. 4 reveal a positive impact of gestation housing on imports, also within three years. The event study results for other key issues are weaker, due to violations of the parallel trends assumption and weak or imprecisely estimated post-treatment effects.

6.5. Robustness to alternative AW indices

To check whether our results with respect to the aggregate AW measure are robust to alternative metrics. First, we construct an index that captures overall changes AW legislation, using the inverse covariance weighting method (Anderson, 2008). The inverse covariance weighted index assigns less weight to highly correlated components, thus maximizing the information contained in the index. Second, we calculate the first component of a principal component analysis, based on the six AW key issues. We construct these alternative AW indices for the origin country in each trade flow observation ($AWindex_{ot}$) and a corresponding index for each destination country ($AWindex_{dt}$). The results for the panel regressions and event study are reported in Table A.6 and Fig. A3 respectively in the appendix. We find that our results are robust to using these alternative measures of overall AW stringency.

6.6. Robustness to alternative fixed effects using chicken and beef as control products

As an additional robustness check, we build on our preferred specification in equation (1) and include bilateral trade in either chicken or beef as a control product and use saturated fixed effects that allow us to control for more unobservables using higher-dimensional fixed effects. We argue that both beef and chicken serve as suitable products to include in the analysis for comparison since AW regulations have had very little impact on their competitiveness compared to the substantial changes to AW legislation that affected the economics of pork production. Pork, chicken and beef constitute the vast majority of meat trade between the countries included in the analysis. In stark contrast to pork production, there are arguably no new EU or national laws that have substantially affected the competitiveness of beef cattle production in the EU since 1991.[7] Similarly, the competitiveness of broiler production in EU has arguably not been substantially affected by the Broilers Directive (2007/43/EC) of 2007.[8]

When analysing bilateral trade flows of pork versus a comparison meat product (chicken or beef) on AW stringency in the origin country, we estimate the following equation, which includes the product

[7] Austria, Finland, and Sweden have minimum requirements for cattle to graze in pasture during part of the year. However, the grazing requirements have more of an impact on dairy cattle and very little impact on beef cattle, which typically graze on pasture much of the growing season in any case. The main potential impact of this directive was to specify maximum stocking densities for broiler production.

[8] A final report by the Directorate-General for Health and Food Safety (2017) found that average stocking densities were not substantially affected in EU countries as a result of the Directive. Higher stocking densities were still permitted as long as producers met certain requirements, which meant that stocking densities were roughly similar before versus after the Broilers Directive came into force.

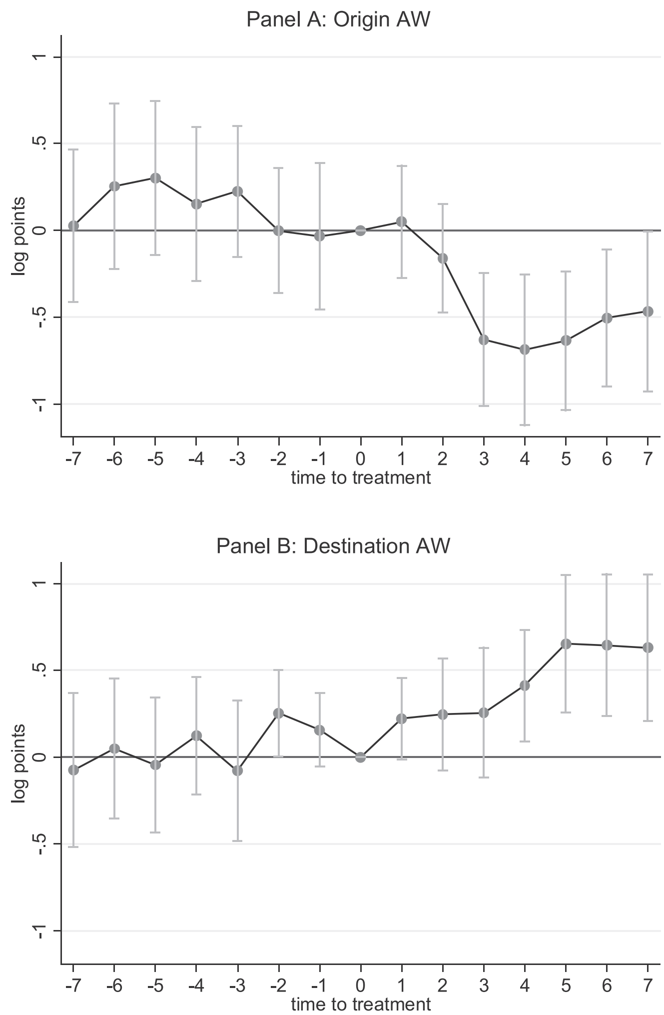

Fig. 2. Event study results, impact of AW stringency in origin country exports and destination country imports. Notes: The aggregate AW measures in the origin country ($\text{AWsum}_{\text{okt}}$) is the treatment variable in Panel A. Aggregate AW in the destination country ($\text{AWsum}_{\text{dkt}}$) is the treatment variable in Panel B.

dimension k:

$$trade_{odkt} = exp(\alpha^{o} AWsum_{okt} + \beta^{o} Y_{okt} + \gamma \text{T}_{odkt} + \delta_{odk} + \delta_{odt} + \delta_{dkt} + \varepsilon_{odkt}). \quad (4)$$

Compared to equation (1), the specification in equation (4) includes species-specific animal welfare stringency ($AWsum_{okt}$) as well as product-specific covariates (Y_{okt}, X_{dkt}, T_{odkt}).AW_{okt}

Take the same values as previously for pork trade flows, and a value of zero for trade flows of chicken and beef. The multi-product specification in equation (4) allows for higher-dimensional fixed effects, with δ_{odk} denoting panel fixed effects and δ_{odt} and δ_{dkt} denoting origin–destination-year and destination-product-year fixed effects respectively. The panel fixed effects control for all time-constant determinants of trade. The origin–destination-year fixed effects control for changes in trade over time for each country-pair that are not specific to a single type of meat. These fixed effects include country-year price indices that are typically included in gravity models of trade, as well as GDP and GDP per capita. Any changes in trade policies for non-EU members that affect all types of meat will also be captured by the origin–destination-year fixed effects. Finally, the destination-product-year fixed effects, δ_{dkt}, effectively control for the "multilateral resistance terms" commonly included in gravity models of international trade (Anderson and van Wincoop, 2003; Head and Mayer, 2014; Yotov et al., 2016) for either the origin country or the destination country, depending on the specification. The origin–destination year and destination-product-year fixed effects also help to control for the effects of EU membership changes with respect to pig AW in particular, and also for regulatory differences before EU accession.

The results of estimating equation (4) using chicken and beef as control groups are reported in columns (1) and (2) respectively of Table A7 in the appendix. We estimate the impact of destination country AW stringency ($AWsum_{dkt}$) in columns (3) and (4), using the same control products, and substituting δ_{dkt} with origin-product-year fixed effects, δ_{okt}. We find that our results for origin country AW are robust to including these additional fixed effects. We find positive effects of destination country AW when using chicken as the control product, but the results are inconclusive when using beef as the control product.

6.7. Robustness to alternative standard errors

The standard errors in the analysis are clustered at the country-pair level, as the origin-product level results in too few clusters (13). In order to check if our results are robust to clustering at the treatment level (origin country), we perform a wild bootstrap test of joint null (Roodman et al., 2019), then plot the histogram of bootstrapped t-statistics with our t-statistics clustering at the origin-product level. We perform this test on the estimates for $AWsum_o$ in our preferred specifications based on pork only, pork versus chicken, and pork versus beef (column (3) of Table 3, and columns (5) and (6) of Table 4). The results of this test are reported in Fig. A4 in the appendix, and suggest that the results are robust using these alternative standard errors.

6.8. Effects on trade with trade partners outside the study area

Our analysis so far has focused on trade between the 13 countries for which we have detailed data on AW stringency, and are a combination of countries that have had relatively stringent AW legislation for pigs, or are large exporters of pork. However, it is a valid question whether more stringent AW legislation vis-à-vis the EU minima has affected these countries' exports and imports with trade partners outside of the study area. Using the same sources for the bilateral trade data and other control variables, we estimate the impacts of AW stringency using our aggregated measure. The results of this analysis are reported in Table A8 in the appendix, using either beef or chicken as the comparison product.

As we do not have data on the AW stringency on other countries, we can instead subsume all unobserved product-country-year covariates using fixed effects, following the approach used in Table A7. We include destination-product-year fixed effects when estimating the impact of origin country pig AW stringency ($AWsum_{okt}$) on exports to all other countries. Likewise, we include origin-product-year fixed effects when estimating the impact of destination country pig AW stringency ($AWsum_{dkt}$) on imports from all other countries. The results in Table A8 suggest that additional pig AW stringency beyond EU minima have not affected exports or imports of pork to countries outside of the study area.

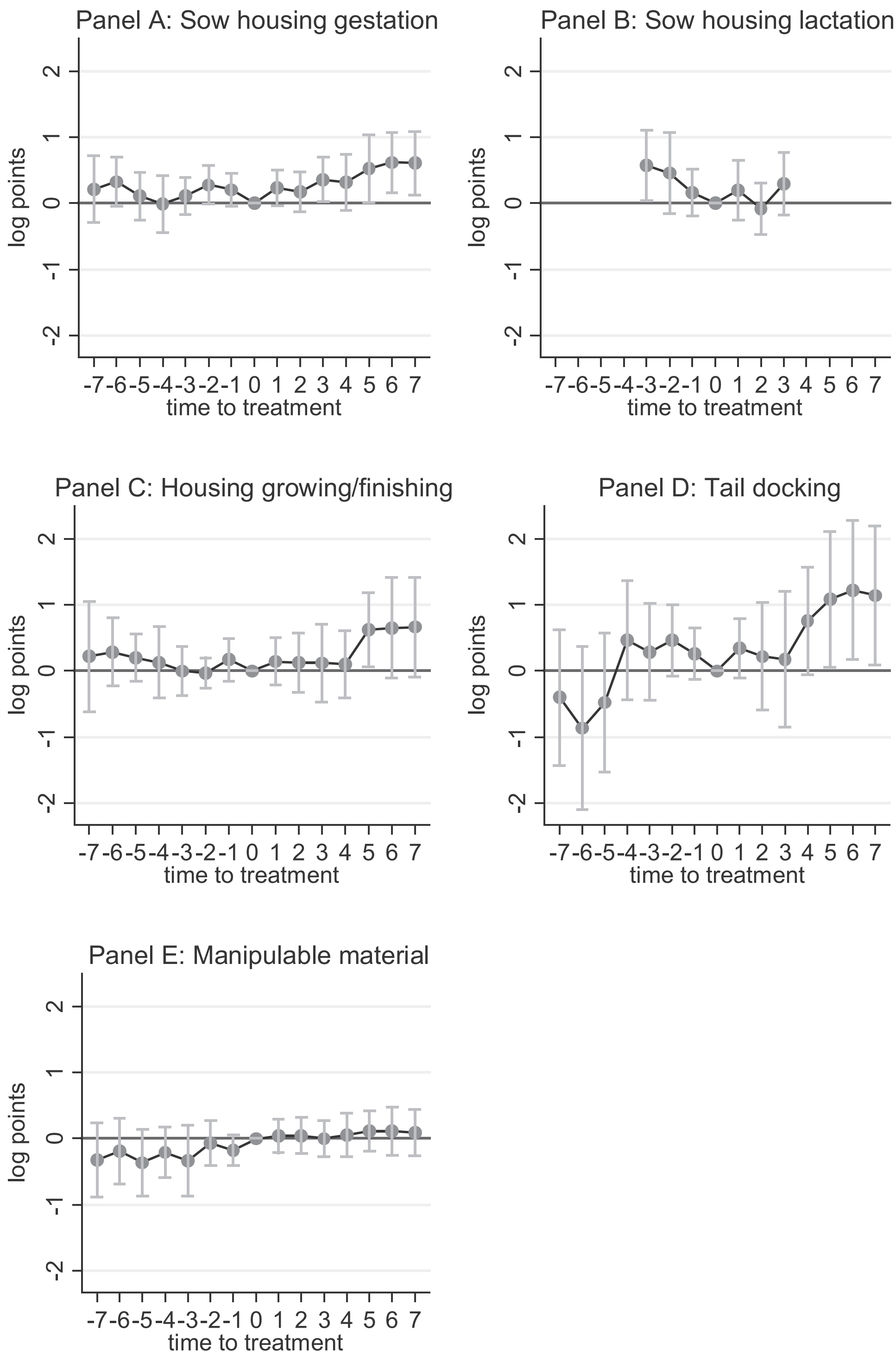

Fig. 4. Event study results by AW key issue, destination country imports.

6.9. Robustness to changes in countries and years included in the analysis

We check how if our results are sensitive to small changes in the countries and years that are included in the analysis, shifting from the 13 EU countries to the 15 EU countries that have been EU members between 1995 and 2019. The results of this exercise are reported in Table A9. We first report our baseline results in column (1), then we drop Poland and restrict the analysis to the years 1995–2019 in column (2). This restriction is the subset of our data for which EU membership is constant throughout the period. Finally, in column (3) we add Portugal and Greece the analysis, to only two older EU members that were not included in the original analysis. We find that Portugal and Greece have not had any major additions in their pig AW national legislation.[9] Our main results are robust to these changes in the composition of the sample.

[9] We checked with several sources in order to determine whether Portugal or Greece have had major additions in their national AW legislation over and above the EU minimum for the same six key issues as the 13 countries that are included in Wallenbeck et al. (2024).

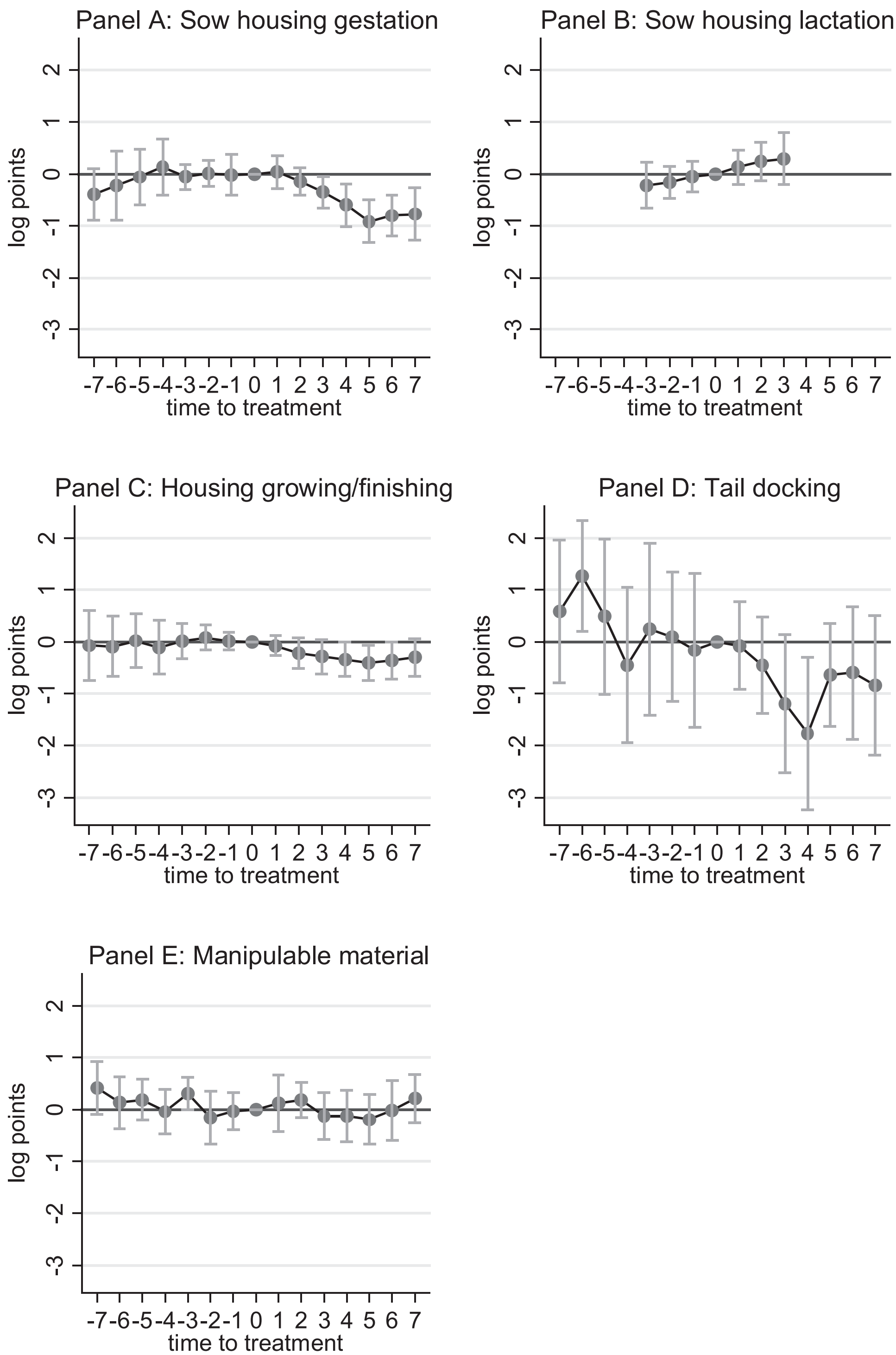

Fig. 3. Event study results by AW key issue, origin country exports.

6.10. Impacts on traded quantities and trade unit values

Our results have thus far focused on bilateral trade values. As a final check, we estimate how traded quantities and trade unit values (the value of trade divided by the quantity of trade, in USD/tonne) responded to changes in AW regulations, based on the main results in Table 3. Traded quantities ought to respond in a similar direction to traded values. Trade unit values may respond positively to more stringent national AW regulations. The results, reported in Table A10 in the appendix, suggest that traded quantities respond as expected, with a point estimate of 0.24 with respect to origin country AW. We cannot detect an impact on trade unit values, although the point estimates for both origin country and destination country AW are positive.

7. Discussion and policy implications

Overall, our first robust finding is that AW regulation stringency has a strong and negative impact on a country's exports. This result is consistent across the panel regressions, the long-differenced IV, and the event study. When studying AW key issues individually, the overall results suggest that more stringent rules for sow housing during gestation has the clearest impact on exports. The positive result for lactation in

Table 5 is not corroborated in the long-differenced IV analysis in Table 6 or in the event study by key issue in Fig. 4 due to a violation of the parallel trend assumption, and thus must be interpreted with caution.

The negative relationship between origin country AW regulation and exports could be driven by several mechanisms. One possible mechanism is that more stringent AW regulations lead to lower exports if the competitiveness channel dominates. Another possible mechanism is that more stringent pig AW regulations are more feasible in countries with a less export-oriented domestic pork industry. For example, countries such as Finland and Sweden, which have relatively stringent AW regulations for pork production, have historically exported relatively little pork. However, the IV analysis helps to rule out the possibility of such reverse causation driving our results.

The other main finding across the analyses is that we do not detect a robust impact of AW regulations on imports, using either the aggregate AW index or separately by key issue. The event study results suggest a positive effect of AW regulation on imports, but these are not supported in the corresponding panel regression and long-differenced IV results. One interpretation of these results is that AW regulations reduce competitiveness in export markets, but do not necessarily reduce competitiveness in the domestic market. The lack of a robust effect on imports could also suggest that national AW policies do not diverge greatly from domestic consumers' preferences for AW.

Our negative findings with respect to pork exports support the position of Harvey et al. (2013) and Grethe et al. (2017), suggesting that the competitiveness of pork production could be sensitive to AW regulations. However, the lack of an effect on imports implies that higher AW stringency is not always leading to a problem of leakage from "low AW havens", the concern emphasized by Grethe (2007). This lack of import response to higher cost pork due to AW regulations could be driven by a combination of consumer preferences for AW or a general home bias in pork, whereby domestic consumers prefer to consume domestic pork produced with higher AW standards, despite the higher cost.

The policy implications of our findings hinge on whether or not our findings can be interpreted as a causal effect of AW regulations. We argue that our IV approach helps to rule out reverse causality, favouring a causal effect of AW regulations on competitiveness. However, since the IV approach uses a long-differenced trade (1991–2020) as the dependent variable, one can argue that the causal interpretation of these results should be restricted to a long-run relationship. Thus, the IV results - cannot lend a causal claim to the exact timing of countries' changes in their AW legislation, and are not directly comparable with the event study results.

If stricter AW regulations with respect to sow housing during gestation indeed reduce exports among the EU countries studied, then policies that subsidize the fixed and variable costs of group sow housing may reduce the adverse impact on exports. Quantifying the economic benefits of such a policy would require an extensive economic welfare analysis, which is beyond the scope of this study.

As we do not detect a robust adverse impact of AW regulations on imports, our findings also suggest that import restrictions may not always be an appropriate policy measure in order to protect pork producers in countries with more stringent AW regulations among these EU countries. Our nuanced results with respect to imports could have potentially important implications and deserves further attention, especially given the many calls to require equivalent AW standards for imported meat.

An important caveat of our results is that they are based differences in stringency relative to EU minima for the 13 countries included in the analysis, and not the impact of EU pig AW directives in general. EU directives could affect trade patterns, particularly with respect to countries outside the EU, given that most other countries in the world have less stringent AW standards than the EU minimum levels. Imports from the rest of the world made up less than one percent of total imports by the 13 countries included in our study in 2020 (see Fig. A1), suggesting that EU directives have a small potential impact on pork imports. However, exports to the rest of the world comprise 42 percent the study area's total pork exports, so there is more scope for EU pig AW directives to affect extra-EU pork exports. We leave the study of the impact of EU minimum standards on pork trade for future research.

8. Conclusions

While the welfare of farm animals remains an important issue for humans in their roles both as citizens and consumers, it is an important empirical question whether more stringent AW regulation has reduced the competitiveness of pork producers. We study this question using trade as an indicator of competitiveness, using detailed data on bilateral trade flows of meat for several European countries during the period 1991–2020, a period where EU directives and national initiatives substantially affected the way pigs are raised. We take advantage of the fact that some countries' AW regulations for pigs went further than EU directives, while some countries only achieved the EU minimum standards. We perform this analysis using a novel dataset of pig AW-regulation stringency that considers several dimensions of AW that have important cost implications for pork producers.

In the panel, long-differenced IV, and event study regression analyses, we find that the relative stringency of pig AW regulations has a large and negative impact on exports. We find that more stringent AW for pigs is associated with significantly lower pork exports. In contrast, we do not detect an effect on pork imports. These results suggest that stricter AW regulations for pigs in the six key issues that we study are associated with a decrease in countries' competitiveness in export markets, but not in the domestic market. The results thus suggest an asymmetric home bias effect, a phenomenon that has received little attention in the gravity model literature, and may offer a fruitful direction for future research.

Pig AW is a complex issue that is composed of important aspects that are specific to key AW issues. Our use of a categorical variable to capture AW stringency permits the study of impacts by AW key issue, but also has its limitations. The collection and use of data on implementation costs specific to each key issue would be a useful endeavour that we leave for future research.

Our results suggest a strong association between pig AW regulation stringency and exports, and the IV approach helps ruling out reverse causality. Based on this, we conclude on a causal link between AW regulation stringency and exports in the long run. However, more research should be devoted to this area to more fully capture the causal effects between AW regulations and competitiveness in agriculture. With this study, we have introduced an approach to how this complicated question can be tackled. This is highly relevant to understand how multiple goals about agricultural competitiveness and high animal welfare standards can be simultaneously achieved.

CRediT authorship contribution statement

Shon Ferguson: Writing – review & editing, Writing – original draft, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Anna Wallenbeck:** Writing – review & editing, Investigation, Funding acquisition, Data curation, Conceptualization. **Sigrid Agenäs:** Writing – review & editing, Funding acquisition, Data curation, Conceptualization. **Helena Hansson:** Writing – review & editing, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

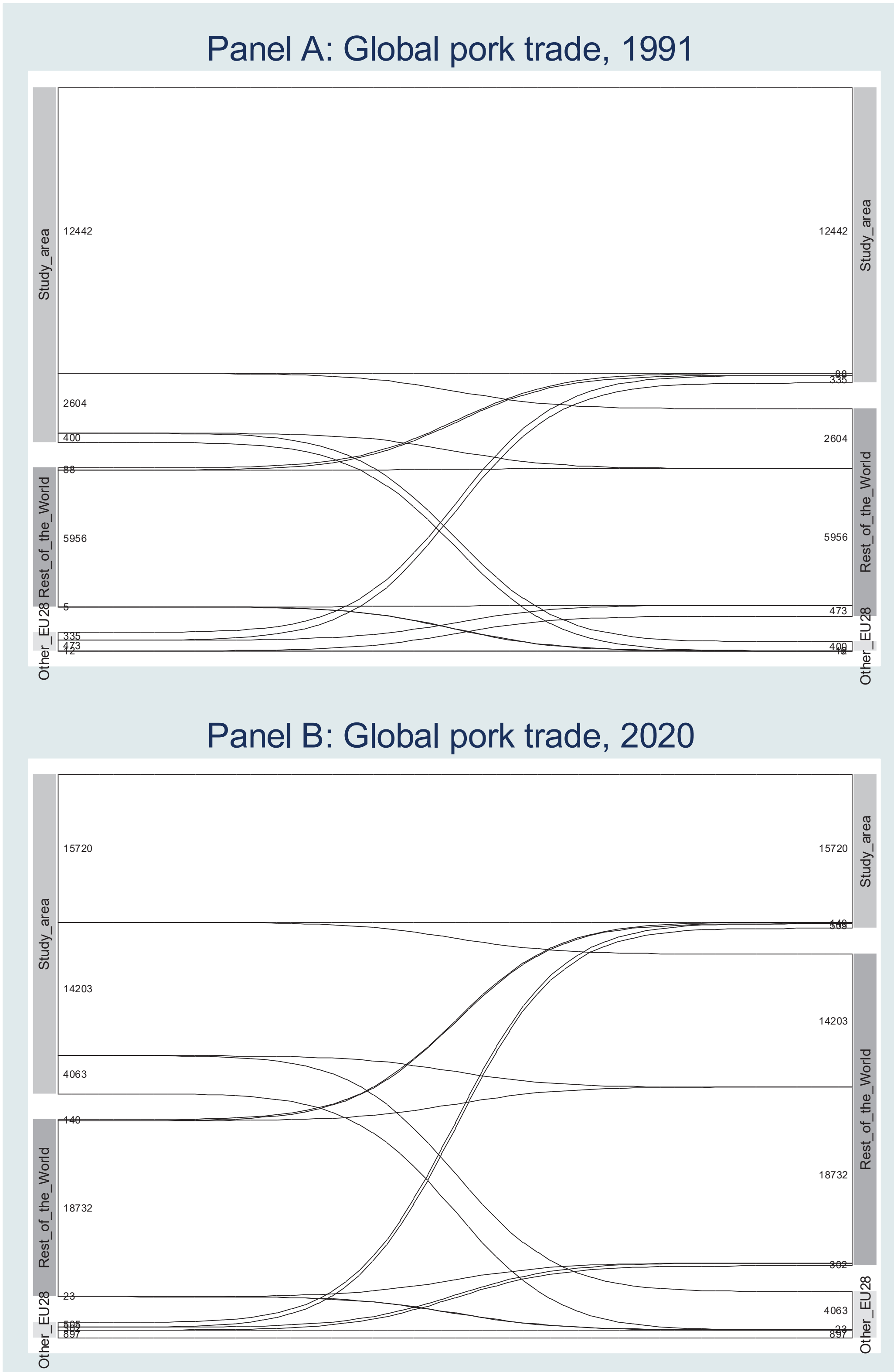

Fig. A1. Sankey diagram of global pork trade in 1991 and 2020 for countries included in the analysis, other EU-28 countries, and the rest of the world, constant 2015 USD millions. Source: FAOstat.

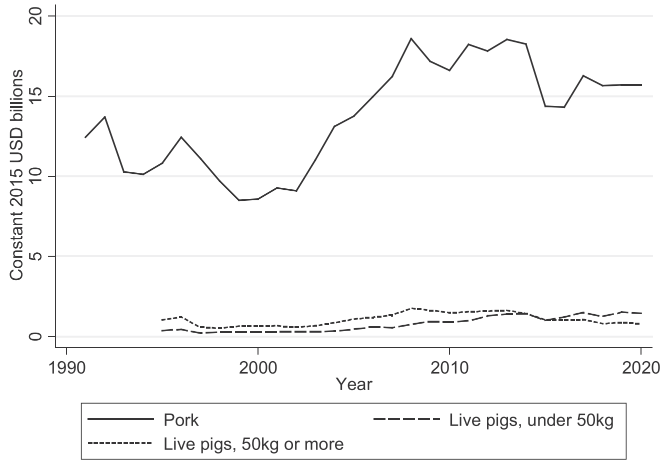

Fig. A2. Total annual trade in pork between the countries included in the analysis, 1991–2020, and total trade in live pigs by weight category (HS010391, "Swine; live, other than pure-bred breeding animals, weighting less than 50 kg", and HS010392, "Swine; live, other than pure-bred breeding animals, weighting 50 kg or more"), 1995–2020. Source: FAOstat and CEPII BACI database.

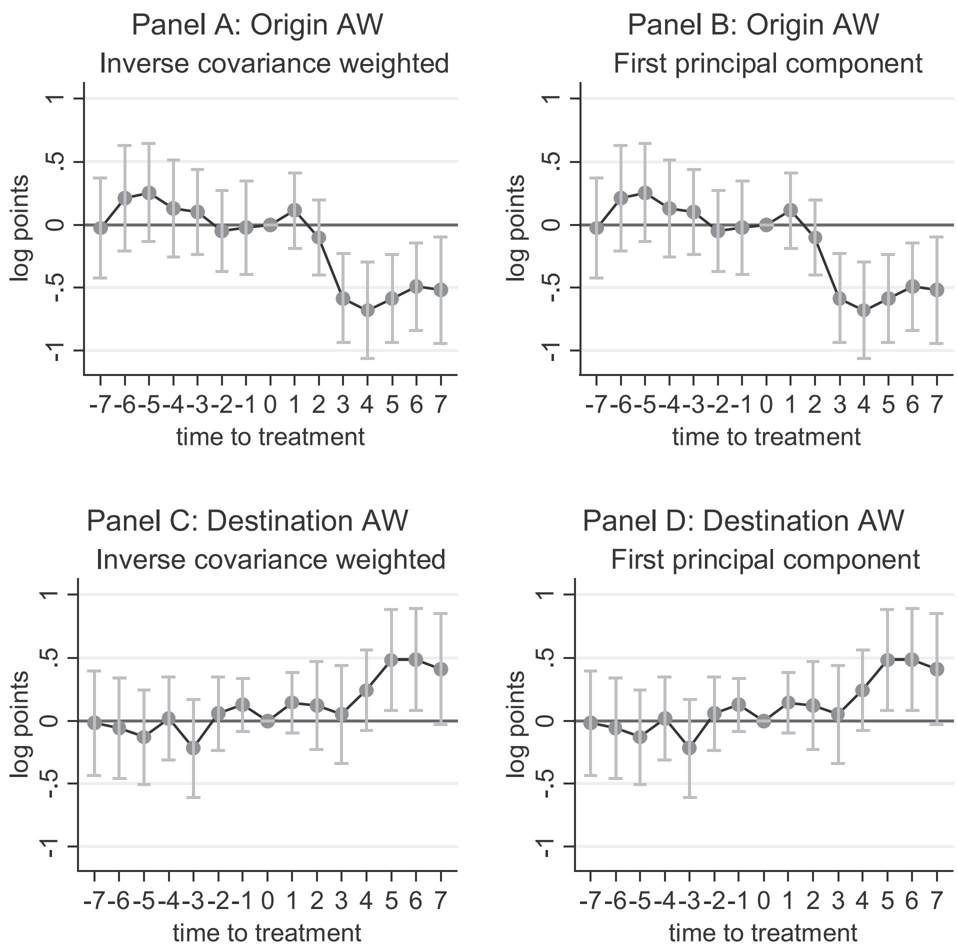

Fig. A3. Robustness: Event study results, impact of AW stringency in origin country exports and destination country imports, using alternative AW composite index. *Notes*: The inverse covariance weighted AW index for the origin country and destination country is the treatment variable in Panels A and C respectively. The first component of a principal component analysis of $AWsum_{ot}$ and $AWsum_{dt}$ are the treatment variable in Panels B and D respectively.

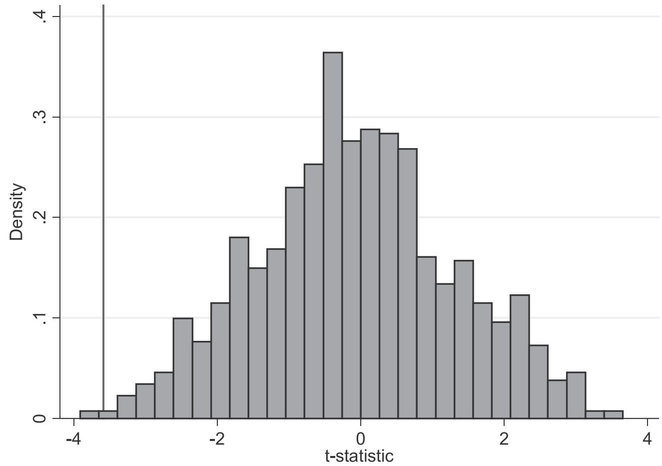

Fig. A4. Robustness to clustering standard errors at the origin-product level *Notes*: Histogram of bootstrapped t-statistics and estimated t-statistic (vertical line) for $AWsum_{ob}$, clustering at the origin-product level, based on a wild bootstrap test of joint null (Roodman et al., 2019). Based on the estimation in column (3) of Table 3.

Table A1
Instrumental variable values by country.

Country	Share of respondents saying that they belong to an animal rights organization, 1990 European Values Study ($share\_org_{o/d,1990}$)
Netherlands	0.125
Belgium	0.074
Sweden	0.069
Austria	0.044
Denmark	0.041
Germany	0.036
France	0.023
United Kingdom	0.019
Italy	0.017
Finland	0.015
Poland	0.012
Ireland	0.010

Notes: Question 131 states: “Please look carefully at the following list of voluntary organisations and activities and say which, if any, do you belong to? One of the options is “Animal rights” (Q144A). Source: EVS (2011).

Table A2
List of FAO products included in analysis.

FAO product code	Description
Pork:	
1035	Meat of pig with the bone, fresh or chilled
1036	Edible offal of pigs, fresh, chilled or frozen
1037	Fat of pigs
1038	Meat of pig boneless, fresh or chilled
1039	Pig meat, cuts, salted, dried or smoked (bacon and ham)
1041	Sausages and similar products of meat, offal or blood of pig
1042	Pig meat preparations
1043	Pig fat, rendered
Beef:	
867	Meat of cattle with the bone, fresh or chilled
868	Edible offal of cattle, fresh, chilled or frozen
869	Cattle fat, unrendered
870	Meat of cattle boneless, fresh or chilled
875	Beef and veal preparations not elsewhere specified
Chicken:	
1058	Meat of chickens, fresh or chilled
1059	Edible offals and liver of chickens and guinea fowl, fresh, chilled or frozen
1061	Poultry meat preparations

Note: Trade in beef and chicken products are included in robustness tests reported in Table A.6 and A.8 in the appendix. Source: FAOstat.

Table A3
Pairwise correlation coefficients, aggregate AW measure and other control variables.

	AWsum	EUmember	GDP	GDP	BSE	FMD	ASF	CSF
$EUmember_{ot/dt}$	−0.02							
$ln\_GDP_{ot/dt}$	−0.07	0.26						
$ln\_GDPpc_{ot/dt}$	0.13	0.51	0.06					
$BSE_{ot/dt}$	−0.02	0.03	0.13	0.03				
$FMD_{ot/dt}$	0.00	0.02	0.05	0.04	0.09			
$ASF_{ot/dt}$	−0.02	0.03	−0.01	−0.11	−0.01	−0.01		
$CSF_{ot/dt}$	−0.02	0.02	0.02	−0.01	−0.01	−0.01	−0.01	
$EnvPol_{ot/dt}$	0.10	0.31	0.22	0.42	−0.08	−0.07	0.07	−0.07

Note: The panel is strongly balanced, implying that the correlation coefficients for the origin-year and destination-year variables are identical, hence the "ot/dt" notation.

Table A4
Average annual pork imports and exports within the study area, per country, 1991–2020.

	Constant 2015 USD, millions	
	imports	exports
Austria	371	300
Belgium	620	1630
Denmark	394	2464
Finland	91	29
France	1692	1006
Germany	3007	2764
Ireland	248	417
Italy	2363	861
Netherlands	704	2259
Poland	796	298
Spain	327	1304
Sweden	391	76
United Kingdom	2741	339

Table A5
First stage of long-differenced IV results, 1991–2020.

	(1)	(2)
Dependent variable:	$\Delta AWsum_{o,2020\text{-}1991}$	$\Delta AWsum_{d,2020\text{-}1991}$
$share\_org_{o,1990}$	11.2***	0.71
	(1.05)	(1.85)
$share\_org_{d,1990}$	0.37	11.4***
	(1.88)	(0.96)
$\Delta EUmember_{ot}$	−0.28*	0.013
	(0.16)	(0.090)
$\Delta EUmember_{dt}$	0.020	−0.43***
	(0.11)	(0.16)
Δln_GDP_{ot}	6.32***	0.18
	(0.94)	(1.23)
Δln_GDPpc_{ot}	0.14	6.96***
	(1.21)	(0.86)
Δln_GDP_{dt}	−5.25***	−0.18
	(0.79)	(1.05)
Δln_GDPpc_{dt}	−0.20	−5.77***
	(1.03)	(0.73)
ΔASF_{ot}	−1.12***	0.030
	(0.10)	(0.18)
ΔASF_{dt}	0.046	−1.13***
	(0.18)	(0.10)
$\Delta EnvPol_{ot}$	−0.66***	−0.011
	(0.10)	(0.10)
$\Delta EnvPol_{dt}$	−0.0047	−0.60***
	(0.11)	(0.088)
Constant	2.12***	1.97***
	(0.45)	(0.41)
Observations	142	142
R-squared	0.44	0.45

Notes: This table reports the first-stage estimates of the TSLS regressions reported in Table 3. The dependent variable is reported at the top of each column. Heteroscedasticity-robust standard errors reported in all specifications. ***p < 0.01, **p < 0.05, *p < 0.1.

Table A6
Robustness to alternative index method for composite AW measures.

	(1)	(2)
	Inverse covariance weighted index	First component, principal component decomposition
Alternative $AWindex_{ot}$	−0.17**	−0.11***
	(0.074)	(0.028)
Alternative $AWindex_{dt}$	0.055*	0.039
	(0.031)	(0.026)
$EUmember_{ot}$	1.78***	1.77***
	(0.32)	(0.32)
$EUmember_{dt}$	0.77***	0.77***
	(0.22)	(0.22)
ln_GDP_{ot}	−2.63	−2.43
	(2.07)	(2.01)
ln_GDPpc_{ot}	3.03	2.77
	(2.27)	(2.21)
ln_GDP_{dt}	1.14	1.04
	(1.53)	(1.44)
ln_GDPpc_{dt}	0.94	1.04
	(1.64)	(1.56)
FMD_{okt}	−0.021	−0.050
	(0.095)	(0.089)
FMD_{dkt}	0.12**	0.12**
	(0.053)	(0.052)
ASF_{okt}	0.11	0.062
	(0.13)	(0.13)
ASF_{dkt}	−0.00032	0.0048
	(0.13)	(0.13)
CSF_{okt}	0.25***	0.24***
	(0.073)	(0.070)
CSF_{dkt}	0.030	0.027
	(0.079)	(0.080)
$EnvPol_{ot}$	−0.53***	−0.53***
	(0.11)	(0.11)
$EnvPol_{dt}$	0.089	0.096
	(0.097)	(0.094)
Fixed effects	Panel and year	
Constant	−28.2**	−27.2**
	(14.2)	(13.9)
Observations	9,360	9,360
Pseudo R-squared	0.91	0.92

Notes: The dependent variable is the value of trade in constant 2015 USD millions. Estimates clustered at the panel-level in all specifications. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table A7
Robustness to alternative fixed effects using chicken or beef as control product.

	(1)	(2)	(3)	(4)
	pork vs beef	pork vs chicken	pork vs beef	pork vs chicken
$AWsum_{okt}$	−0.23***	−0.23***		
	(0.059)	(0.040)		
BSE_{okt}	−1.55***			
	(0.20)			
ASF_{okt}	−0.078	−0.16**		
	(0.11)	(0.081)		
CSF_{okt}	0.25***	0.13*		
	(0.067)	(0.071)		
FMD_{okt}		0.064		
		(0.087)		
$AWsum_{dkt}$			−0.017	0.12**
			(0.058)	(0.051)
BSE_{dkt}			0.20*	
			(0.12)	
ASF_{dkt}			−0.29***	0.20**
			(0.11)	(0.10)
CSF_{dkt}			0.26***	−0.075
			(0.065)	(0.064)
FMD_{dkt}				0.0045
				(0.048)
Fixed effects:	Panel, origin–destination-year, destination-product-year		Panel, origin–destination-year, origin-product-year	
Constant	5.53***	5.52***	5.52***	5.46***
	(0.0051)	(0.0046)	(0.013)	(0.015)
Observations	9,166	9,156	9,166	9,138
Pseudo R-squared	0.96	0.97	0.97	0.97

Notes: This table estimates a Poisson model based on equation (4). The dependent variable is the value of trade in constant 2015 USD millions. We include an indicator variable for the EU ban on UK beef exports due to BSE, which equals 1 for bilateral trade flows of beef to or from the UK between 1996 and 2007, and 0 otherwise (European Commission, 2006). Estimates clustered at the panel-level in all specifications. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table A8
Effects on trade with trade partners outside the study area.

	Exports from study area		Imports to study area	
	(1)	(2)	(3)	(4)
	pork vs beef	pork vs chicken	pork vs beef	pork vs chicken
$AWsum_{okt}$	−0.12	0.074		
	(0.097)	(0.070)		
BSE_{okt}	−1.47***			
	(0.45)			
ASF_{okt}	−0.63***	−0.79***		
	(0.21)	(0.16)		
CSF_{okt}	−0.22*	−0.20*		
	(0.12)	(0.12)		
FMD_{okt}		−0.32**		
		(0.14)		
$AWsum_{dkt}$			−0.048	0.011
			(0.051)	(0.077)
BSE_{dkt}			0.044	
			(0.13)	
ASF_{dkt}			−0.17	−0.024
			(0.13)	(0.12)
CSF_{dkt}			0.35***	0.088
			(0.082)	(0.094)
FMD_{dkt}				0.027
				(0.093)
Fixed effects:	Panel, origin–destination-year, destination-product-year		Panel, origin–destination-year, origin-product-year	
Constant	4.37***	4.30***	5.12***	5.04***
	(0.015)	(0.012)	(0.0081)	(0.014)
Observations	99,099	98,197	113,882	110,924
Pseudo R-squared	0.93	0.93	0.96	0.96

Notes: This table estimates a Poisson model based on equation (4). The estimates in columns 1 and 2 are restricted to bilateral trade flows from the study area countries to all other countries in the world. The estimates in columns 3 and 4 are restricted to bilateral trade flows from all other countries in the world to the study area countries. The dependent variable is the value of trade in constant 2015 USD millions. We include an indicator variable for the EU ban on UK beef exports due to BSE, which equals 1 for bilateral trade flows of beef to or from the UK between 1996 and 2007, and 0 otherwise (European Commission, 2006). Estimates clustered at the panel-level in all specifications. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table A9
Robustness to changes in countries and years included in the analysis.

	(1)	(2)	(3)
	Baseline (13 countries)	Drop Poland, drop UK 2020, keep 1995–2020	Column (2) + add Portugal & Greece (EU15, 1995–2020)
$AWsum_{ot}$	−0.25***	−0.21***	−0.19***
	(0.064)	(0.058)	(0.060)
$AWsum_{dt}$	0.091	0.090*	0.089*
	(0.062)	(0.049)	(0.049)
$EUmember_{ot}$	1.77***		
	(0.32)		
$EUmember_{dt}$	0.78***		
	(0.22)		
ln_GDP_{ot}	−2.44	−1.19	−1.09
	(2.01)	(1.84)	(1.65)
ln_GDPpc_{ot}	2.78	0.72	0.60
	(2.21)	(2.01)	(1.76)
ln_GDP_{dt}	1.02	1.80	1.54
	(1.43)	(1.43)	(1.34)
ln_GDPpc_{dt}	1.06	−0.56	−0.63
	(1.55)	(1.75)	(1.64)
FMD_{ot}	−0.049	0.062	0.050
	(0.089)	(0.089)	(0.083)
FMD_{dt}	0.11**	0.11**	0.087*
	(0.052)	(0.048)	(0.049)
ASF_{ot}	0.063	−0.34***	−0.36***
	(0.13)	(0.089)	(0.087)
ASF_{dt}	0.0056	0.20	0.19
	(0.13)	(0.18)	(0.17)
CSF_{ot}	0.24***	−0.061	−0.077
	(0.070)	(0.075)	(0.073)
CSF_{dt}	0.026	0.0028	0.0073
	(0.080)	(0.047)	(0.048)
$EnvPol_{ot}$	−0.53***	−0.49***	−0.49***
	(0.11)	(0.077)	(0.067)
$EnvPol_{dt}$	0.095	−0.0018	−0.025
	(0.093)	(0.069)	(0.060)
Fixed effects	Panel and year	Panel and year	Panel and year
Constant	−27.2**	0.13	3.61
	(13.8)	(15.5)	(13.9)
Observations	4,680	3,300	4,550
Pseudo R-squared	0.92	0.94	0.94

Notes: The dependent variable is the value of trade in constant 2015 USD millions. Estimates clustered at the panel-level in all specifications. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table A10
Panel regression results for traded quantities and trade unit values.

	(2)	(3)
Dep. variable:	$trade\_quantity_{odt}$	$trade\_unit\_value_{odt}$
$AWsum_{ot}$	−0.24***	0.015
	(0.059)	(0.032)
$AWsum_{dt}$	0.036	0.021
	(0.047)	(0.035)
$EUmember_{ot}$	1.42***	−0.26*
	(0.29)	(0.14)
$EUmember_{dt}$	0.81***	0.023
	(0.22)	(0.096)
ln_GDP_{ot}	−3.32*	0.67
	(1.89)	(0.46)
ln_GDPpc_{ot}	3.93*	−0.60
	(2.17)	(0.55)
ln_GDP_{dt}	0.76	−0.16
	(1.45)	(0.66)
ln_GDPpc_{dt}	0.87	0.57
	(1.59)	(0.76)
FMD_{ot}	−0.035	−0.034
	(0.095)	(0.093)
FMD_{dt}	0.090	0.096**
	(0.058)	(0.047)
ASF_{ot}	0.16	−0.17***
	(0.12)	(0.059)
ASF_{dt}	0.092	−0.029
	(0.13)	(0.060)
CSF_{ot}	0.17***	0.16***
	(0.064)	(0.039)
CSF_{dt}	0.0022	0.15*
	(0.072)	(0.084)
$EnvPol_{ot}$	−0.39***	0.049
	(0.11)	(0.045)
$EnvPol_{dt}$	−0.00021	0.063
	(0.088)	(0.049)
Fixed effects	Panel and year	Panel and year
Constant	–23.3	−1.81
	(14.3)	(4.68)
Observations	4,680	4,504
Pseudo R-squared	0.94	0.19

Notes: The dependent variable in column (1) is the quantity of trade, in tonnes. The dependent variable in column (2) is trade unit value (the value of trade divided by the quantity of trade), in USD per kg. Estimates clustered at the panel-level in all specifications. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

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