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Cross-Border Transport of Companion Animals into the European Union: Five-Year Patterns, Border-Crossing Flows and Regulatory Compliance

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Abstract

International transport of companion animals presents important challenges for veterinary border control, biosecurity and disease prevention within the European Union (EU). This study analysed consignment-level data extracted from the Commission's Trade Control and Expert System New Technology (TRACES NT)system to characterize companion-animal imports from third countries into the EU between 2021 and 2025. Descriptive statistics, chi-square tests and binary logistic regression were used to examine temporal and geographical patterns, species distribution and border-control outcomes. A total of 3250 consignments were recorded, of which 1726 (53.1%) were accepted and 1524 (46.9%) were rejected. Dogs and cats accounted for the majority of consignments, while non-EU European countries represented the principal recorded geographical category. Import activity was concentrated at a limited number of Border Control Posts, particularly in the Netherlands, Lithuania and Bulgaria. Administrative and documentary deficiencies accounted for 73.2% of all rejected consignments, whereas animal health and welfare concerns represented only 9.9%. Although unadjusted analyses identified significant associations between geographical origin and border-control outcomes, geographical origin was not independently associated with rejection odds after adjustment for species, year of entry and EU entry country. These findings highlight the importance of documentary verification, digital certification, coordinated information exchange and flexible border-control capacity in managing cross-border companion-animal transport.

Keywords: import; transport; companion animals; border control; veterinary legislation; biosecurity

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1. Introduction

The international movement of companion animals has increased substantially during the last two decades [1] as a consequence of globalization [2], expanding pet ownership [3,4], and the growing demand for international trade and relocation of pets. While this increased mobility provides important social and economic benefits [5,6], it also presents significant veterinary challenges associated with the transboundary spread of infectious diseases, illegal animal trade, animal welfare, and biosecurity [7]. Consequently, the importation of companion animals has become an increasingly important component of veterinary public health and border inspection systems worldwide.

The European Union represents one of the world's largest regulated markets for the importation of companion animals from third countries. Within the EU, cross-border movements of companion animals are embedded in a harmonised regulatory and border-control framework that determines the conditions under which animals can enter the Union and the procedures applied at designated border-crossing points. Regulation (EU) 2016/429 establishes the overarching Union framework for animal-health protection and the prevention and control of transmissible animal diseases, while Regulation (EU) 2017/625 provides the legal framework for official controls carried out at designated Border Control Posts (BCPs) [8,9]. Specific requirements applicable to the entry of companion animals from third countries are further established through the relevant implementing and delegated acts adopted under this framework [10–13]. These provisions make border-control infrastructure and procedures an integral part of the cross-border transport process: consignments arriving at an EU entry point must satisfy the applicable regulatory conditions before continuing through the Union's transport network. Consequently, differences in origin, species composition, entry-point selection and border-control outcomes are not only veterinary control variables but also characteristics of cross-border transport flows that can inform the planning and organisation of border-crossing operations. Together with the rules governing intra-EU movement and disease surveillance, these provisions introduce the current regulatory framework for controlling the movement and entry of companion animals, supporting the prevention of disease introduction, the control of illegal animal trade, the protection of animal welfare and public health, and effective traceability of animals entering the EU [14,15].

Despite the existence of a harmonised regulatory framework, ensuring consistent compliance within the official border control system remains challenging [16]. Previous investigations have demonstrated that a substantial proportion of non-compliant consignments are rejected because of documentary and administrative deficiencies rather than confirmed animal health risks [17,18]. Incorrect veterinary certificates, incomplete documentation, inconsistencies in animal identification and failures to comply with certification requirements remain among the most frequently reported causes of rejection [19]. These deficiencies increase the administrative burden on veterinary authorities while creating opportunities for illegal animal movements and document fraud.

The increasing complexity of international trade networks further complicates veterinary border inspections by involving multiple stakeholders, including exporters, transport operators, official veterinarians and importers [20]. These complex patterns can lead to gaps in compliance and inconsistencies in the application of veterinary requirements [21,22]. Maintaining effective veterinary oversight throughout this process therefore requires efficient traceability systems, standardized certification procedures and coordinated regulatory enforcement.

Existing research on the international movement of companion animals has predominantly examined animal-health risks, disease introduction, welfare and regulatory compliance, whereas the transport dimension of these movements has received comparatively limited empirical attention. In particular, there is limited EU-level evidence on how companion-animal movements are distributed across geographical origins and border-crossing points, how these flows vary over time, and how regulatory outcomes are associated with the characteristics of the movements. This represents a relevant knowledge gap because border-control requirements operate at specific transport nodes and can influence the continuity and predictability of cross-border movements. Addressing this gap requires the integration of transport-flow characteristics with regulatory outcomes rather than examining compliance solely as a veterinary control issue.

This study addresses this gap by providing a five-year empirical analysis of cross-border companion-animal movements from third countries into the EU using consignment-level TRACES NT data for 2021–2025. The analysis characterises temporal and geographical patterns, species composition, entry-point concentration and border-control outcomes, and examines associations between movement characteristics and regulatory compliance. The contribution is twofold. First, the study provides empirical evidence on the spatial and temporal organisation of a relatively underexamined category of cross-border transport flows. Second, it demonstrates how regulatory compliance data collected at border-crossing points can be used to inform the planning of border-control capacity, information exchange and transport governance. By connecting animal-movement regulation with the organisation and management of cross-border flows, the study extends the discussion of companion-animal transport beyond veterinary risk assessment towards a broader policy perspective.

2. Materials and Methods

2.1. Study Design

This retrospective observational study analysed routinely collected administrative records of companion-animal consignments entering the European Union (EU) from third countries between 1 January 2021 and 31 December 2025. The study was designed to characterise temporal and geographical patterns of cross-border movements of companion animals. The study was based exclusively on administrative data extracted from the European TRACES NT. No experimental procedures involving animals or human participants were conducted.

2.2. Data Source

Data were obtained from the Trade Control and Expert System New Technology (TRACES NT), the European Commission's electronic platform supporting official certification, traceability and border-control procedures for animals and animal products entering the European Union. The system records information associated with consignments subject to official controls and therefore provides a structured source for examining cross-border movements at EU entry points.

The dataset comprised recorded consignments of companion animals entering EU Member States from third countries during the study period. For each consignment, the available variables included animal species, country and region of origin, receiving entity, country of destination, EU entry country, Border Control Post (BCP), date of border-control decision and inspection outcome. Recorded reasons for rejection were also extracted where available. The data were accessed through authorised access to TRACES NT by the first author.

The analysis was restricted to consignments transported by air or land. Companion animals travelling with their owners as part of passenger movements were not included because such movements are subject to different recording and control arrangements and were not represented in the analysed cargo-consignment dataset. Accordingly, the unit of analysis was the individual recorded consignment rather than the individual animal.

The individual consignment was retained as the unit of analysis. Each record contained a single species classification, as registered in TRACES NT (Dog, Cat or Carnivores), and species-related analyses were based on this consignment-level classification. No mixed-species consignments were identified in the study dataset. Therefore, the animal numbers reported in the text, tables and figures reflect the actual recorded numbers, without estimates or adjustments for mixed-species consignments.

An additional category, designated as "EU-Greece" in records, was retained in the analysis as registered. This category refers to consignments associated with owners recorded in Greece, while Croatia was indicated as the EU country of entry. Although the consignments entered the EU from third countries, the actual third country of dispatch was not specified in the available records. Therefore, the designation reflects the country associated with the registered owner rather than the verified geographical origin of the animals. These records were retained in the dataset and in the corresponding origin distribution to preserve the original classification provided by the source database.

2.3. Data Processing

Prior to analysis, the dataset was screened for completeness, consistency and duplicate records. Duplicate entries were removed where applicable, variable names were standardised and categorical values were harmonised to ensure consistent classification across the five-year study period. Records were retained when the relevant information required for the corresponding analysis was available.

Countries of origin were aggregated into broader geographical regions to enable comparative analysis and avoid sparse categories. The regions comprised North America, South America, Africa, non-EU Europe, the Middle East and Asia/Oceania. The category "non-EU Europe" included European countries outside the European Union, whereas EU Member States were considered destination countries and were not included in the origin-region classification.

Border-control outcomes were classified according to the official decision recorded in TRACES NT as either "accepted" or "rejected". For rejected consignments, the recorded reasons were reviewed and grouped into broader analytical categories: documentary deficiencies, administrative irregularities, animal health and welfare concerns, and other regulatory non-compliance. Where more than one reason was recorded for a consignment, the classification procedure followed the predefined categorisation applied to the dataset. The final analytical dataset contained 3250 consignments transported by air or land, of which 1726 (53.11%) were accepted and 1524 (46.89%) were rejected.

Classification of Transport Flows

For the purposes of this study, a cross-border movement was defined as the recorded transport of one or more companion animals from a third country through an EU entry point, as represented by an individual TRACES NT consignment record. The country of origin represented the third country from which the consignment entered the EU transport chain, while the EU entry country and BCP represented the border-crossing location recorded in the system. This distinction allowed the analysis to examine both the geographical origins of movements and their concentration across EU border-control nodes. Because the dataset covered cargo consignments transported by air or land, the analysis describes recorded cargo movements rather than the full volume of companion-animal mobility into the EU, including animals travelling with passengers.

2.4. Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics, version 26 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarise the number and proportion of consignments according to year, animal species, geographical origin, country of destination, EU entry country, Border Control Post (BCP) and border-control outcome. Rejection reasons were summarised as frequencies and percentages of all rejected consignments.

Associations between categorical variables were examined using Pearson's chi-square test. The analyses evaluated the relationships between geographical origin and

border-control outcome, animal species and border-control outcome, and other relevant categorical characteristics of the consignments where applicable. Statistical significance was set at $p < 0.05$.

In addition to the descriptive and bivariate analyses, a binary logistic regression model was used to investigate the association between geographical origin and consignment rejection. The dependent variable was border-control outcome (accepted = 0; rejected = 1), while geographical origin was included as the primary explanatory variable. Species, year of entry and EU entry country were included as covariates to account for differences in consignment characteristics and entry locations. Results were expressed as adjusted odds ratios (aORs) with 95% confidence intervals (CIs). Categories with sparse observations were combined where appropriate to improve model estimability. The 37 consignments originating from Australia were excluded from the conventional maximum-likelihood model because no rejected consignments were recorded for this category, resulting in complete separation. Europe-non-EU was selected as the reference category for geographical region in the logistic regression model. This category was chosen as a geographical and interpretative reference, allowing the odds of consignment rejection in other regions to be compared with those of consignments originating from non-EU European countries. The overall contribution of geographical origin was assessed using a joint Wald test. Statistical significance was set at $p < 0.05$.

Heatmaps were used to provide a descriptive visualisation of the geographical distribution and relative concentration of recorded consignments across EU entry countries and Border Control Posts (BCPs). The visualisations were based on recorded frequencies and proportions and were intended to identify locations with comparatively high consignment activity. They were not used to infer statistically significant spatial clusters or spatial autocorrelation. Accordingly, geographical concentration in this study refers to the descriptive distribution of recorded consignments rather than formally defined spatial hotspots. Sankey diagrams were used to illustrate the main origin-to-entry-point movement pathways. These graphical representations were used to facilitate interpretation of spatial and flow patterns identified in the dataset and were not treated as additional inferential statistical analyses.

2.5. Ethical Considerations

The study used routinely collected administrative data obtained from the TRACES NT system. The analytical dataset did not contain directly identifiable personal information, and no animals were experimentally handled, sampled or subjected to procedures for the purposes of this study. No human participants or biological samples were involved. On this basis, the study did not require formal ethical approval under the applicable institutional requirements for research involving animals or human participants.

3. Results

3.1. Spaciotemporal Trends of Imported Consignments

The annual number of imported consignments varied substantially during the study period from January 2021 to December 2025 (Figure 1). The heatmap illustrates the spatiotemporal distribution of cargo consignments entering the European Union through different Border Control Posts (BCPs), showing marked differences in import intensity between Member States and across years. A relatively small number of Member States accounted for a large proportion of the recorded consignments, indicating a pronounced spatial concentration of entry activity.

The Netherlands represented the largest share of recorded consignments, accounting for 18.9% of the total during the study period. Its highest annual contribution occurred in

2022, when it accounted for 8.2% of all consignments recorded for the five-year period. Lithuania and Bulgaria accounted for 14.3% and 13.6%, respectively, of total consignments. Lithuania showed a pronounced increase in 2024, when its contribution reached 7.8%, whereas Bulgaria displayed a comparatively more stable distribution across the study period.

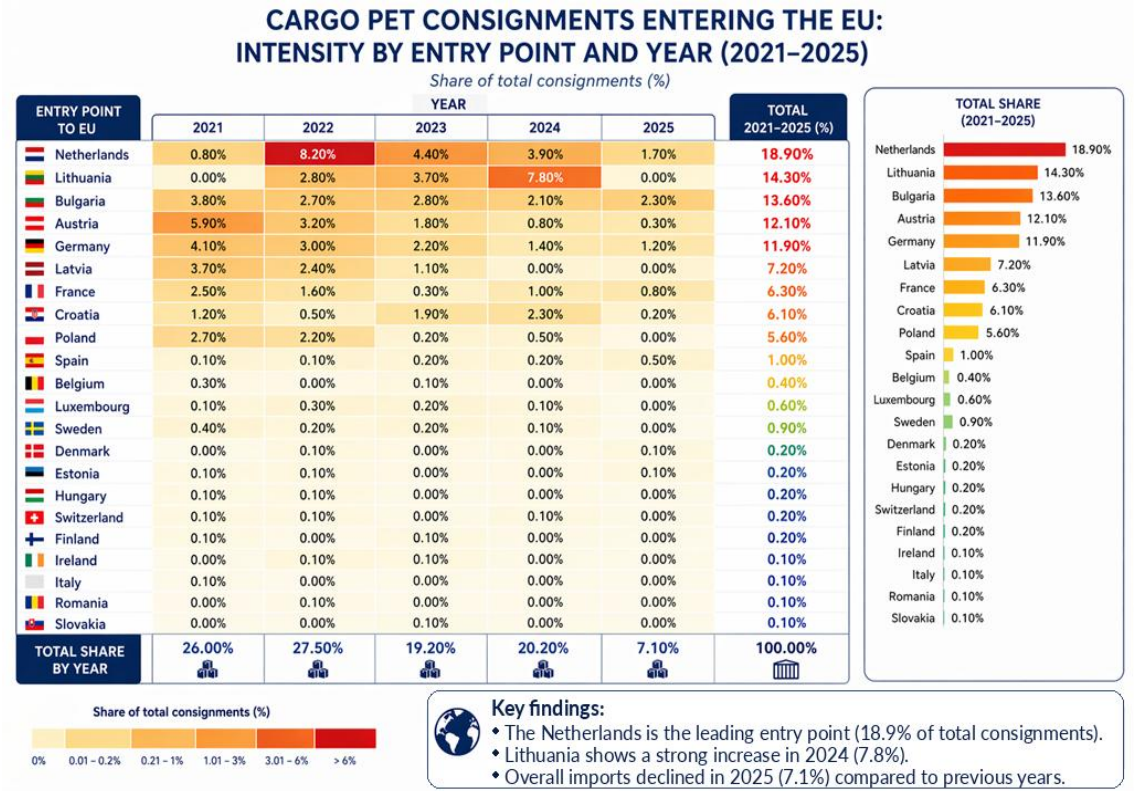


Figure 1. Spatiotemporal Distribution of Cargo Companion Animal Imports Across EU Entry Points (2021–2025). Percentages represent the share of total cargo pet consignments entering the EU through the border control posts (BCP).

Austria (12.1%) and Germany (11.9%) also accounted for substantial shares of the recorded entry activity. Both countries showed lower contributions in the later part of the study period compared with 2021–2022. Intermediate shares were observed for Latvia (7.2%), France (6.3%), Croatia (6.1%) and Poland (5.6%). Latvia contributed a larger share during the earlier years, while Croatia showed an increase during 2023–2024. France and Poland maintained relatively consistent contributions across the study period. The remaining Member States each accounted for less than 1% of the recorded consignments.

At the temporal level, the largest annual volume was recorded in 2022, which represented 27.5% of all consignments in the dataset, followed by a progressive decline towards 2025, when 7.1% of consignments were recorded. The heatmap also indicates that entry points with larger overall volumes exhibited greater variation between years, reflecting differences in the temporal distribution of cross-border companion-animal movements across EU entry points.

3.2. Pet Species Distribution

Dogs (*Canis familiaris*) accounted for the largest proportion of imported companion-animal consignments during the study period, representing 65.9% of the total, followed by cats (*Felis catus*) at 27.7% (Figure 2). Other species, grouped within the carnivore category used in the dataset, accounted for the remaining 6.4% of consignments. The relative

distribution of species remained broadly consistent across the five-year period, although modest annual variations were observed.

Pet species imported to the EU (2021–2025)

Entry to EU	Dog	Cat	Carnivores	Total
Netherlands	13.2%	5.8%	0.0%	18.9%
Lithuania	8.5%	5.8%	0.0%	14.3%
Bulgaria	9.1%	4.3%	0.2%	13.6%
Austria	4.8%	1.7%	5.6%	12.1%
Germany	7.4%	4.4%	0.1%	11.9%
Latvia	6.2%	1.0%	0.0%	7.2%
France	3.7%	2.4%	0.2%	6.3%
Croatia	5.5%	0.6%	0.0%	6.1%
Poland	4.6%	1.0%	0.0%	5.6%
Spain	0.8%	0.2%	0.0%	1.0%
Sweden	0.6%	0.2%	0.1%	0.9%
Luxembourg	0.6%	0.1%	0.0%	0.6%
Belgium	0.2%	0.1%	0.1%	0.4%
Denmark	0.2%	0.1%	0.0%	0.2%
Estonia	0.2%	0.0%	0.1%	0.2%
Finland	0.2%	0.0%	0.0%	0.2%
Hungary	0.1%	0.1%	0.0%	0.2%
Switzerland	0.2%	0.0%	0.0%	0.2%
Ireland	0.1%	0.0%	0.0%	0.1%
Italy	0.1%	0.0%	0.1%	0.1%
Romania	0.1%	0.0%	0.0%	0.1%
Slovakia	0.0%	0.1%	0.0%	0.1%
Total	**65.9%**	**27.7%**	**6.4%**	**100.0%**

% of total imported pets: 0% 7% 14% | 0% 3% 6% | 0% 3% 6% | 0% 10% 20%

Note: Percentages are shown with one decimal place.

Figure 2. Distribution of pet animal species regarding the member states as points of entry to the EU, 2021–2025, in percentage.

The distribution of species also varied across EU Member States serving as points of entry (Figure 2), reflecting differences in the composition of consignments recorded at individual entry locations.

3.3. Geographical Origin of Consignments

Companion-animal consignments originated from multiple geographical regions, although the distribution was strongly concentrated in a limited number of source regions (Figure 3). Non-EU European countries accounted for the largest share of consignments (42.5%), followed by Asia and Oceania (17.1%), North America (16.3%), the Middle East (9.7%), Africa (6.7%) and South America (5.1%). The regional distribution remained broadly stable over the study period, although moderate year-to-year variations were observed.

The distribution of consignments after entry into the EU also showed distinct destination patterns. In 41.0% of consignments, the destination remained within the Member State of entry, whereas 29.7% were recorded with a destination in another EU Member State. Thus, a substantial proportion of recorded movements continued beyond the initial border-crossing country, while another substantial proportion remained within the Member State through which the consignment entered the EU.

A statistically significant association was identified between geographical origin and destination category ($\chi^2 = 439.930$, df = 42, $p < 0.01$). This association indicates that the distribution of destinations differed according to the geographical origin of the consign-

ments. The result provides evidence of non-random variation in origin–destination patterns within the analysed dataset, but does not by itself establish the mechanisms underlying these differences.

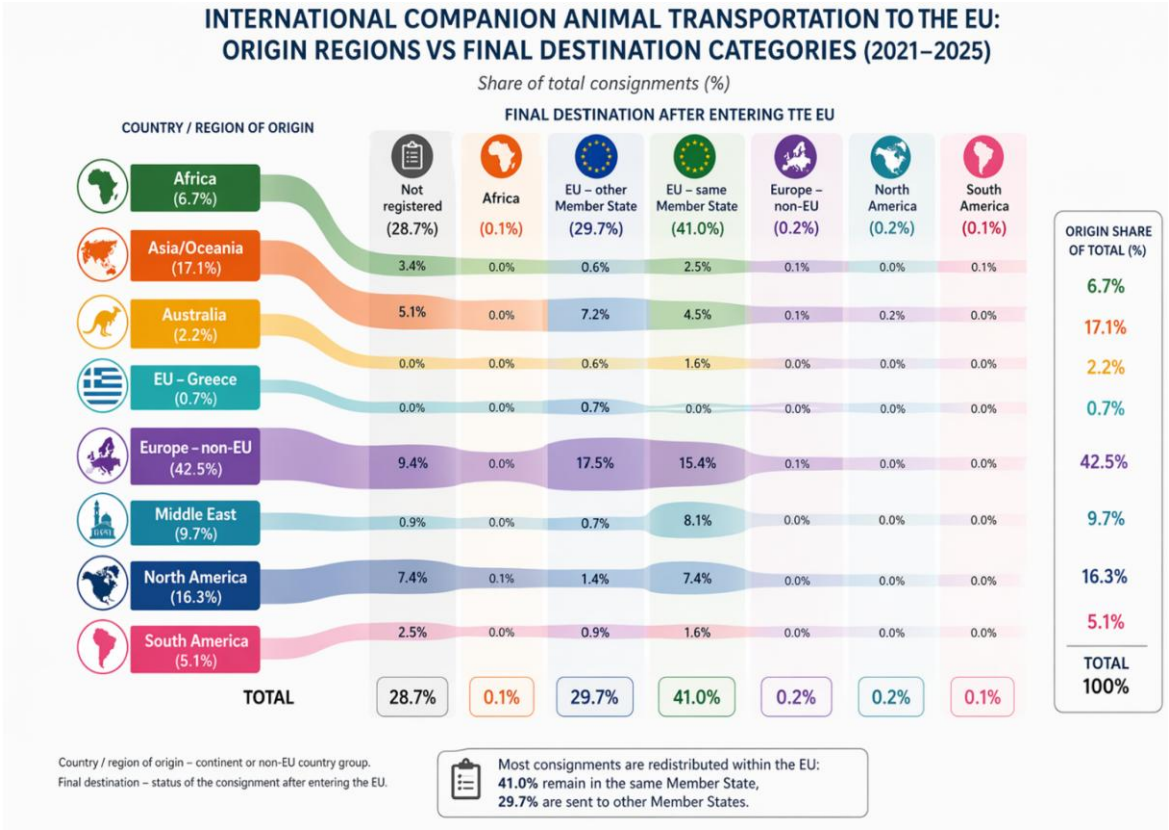


Figure 3. Spatial distribution and cross-border flow patterns of cargo consignments with companion animals entering the European Union, 2021–2025. The figure combines the geographical distribution of consignments with the principal recorded pathways between regions of origin, animal species, EU Border Control Posts and destination categories. Note: Country of origin—countries grouped by geographical region or continent. Country of destination—countries grouped by geographical region or continent. "EU-Greece" represents consignments associated with owners registered in Greece, with Croatia recorded as the EU country of entry. The actual third country of dispatch was not specified in the available TRACES NT records; therefore, this designation reflects the original database classification and should not be interpreted as verified geographical origin or intra-EU movement.

The heatmap showed spatial concentration of consignments across selected geographical regions and EU entry points. The Sankey diagram further illustrates the principal recorded pathways between regions of origin, animal species and EU Border Control Posts (Figure 3), providing a visual representation of the concentration and distribution of cross-border movements within the dataset.

3.4. Validation Outcomes

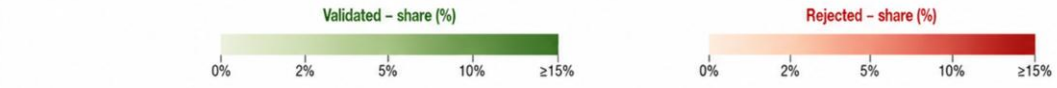
Of the 3250 companion-animal consignments recorded during the study period, 1726 (53.1%) were accepted for entry into the European Union and 1524 (46.9%) were rejected following official border control (Figure 4). The proportions of accepted and rejected consignments remained relatively similar across the study period, although the absolute number of consignments varied between years.

Non-EU European countries accounted for the largest share of both accepted and rejected consignments, representing 42.3% of accepted and 44.8% of rejected consignments. Asia and Oceania accounted for 17.0% of accepted and 18.2% of rejected consignments, while North America accounted for 16.3% and 15.4%, respectively. These distributions broadly corresponded to the overall geographical composition of consignments shown in Figure 3.

The largest number of consignments was recorded in 2022, followed by lower volumes in the subsequent years, reaching 7.1% of the total dataset in 2025. The relative proportions of accepted and rejected consignments showed comparatively limited variation across the study period.

Share of cargo consignments for imported pets, distributed by year and country (continent) of origin – validated vs rejected

Origin	Year										Total		Chi-square	Sig
	2021		2022		2023		2024		2025					
	Validated	Rejected	Validated	Rejected	Validated	Rejected	Validated	Rejected	Validated	Rejected	Validated	Rejected		
Africa	1.20%	1.20%	2.60%	2.60%	1.70%	1.60%	0.80%	0.70%	0.50%	0.50%	6.80%	6.60%		
Asia	7.10%	7.70%	2.70%	3.00%	1.40%	1.50%	4.50%	4.90%	1.20%	1.20%	17.00%	18.20%	Validated: 211.348	p < 0.01
Australia	0.80%	0.00%	0.50%	0.00%	0.40%	0.00%	0.20%	0.00%	0.30%	0.00%	2.10%	0.00%		
EU-Greece	0.00%	0.00%	0.00%	0.00%	0.70%	0.80%	0.00%	0.00%	0.00%	0.00%	0.70%	0.80%		
Europe-non-EU	11.50%	12.50%	12.00%	14.00%	7.80%	8.40%	9.20%	8.80%	1.20%	1.00%	42.30%	44.80%		
Middle East	2.10%	2.20%	2.80%	2.40%	2.20%	1.60%	1.40%	2.10%	1.10%	0.60%	9.60%	8.90%	Rejected: 176.432	p < 0.01
North America	2.50%	2.60%	5.00%	4.90%	3.50%	3.20%	3.10%	3.10%	2.10%	1.50%	16.30%	15.40%		
South America	0.80%	0.90%	1.20%	1.40%	1.40%	1.40%	1.00%	1.00%	0.60%	0.70%	5.10%	5.40%		
Total	26.00%	27.20%	27.50%	28.20%	19.20%	18.60%	20.20%	20.50%	7.10%	5.50%	100.00%	100.00%		



Percentages are shown with one decimal place and may not sum to 100% due to rounding.

Figure 4. Cargo consignments of imported pets by origin and validation status, 2021–2025. Note: Country of origin—countries grouped by geographical region or continent. "EU-Greece" represents consignments associated with owners registered in Greece, with Croatia recorded as the EU country of entry. The actual third country of dispatch was not specified in the available TRACES NT records; therefore, this designation reflects the original database classification and should not be interpreted as verified geographical origin or intra-EU movement.

A statistically significant association was initially observed between geographical origin and border-control outcome ($\chi^2 = 211.348$, df = 28, $p < 0.01$). A significant association was also identified in the analysis of rejected consignments by geographical origin ($\chi^2 = 176.432$, df = 24, $p < 0.001$). These findings indicated that the distribution of border-control outcomes varied across geographical-origin categories.

However, to determine whether geographical origin was independently associated with consignment rejection after accounting for other relevant factors, a multivariable binary logistic regression analysis was performed, adjusting for species, year of entry, and EU entry country. In contrast to the unadjusted chi-square findings, geographical origin

was not significantly associated with the odds of consignment rejection in the adjusted model (joint Wald test: $\chi^2(6) = 3.43$, $p = 0.753$). Furthermore, none of the individual geographical-origin categories showed a statistically significant difference in rejection odds compared with consignments classified under the non-EU Europe reference category. The adjusted odds ratios ranged from 0.759 for South America to 1.075 for EU-Greece, with all corresponding 95% confidence intervals including unity.

Taken together, these results suggest that although border-control outcomes differed significantly across geographical-origin categories in the unadjusted analyses, these differences were no longer statistically significant after adjustment for species, year of entry, and EU entry country. Thus, geographical origin did not independently explain the odds of consignment rejection within the adjusted model. The regression analysis therefore provides a more detailed comparative assessment by accounting for the simultaneous contribution of the other variables included in the model. The estimated odds ratios represent associations within the analysed dataset and should not be interpreted as evidence of a causal effect of geographical origin (Table 1).

Table 1. Adjusted association between recorded geographical-origin category and consignment rejection.

Geographical Origin	Adjusted OR	95% CI	*p*-Value
Europe-non-EU	1.00	Reference	–
Africa	0.967	0.696–1.344	0.841
Asia/Oceania	0.889	0.711–1.112	0.302
EU-Greece	1.075	0.452–2.559	0.870
Middle East	1.002	0.748–1.344	0.988
North America	0.843	0.638–1.115	0.232
South America	0.759	0.517–1.114	0.159

Abbreviations: OR, odds ratio; CI, confidence interval. Note: The dependent variable was consignment rejection (1 = rejected; 0 = accepted). Europe-non-EU was the reference category for geographical origin. The model was adjusted for species, year of entry and EU entry country. The 37 consignments recorded under Australia were excluded from the model because no rejected consignments were observed in this category, resulting in complete separation. The joint Wald test assessed the overall contribution of the recorded geographical-origin categories to the model. Statistical significance was set at $p < 0.05$. "EU-Greece" represents consignments associated with owners registered in Greece, with Croatia recorded as the EU country of entry. The actual third country of dispatch was not specified in the available TRACES NT records; therefore, this designation reflects the original database classification and should not be interpreted as verified geographical origin or intra-EU movement.

Major entry countries, including the Netherlands, Lithuania, Germany and Austria, accounted for substantial proportions of both accepted and rejected consignments (Figure 5). Dogs represented the majority of both accepted (65.9%) and rejected (66.3%) consignments. Cats accounted for slightly more than one-quarter of consignments in both outcome groups, while the remaining species categories represented substantially smaller proportions.

Share of cargo consignments for imported pets, by entry to EU and species – validated vs rejected

Entry to EU	Dog		Cat		Carnivores		Total		Chi-square	Sig
	Validated	Rejected	Validated	Rejected	Validated	Rejected	Validated	Rejected		
Austria	4.8%	5.4%	1.7%	1.9%	5.6%	6.4%	12.1%	13.6%		
Belgium	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.4%	0.5%		
Bulgaria	9.1%	2.2%	4.3%	0.0%	0.2%	0.1%	13.6%	2.3%		
Croatia	5.5%	6.2%	0.6%	0.7%	0.0%	0.0%	6.1%	6.9%		
Denmark	0.2%	0.2%	0.1%	0.1%	0.0%	0.0%	0.2%	0.3%		
Estonia	0.2%	0.2%	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	Validated: 745.568	P<0.01
Finland	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.2%	0.2%		
France	3.7%	4.1%	2.4%	2.7%	0.2%	0.3%	6.3%	7.1%		
Germany	7.4%	8.1%	4.4%	5.0%	0.1%	0.1%	11.9%	13.3%		
Hungary	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.2%	0.2%		
Ireland	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%		
Italy	0.1%	0.1%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%		
Latvia	6.2%	7.0%	1.0%	1.1%	0.0%	0.0%	7.2%	8.1%		
Lithuania	8.5%	9.6%	5.8%	6.6%	0.0%	0.0%	14.3%	16.1%		
Luxembourg	0.6%	0.7%	0.1%	0.1%	0.0%	0.0%	0.6%	0.7%	Rejected:	
Netherlands	13.2%	14.9%	5.8%	6.6%	0.0%	0.0%	18.9%	21.5%	684.320	P<0.01
Poland	4.6%	5.2%	1.0%	1.1%	0.0%	0.0%	5.6%	6.3%		
Romania	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%		
Slovakia	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.1%	0.1%		
Spain	0.8%	0.9%	0.2%	0.3%	0.0%	0.0%	1.0%	1.1%		
Sweden	0.6%	0.7%	0.2%	0.2%	0.1%	0.1%	0.9%	1.0%		
Switzerland	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.2%	0.2%		
Total	**65.9%**	**65.3%**	**27.7%**	**26.5%**	**6.4%**	**7.2%**	**100.0%**	**100.0%**		

Share (%) – Dog: 0% 5% 10% ≥15%

Share (%) – Cat: 0% 3% 6% ≥9%

Share (%) – Carnivores: 0% 3% 6% ≥9%

Share (%) – Total: 0% 10% 20% ≥25%

Note: Percentages are shown with one decimal place and may not sum to 100% due to rounding.

Figure 5. Validation status of companion animal consignments at EU entry points, 2021–2025.

A statistically significant association was identified between the recorded entry-point categories and border-control outcome ($\chi^2 = 745.568$, df = 76, $p < 0.01$ for accepted consignments; $\chi^2 = 684.320$, df = 42, $p < 0.001$ for rejected consignments). These findings indicate that the distribution of inspection outcomes varied across entry-point categories.

3.5. Reasons for Consignment Rejection

Among rejected consignments, administrative and documentary deficiencies represented the largest category of recorded reasons for rejection, accounting for 73.2% of all rejected consignments (Figure 6). This category was the predominant reason across the geographical-origin and species categories examined. Rejection reasons were significantly associated with geographical origin ($\chi^2 = 93.563$, df = 9, $p < 0.01$) and animal species ($\chi^2 = 76.592$, df = 9, $p < 0.01$).

Non-EU European countries accounted for the largest proportion of rejected consignments (39.1%), followed by North America (19.4%) and Asia (including Oceania) (17.5%). Dogs represented 65.0% of rejected consignments, followed by cats (24.2%), carnivores (8.7%) and other mammals (2.1%). The most frequently recorded deficiencies included missing or incomplete veterinary certificates, absence of original certificates, missing laboratory reports such as rabies serology, mismatches in identification marks, invalid dates or incorrect certificate models, and missing signatures or official stamps.

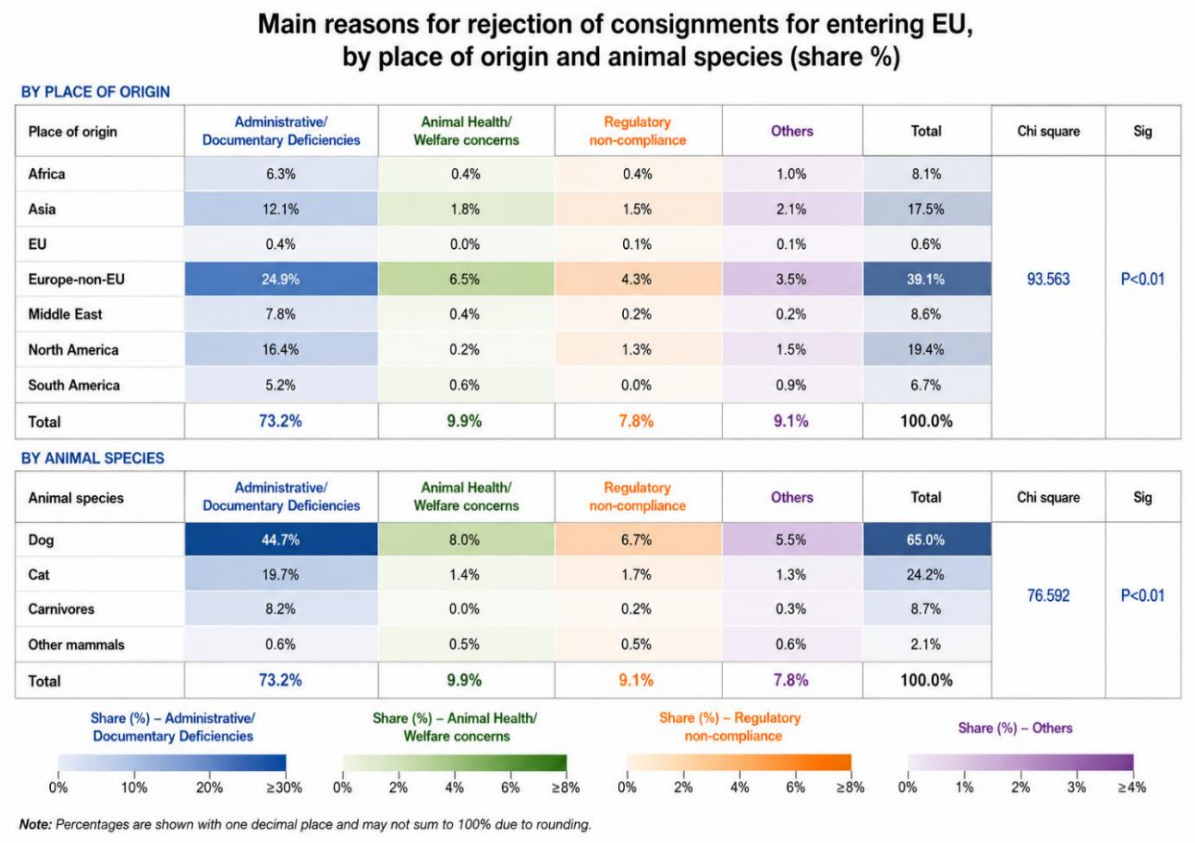


Figure 6. Patterns of consignment rejection by origin and animal species at EU borders, 2021–2025. Note: Other mammals (not included in the definition of pet animals)—bats; even-toed ungulates; marsupials; racoons; rodents; sloths; hyrax. "EU" refers to consignments accompanying owners who are citizens of an EU Member State and entered the European Union from a third country.

A more detailed examination of the recorded rejection reasons revealed that administrative and documentary deficiencies represented the predominant category, accounting for 924 cases (73.2% of records with a specified primary rejection reason). Animal health and welfare concerns accounted for 125 cases (9.9%). Within the administrative and documentary category, the most frequently recorded deficiencies were missing certificates (399; 43.2%), absence of original certificates (225; 24.4%), missing laboratory reports (208; 22.5%), and invalid dates (203; 22.0%). Other recorded issues included the use of an incorrect certificate model (160; 17.3%), discrepancies in identification marks (144; 15.6%), missing signatures or stamps (81; 8.8%), and absence of additional guarantees (53; 5.7%).

Among animal health and welfare concerns, unsuitable means of transport was the most frequently recorded issue (96; 76.8%), followed by non-satisfactory test results (18; 14.4%), animals considered unfit to travel or found dead (10; 8.0%), and diseased or suspected animals (3; 2.4%). The detailed distribution of the specific reasons within these two main categories is presented in Table 2.

Table 2. Detailed breakdown of administrative/documentary deficiencies and animal health/welfare concerns among rejected companion-animal consignments (2021–2025).

Main Category	Specific Reason for Rejection	*n*	% within Main Category
Administrative and documentary deficiencies (*n* = 924)	Missing certificate	399	43.2
	Absence of original certificate	225	24.4
	Missing laboratory report	208	22.5
	Invalid dates	203	22.0

Animal health and welfare concerns (*n* = 125)	Wrong certificate model	160	17.3
	Identification mark mismatch	144	15.6
	Missing signature/stamp	81	8.8
	Absence of additional guarantees	53	5.7
	Unsuitable means of transport	96	76.8
	Non-satisfactory test results	18	14.4
	Animals unfit to travel or dead animals	10	8.0
	Diseased or suspected animals	3	2.4

Note: Percentages are calculated within each respective main category. Multiple specific deficiencies or concerns could be recorded for an individual consignment; therefore, the specific reasons are not mutually exclusive.

Regulatory non-compliance constituted a further 7.8% of rejection reasons. These cases included failure to meet applicable national import requirements, consignments originating from non-approved establishments, countries or territories, and other breaches of applicable import legislation. Other recorded reasons accounted for the remaining 9.1%.

Overall, the distribution of rejection reasons indicates that documentary and administrative deficiencies constituted the predominant recorded basis for refusal of entry in the analysed dataset, while animal health and welfare concerns represented a smaller proportion of recorded rejection outcomes.

4. Discussion

4.1. Spatial and Temporal Organisation of Cross-Border Movements

The analysis identified substantial spatial concentration in the distribution of companion-animal consignments entering the European Union (EU). A relatively small number of Member States accounted for a large proportion of the recorded entry activity, with the Netherlands, Lithuania, Bulgaria, Austria and Germany representing the principal entry countries during the study period. This pattern is consistent with the broader organisation of European transport networks, in which major international airports, freight facilities and strategically located border-crossing points accommodate disproportionately large transport volumes [23,24]. In this context, the concentration observed in the present dataset is better interpreted as concentration of transport activity at specific entry nodes rather than as evidence of a formal hub-and-spoke network.

The Netherlands represented the largest share of recorded consignments. Its position is consistent with its established importance within European international logistics and air-cargo transport networks [23]. The substantial activity recorded in Lithuania during the later part of the study period indicates that the distribution of entry activity was not static. Changes in transport routes and regional mobility may have contributed to this redistribution, particularly in the context of wider changes affecting transport networks in Eastern Europe [25,26]. However, the TRACES NT data do not contain sufficient information to determine whether changes in route selection, transport operators, passenger mobility, geopolitical conditions or other factors were responsible.

Bulgaria showed a comparatively stable contribution throughout the study period. Its position as an EU external-border entry country provides an important transport connection between neighbouring non-EU countries and the EU internal market. The activity observed at Bulgarian entry points is consistent with the established role of major road-border crossings, including Kapitan Andreevo and Kalotina, in cross-border movement and veterinary control [27,28]. From a transport-management perspective, the persistence of activity at such locations indicates that border-control capacity needs to remain aligned

with the characteristics and volume of movements passing through established entry corridors.

Austria and Germany also accounted for substantial shares of recorded consignments, although their contributions declined during the later study years. Changes in air-transport routes, operational disruptions and measures addressing illegal companion-animal trade may have influenced this pattern [29–31], although the available data do not allow these factors to be distinguished. Moderate contributions were recorded for Latvia (7.2%), France (6.3%), Croatia (6.1%) and Poland (5.6%). Latvia showed a decline after stronger activity in the earlier years, whereas Croatia increased temporarily in 2023–2024. France and Poland maintained relatively stable contributions. The operational importance of transport disruptions is illustrated by the 2023 air traffic control industrial action, when France accounted for 99% of approximately 3 million minutes of en-route ATFM delays across Europe [32]. Although no direct effect on companion-animal movements can be established, such disruptions may affect the continuity and distribution of cross-border transport flows. Variations between entry points may also reflect logistical factors and the specialisation of individual BCPs [33].

The temporal distribution showed a pronounced peak in 2022, followed by lower recorded volumes in subsequent years. This pattern may be considered in the context of the post-COVID-19 recovery and restructuring of international transport, together with wider economic and geopolitical changes [34–36]. However, the available data cannot establish whether the decline resulted from reduced demand, changes in routing, recording practices or other external factors. The findings therefore describe changes in recorded transport activity rather than underlying demand for companion-animal mobility.

Although the volume and geographical distribution of recorded consignments varied during the study period, the persistence of accepted and rejected outcomes across the different years indicates that compliance-related issues remained present throughout the observation period. This finding highlights the relevance of interventions addressing exporting-country practices, certification procedures and the security and verification of accompanying documentation [37]. However, the present data do not allow changes in the underlying causes of non-compliance or the effectiveness of specific interventions to be assessed directly.

The concentration of movements at particular BCPs has direct implications for border-management planning. High-volume entry points represent locations where transport flows and regulatory procedures converge, making the availability of appropriate inspection capacity, trained personnel and consistent procedures particularly important [38]. International guidance has similarly emphasised the importance of harmonised procedures for the inspection and movement of animals across borders [39]. At the same time, changes in the relative importance of individual entry points, such as the increase observed for Lithuania, indicate that capacity planning should remain sufficiently flexible to accommodate changes in transport patterns rather than relying solely on historical traffic distributions [40].

4.2. Origin, Destination and Internal Redistribution

The predominance of non-EU European countries among the recorded origins reflects the importance of geographical proximity in cross-border companion-animal transport. Movements from neighbouring countries can make use of established road corridors and subsequently continue through the EU internal transport network after completion of the required external-border controls. This is consistent with the broader integration of European transport and trade networks, in which external-border entry points provide access to an extensive internal market [41].

The destination data demonstrate that the EU entry point did not necessarily represent the final destination of a consignment. While 41.0% of consignments remained in the Member State of entry, 29.7% were destined for another EU Member State. This indicates that several Member States functioned both as external entry points and as transit or redistribution locations within the EU transport network. Comparable patterns of cross-border redistribution have been described in European trade networks, where the integration of national markets facilitates movements beyond the country of initial entry [42].

The significant association between geographical origin and destination category indicates that destination patterns were not distributed uniformly across source regions. The finding is relevant from a transport perspective because it suggests that the organisation of companion-animal movements is influenced by the geographical characteristics of the transport chain rather than being determined solely by the location of the initial border crossing. Long-distance movements originating in Asia/Oceania and North America may involve different transport configurations from movements originating in neighbouring European countries, including greater reliance on established international air-cargo networks [43].

The recorded destination information should nevertheless be interpreted cautiously. Administrative databases designed primarily for regulatory control do not necessarily provide complete visibility of the subsequent movement of animals after border clearance. The presence of records with no registered final destination may therefore reflect limitations in administrative traceability rather than an absence of subsequent movement. This limitation reinforces the importance of interoperable digital information systems capable of maintaining continuity of movement information beyond the initial border-control event [38,44].

4.3. Species Composition and Border-Control Outcomes

Dogs and cats accounted for the majority of recorded consignments throughout the study period. Their predominance corresponds with their central position in international companion-animal ownership and movement [45,46]. The relatively stable species distribution across the study period indicates that the overall composition of recorded cargo movements did not undergo major structural change.

Dogs predominated among both accepted (65.9%) and rejected (66.3%) consignments, while cats represented slightly more than one-quarter of both outcome groups. This distribution largely reflects the overall dominance of dogs in the recorded movements rather than demonstrating a higher probability of non-compliance. Nevertheless, their relevance to rabies prevention and the control of illegal puppy trade supports particular attention to identification, health certification and other regulatory requirements during border inspection [47].

Significant associations between species, entry-point characteristics and border-control outcomes indicate variation across categories of movements and entry locations. These differences should not be interpreted as evidence of intrinsically higher compliance risk associated with particular species or BCPs, as they may also reflect variations in consignment volume, origin and documentation. Similarly, the comparatively higher proportion of accepted consignments at certain BCPs, including those in Bulgaria, may be related to the origin and composition of consignments, compliance practices among exporting operators or established inspection procedures [48]. The available data do not allow these factors to be distinguished. A high number of rejected consignments at a particular BCP may therefore reflect a larger inspection volume rather than poorer compliance at that location.

The veterinary relevance of border-control procedures is particularly evident in relation to rabies prevention and other transboundary disease-control programmes [49,50].

Identification, vaccination and certification requirements remain essential components of these controls [51]. Illegal animal movements, geopolitical instability and fraudulent vaccination documentation continue to challenge rabies-free and rabies-eliminating countries [52]. Previous incursions in EU Member States, Switzerland and the United Kingdom further demonstrate the importance of verifying animal identification, vaccination records and accompanying veterinary documentation at BCPs [52]. The findings of the present study therefore reinforce the relevance of maintaining robust documentary and identification controls alongside the management of transport flows through major entry points.

The same consideration applies to the observed differences between BCPs. Major entry points processed substantial numbers of both accepted and rejected consignments. A high number of rejected consignments at a particular BCP therefore does not necessarily indicate poorer compliance at that location; it may simply result from the larger number of consignments inspected. This distinction is important when using administrative inspection data to compare border-crossing locations.

4.4. Documentary Compliance and Border-Control Processes

Administrative and documentary deficiencies represented the predominant recorded category of rejection reasons (73.2%), exceeding the proportion associated with animal health and welfare concerns. This finding is consistent with previous studies identifying incomplete certification, identification inconsistencies and other documentary deficiencies as important causes of non-compliance in animal transport [17–19].

The detailed breakdown of rejection reasons provides further insight into the main areas of non-compliance identified during veterinary border control. The predominance of administrative and documentary deficiencies highlights the importance of accurate and complete certification before consignments arrive at EU entry points. In particular, missing or non-original certificates, absent laboratory reports, invalid dates, and discrepancies in animal identification indicate that document verification remains a critical component of border control procedures. These findings support the need for improved pre-arrival verification, consistent application of certification requirements, and effective digital validation of the accompanying documentation.

Although less frequent than documentary deficiencies, animal health and welfare concerns also represent an important component of the recorded rejection outcomes. The high proportion of unsuitable means of transport within this category draws attention to the need for appropriate transport conditions and compliance with animal welfare requirements during international movement. The identification of non-satisfactory test results and animals unfit to travel further underlines the importance of combining documentary checks with veterinary assessment. Thus, the findings indicate that effective border control requires an integrated approach addressing both documentary compliance and the health and welfare status of transported animals.

From a transport perspective, documentary compliance is not simply an administrative issue. Documentation is an information component of the cross-border transport process, linking the physical movement of animals with the regulatory information required for continuation of that movement. Missing certificates, inconsistent identification data, missing laboratory results or invalid certification can therefore interrupt the movement at the border-crossing point. Such interruptions may require additional verification, correction of documentation, temporary holding or refusal of entry and consequently have operational implications for both authorities and transport operators.

The finding is also relevant to the increasing digitalisation of border-management systems. The use of electronic certification and traceability systems provides opportunities to improve the completeness and consistency of information before a consignment

reaches the physical border-crossing point. However, digitalisation alone does not eliminate compliance problems. The quality of information entered into the system, the authenticity of supporting documentation and the interoperability of information exchanged between competent authorities remain important determinants of effective digital control.

The European Commission has reported a substantial proportion of fraud notifications involving companion animals originating from non-EU countries, including forged animal-health certificates, falsified laboratory reports and the misdeclaration of commercial movements as non-commercial movements [53]. Such practices demonstrate the connection between documentary verification and the physical management of cross-border movements. Strengthening digital authentication, information exchange and cooperation between veterinary authorities, customs administrations and other competent agencies may therefore improve both regulatory control and the predictability of legitimate transport flows [54].

The predominance of documentary deficiencies should not, however, be interpreted as evidence that animal-health risks are unimportant. Rather, documentation and identification requirements constitute preventive control mechanisms through which health-related eligibility is assessed before animals proceed into the EU internal market. Effective documentary verification can therefore contribute to disease prevention even when the immediate reason for refusal is administrative rather than clinical.

4.5. Implications for Transport and Border-Management Policy

The findings have several implications for the management of cross-border companion-animal transport. First, the spatial concentration and temporal variation in recorded consignments indicate that border-control capacity should be planned in response to actual and changing transport flows. Concentration at a limited number of BCPs creates opportunities for specialised expertise and efficient resource allocation, but also increases the operational importance of individual entry points within the wider system.

Second, the substantial proportion of consignments continuing beyond the Member State of entry highlights the need to consider external-border controls as one stage within a broader movement chain. Improved information continuity between entry controls and subsequent intra-EU movement stages could strengthen traceability and support more efficient regulatory management.

Third, the predominance of documentary deficiencies supports the development of upstream measures, including improved guidance for exporters and transport operators, standardised certification, pre-arrival verification and secure digital exchange of documentation. These measures would complement rather than replace physical veterinary inspection. Monitoring changes in entry-point volumes would also allow competent authorities to adapt staffing, infrastructure and information-management capacity. Such an approach is consistent with risk-based border management, while recognising that the available dataset does not provide sufficient information to quantify relative risks associated with individual routes, operators or origins.

Strengths and Limitations

The principal strength of the study is the use of official TRACES NT records covering a continuous five-year period and multiple EU Member States. The dataset provides a consistent administrative basis for examining temporal patterns, geographical origins, entry-point concentration and border-control outcomes. The combination of descriptive statistics with spatial heatmaps and Sankey visualisation also provides a means of examining transport patterns from complementary perspectives.

Several limitations should nevertheless be considered. The analysis was restricted to consignments recorded in TRACES NT and therefore does not represent the full volume

of companion-animal movements into the EU. In particular, non-commercial pet movements accompanying passengers, undeclared imports and illegal movements outside the official control system are not captured in the analysed dataset. The findings should therefore be interpreted as describing officially recorded cargo consignments rather than overall companion-animal mobility.

The database was primarily developed for regulatory and traceability purposes rather than transport or epidemiological research. Consequently, information concerning individual animals, transport operators, journey characteristics, duration, intermediate stops and subsequent movements may be limited or unavailable. The study can therefore identify spatial and temporal associations in recorded movements but cannot determine the causal mechanisms responsible for changes in routing, entry-point selection or inspection outcomes.

The use of aggregated geographical categories reduces the influence of sparse observations but may conceal differences between individual countries within the same region. The logistic regression analysis provides an adjusted assessment of the association between recorded geographical-origin categories and consignment rejection, while its interpretation remains subject to the limitations of the available administrative variables. In particular, the exclusion of the 37 consignments from Australia due to complete separation and the inclusion of EU-Greece as a separately recorded category should be considered when interpreting the model. The geographical-origin variable does not represent a verified country of dispatch for all records. Furthermore, the available dataset did not contain consistently recorded transport-mode, operator or journey-level information, preventing a reliable assessment of route-specific or mode-specific rejection risks. Future research combining TRACES NT information with transport-route data, operator characteristics, journey duration, air- and road-traffic statistics and more detailed origin-destination information could provide a more comprehensive assessment of the factors shaping cross-border companion-animal transport.

The geographical patterns presented in the heatmaps should be interpreted as descriptive concentrations of recorded consignments rather than statistically confirmed spatial clusters. The observed predominance of particular EU entry countries may reflect differences in international transport connectivity, cargo-handling capacity and the operational roles of individual BCPs. The available dataset did not provide consistently standardised geographical coordinates for all entry points, limiting the application of formal spatial autocorrelation and hotspot-detection methods.

Overall, the findings demonstrate that companion-animal movements constitute a measurable component of cross-border transport in which physical flows, border infrastructure and regulatory information are closely interconnected. The spatial concentration of entry activity and the predominance of documentary causes of rejection indicate that effective management requires attention not only to veterinary inspection capacity but also to the organisation and continuity of information throughout the movement chain.

5. Conclusions

This study provides a five-year assessment of officially recorded cargo consignments of companion animals entering the European Union from third countries, demonstrating pronounced spatial and temporal variation in cross-border transport activity. The movements were concentrated among a limited number of EU entry countries and Border Control Posts, while a substantial proportion of consignments continued to destinations beyond the Member State of initial entry. These findings indicate that external border-crossing points represent important nodes within a wider European transport chain rather than isolated locations of veterinary control.

The analysis also showed that documentary and administrative deficiencies constituted the predominant recorded reason for rejection. This finding highlights the importance of regulatory information as an integral component of cross-border animal transport, since incomplete or inconsistent documentation can interrupt movements at the border and affect their continuity within the EU transport network.

The results support the integration of transport-flow characteristics with border-management planning. Monitoring changes in the volume and geographical distribution of consignments can assist in adapting inspection capacity at high-volume or emerging entry points, while improved digital certification, information exchange and coordination between competent authorities and transport-chain stakeholders may reduce avoidable compliance-related disruptions.

The study is limited to officially recorded TRACES NT cargo consignments and therefore does not represent the full volume of companion-animal movements into the EU. Nevertheless, the findings demonstrate the value of combining administrative border-control data with a transport-oriented analysis of origins, entry points, destinations and inspection outcomes. This approach can contribute to more informed planning of EU external-border infrastructure, regulatory processes and the management of cross-border companion-animal transport.

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Data Availability Statement: The data supporting the findings of this study were obtained from the TRACES NT (Trade Control and Expert System New Technology) platform, the European Commission's official electronic system for certification, traceability, and veterinary border control of animals and animal products. The dataset was accessed by the first author through authorised personal access and comprised recorded cargo consignments of companion animals imported from third countries into EU Member States during the study period. Due to the restricted-access nature of the TRACES NT system and applicable data access conditions, the underlying dataset is not publicly available and cannot be deposited in an open-access repository. The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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tion, statistical analyses, interpretation of results, or formulation of scientific conclusions. After using this tool, the authors reviewed, edited, and made the content their own, validating the outcome as needed; the authors take full responsibility for the content of the publication.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

TRACES NT	Trade Control and Expert System New Technology
ATFM	Air Traffic Flow Management

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