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End of the Cage Age? A Study on the Impacts of the Transition from Cages on the EU Laying Hen Sector

Edward Majewski [1,2,*], Norbert Potori [3], Piotr Sulewski [1], Adam Wąs [1], Martyna Mórawska [1], Monika Gębska [1], Agata Malak-Rawlikowska [1,2], Anna Grontkowska [1], Viktor Szili [3] and Adél Erdős [3]

1 Institute of Economics and Finance, Warsaw University of Life Sciences, 02-787 Warsaw, Poland; piotr_sulewski@sggw.edu.pl (P.S.); adam_was@sggw.edu.pl (A.W.); monika_gebska@sggw.edu.pl (M.G.); agata_malak_rawlikowska@sggw.edu.pl (A.M.-R.); anna_grontkowska@sggw.edu.pl (A.G.)
2 Foundation Science and Education for Agri-Food Sector, 01-462 Warsaw, Poland
3 Institute of Agricultural Economics Nonprofit Kft. (AKI), 1093 Budapest, Hungary; potori.norbert@aki.gov.hu (N.P.); szili.viktor@aki.gov.hu (V.S.); erdos.adel.dorottya@aki.gov.hu (A.E.)
* Correspondence: edward_majewski@sggw.edu.pl

Abstract: This paper's main objective is to assess the impacts of the ban on cages for housing laying hens, planned by the European Commission to raise animal welfare standards beyond the level set in the current legislation. The farm-level economic assessments of the ban were carried out in three stages: farm surveys and expert consultations, farm-level analyses, and aggregation to the EU-27 egg production sector. Four scenarios were constructed. All financial estimates were conducted with fixed prices from the year 2021 for which the reference scenario was built. Alternative hen-housing systems were barn (Voliera), free range, and organic. Until now, more than 50% of laying hens in the EU have already been transferred to alternative systems. The remaining part is subject to the transition. The basic assumptions included a reduction in yields due to the required lower densities and specifics of the production systems. A factor strongly differentiating the scenarios is likelihood of exists form the sector, as declared in the survey by many farmers, mainly those reaching retirement age without successors and keeping relatively small flocks of hens. The introduction of the ban will cause a decrease in egg production, varying between the scenarios. Substantial investments will be required within the range of 2–3.2 billion EUR, depending on the scenario.

Keywords: hen-housing systems; ban on cages; economic impact assessment; animal welfare farm survey

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1. Introduction

In the first decades of the 20th century, eggs were produced mainly in small flocks [1]. Since the 1940s, the intensive production model, characterized by a higher stocking density and various forms of cage housing, began to gain importance [1–3]. The development of intensive egg production was fostered by innovations introduced in the 1960s, such as the "hybrid laying hen with high laying capacity and good health" and mechanized housing systems [1,2]. Initially, intensive cage egg production began with flat-deck systems that were replaced with multitier batteries, reducing construction costs but worsening the welfare of laying hens [1]. Battery systems of cages connected with automatic feed chains significantly reduced labor inputs and were better suited to large-scale egg production than deep litter systems [2]. As a result, by the 1970's, most laying hens in developed countries were kept in battery cages, also called conventional cages [4]. High productivity and better profits were the key decisive factors for the success of the cage housing system [5].

The growing adoption of the cage system soon raised concerns about the welfare of the caged animals [2,6]. Notable publications, such as "Animal Machines" [7] or the "Brambell Report" [8], which highlighted animal suffering, inspired and led to the development of legislation to protect farm animals [9].

The first country to ban the conventional cage system was Switzerland in 1992, followed by more European countries that introduced national regulations to reduce stocking density. Finally, by 2012, the European Union (EU) implemented a complete ban on the use of conventional cages, replacing them with "enriched cages" and other alternative solutions [10]. The growing awareness of animal welfare among EU egg consumers has been increasingly supporting a move away from cage systems [11]. The "End the Cage Age" campaign that was initiated in 2018 resulted in the collection of 1.4 million signatures in support of the EU's ban on the cage system. On 30 June 2021, the European Commission (EC) announced a policy initiative to phase out cages in the EU [12], which may have a considerable impact on the egg industry.

In this context, the primary purpose of this study is to assess the potential impacts of the ban on cages on the production of eggs from the EU laying hen sector as well as the financial performance of farms transitioning to alternative hen-housing systems. This paper draws inspiration and recapitulates some of the key findings from the report co-authored by the authors of this paper for Copa-Cogeca, titled "An assessment of the impacts the phasing out of cages in EU livestock farming: the pig and layer sectors" [13]. Considering there are no similar assessments in the literature, we contribute to closing the research gap and providing results that might also be useful for policymakers.

2. Literature Review

2.1. Short Review of the Fundamental Technological Solutions

Egg production systems can be classified based on how the hens are housed, their access to outdoor space, and the production methods (e.g., conventional, organic). Two fundamental systems are used to house hens: caged and non-caged. Caged housing systems include conventional and enriched (also known as furnished) cages, while non-caged systems (referred to as alternative) include floor (barn, single level), aviary (multi-tier), and outdoor (free-range) systems [2,13].

Conventional laying cages typically consist of small enclosures with sloping floors made of welded wire mesh and provide equipment for feeding, drinking, egg collection, manure removal, and inserting and removing hens [14]. The space available for the hens in conventional cage systems usually varies between 430 and 560 cm^2, sometimes even less in developing countries.

Enriched (furnished) cages, which have been mandatory in the EU since 2012 as a replacement for conventional cages, were introduced to address fundamental animal welfare concerns. According to Directive 99/74/EC [10], each hen in an enriched cage has a minimum of 750 cm^2 surface area, increased cage height, a perch, and a nest box. These changes (including friable litter) are intended to enable the hens to exhibit some of their natural behavior [14]. Despite these improvements, enriched cages have continued to face criticism for their limited space and for restrictions on the hens' natural and basic behaviors, such as exercise, flying, and dustbathing [15].

Space-related issues have largely been eliminated with non-cage systems. The barn/aviary system, which is considered an acceptable alternative to enriched cages, is based on floor accommodation with several levels (tiers), allowing for the hens to utilize the vertical space within the barn. The floor at the ground level is covered with litter, and the upper levels are arranged so that manure is prevented from falling on the hens [16]. Each hen in this system has a minimum of 1100 cm^2 of usable area, and there is one nest box for every seven laying hens along with perches [15]. In the case of a single-level barn, the hens are housed on the floors of the buildings, which are typically equipped with nest boxes that collect the eggs automatically.

In the outdoor systems (free-range system), the housing is generally the same as for the barn/aviary systems, but the birds have access to the outside range area during daylight hours (at least 4 m^2 per hen (as per Regulation 589/2008 [17])—marketing standards for eggs) [16]. Open-air runs must primarily be covered with vegetation and not used for any "other purposes other than orchards, woodland or livestock grazing" [15]. A specific form of free-range system is the organic system in which the permitted stocking density is six hens per square meter, whereas in conventional systems, the allowed density is nine birds per m^2 [2,14].

Each of the technological solutions discussed above has its advantages and disadvantages. Undoubtedly, the primary drawback of the cage system is limited space. On the other hand, in addition to lower production costs, it is pointed out that the cage system is associated with a relatively low risk of disease and parasitism due to better hygiene than the other housing systems. It also facilitates the production of cleaner eggs, reduces air pollution from dust, and minimizes the risk of feather pecking and cannibalism [1].

2.2. Welfare Issues

The welfare issue has been central to the shift away from conventional and, now, enriched cages. Historically, animal welfare was primarily defined in terms of five freedoms [9,18,19]:

- freedom from thirst, hunger, or malnutrition;
- freedom from discomfort (appropriate comfort and shelter);
- freedom from pain, injury, or disease (prevention or rapid diagnosis and treatment of injury and disease);
- freedom to display most normal patterns of behavior;
- freedom from fear and distress. However, there is a growing emphasis on positive experiences, including comfort, pleasure, and a sense of control [20]. Consequently, good welfare encompasses a combination of factors, including adequate nutrition, an appropriate environment, optimal health, the expression of normal behaviors, and positive mental experiences [18].

The literature exploring the influence of various hen-housing systems on welfare is extensive. Nevertheless, many studies yield contradictory results, assessing many welfare issues somewhat ambiguously, even though the general principles of welfare are generally uncontroversial. Comprehensive reviews, drawing from numerous studies on hen welfare, can be found in the publications of such authors as Hartcher and Jones [18]; Molnár and Szollosi [21]; Sosnówka-Czajka et al. [5]; Dikmen et al. [3]; DeJong and Blokhuis [22]; Kollenda et al. [15]; and Blokhuis et al. [23].

The synthetic (general) opinion formulated by the researchers participating in the LayWel project [23] (p. 102) suggests that: "with the exception of conventional cages, all systems have the potential to provide satisfactory welfare for laying hens. However, this potential is not always realized in practice. Among the numerous explanations are management, climate, design, different responses by different genotypes and interacting effects". In general, the current state of knowledge indicates that specific hen-housing systems present varying levels of risk for different welfare aspects (Table 1).

Some studies suggest improved welfare for hens in enriched cages due to stress reduction, decreased aggression, better bone mineralization, and less feather-eating and pecking [5]. Nevertheless, enriched cages are also censured for restricting essential natural behaviors, like exercising, dustbathing, and flying [15]. On the other hand, beak trimming, often seen as a solution to cannibalism, and feather pecking, two main problems in non-cage systems, can hardly be treated as an improvement to the hens' welfare [4]. Another concern is mortality, which tends to be lower in enriched cages compared to conventional cages and other non-cage systems [14].

Compared to other systems, cages perform well in air quality (typically worst in barn and aviary systems because of the increased movement of the hens and dust generation). However, in alternative systems, the higher mobility of the hens causes a higher risk of bone fractures, feather pecking, and cannibalism [21,24,25].

The lack of exercise can also lead to issues, such as bone weakness or poor plumage condition, affecting hens not only in conventional but also in enriched cages [15,26,27]. In the case of enriched cages, these problems are partly mitigated by providing access to perches, scratch areas, dustbathing areas, and nesting boxes, allowing for the expression of several natural behaviors [28]. However, scratching and dustbathing opportunities may be limited if the litter is quickly depleted, potentially leading to increased stress for the hens excluded from dustbathing by more aggressive birds [15].

Table 1. Assessment of the potential impact of specified features of different hen-housing systems on welfare and environment.

Indicator	Conventional Cage	Enriched Cage		Non-Cage	
		Small	Medium/Large	Indoor	Outdoor
Mortality rate	••	••	•••	•••	•••
Mortality due to feather pecking or cannibalism	•	••	••	••	••
Red mite	••	••	••	••	••
Bumble foot	•	••	••	•••	•••
Feather loss	••	••	••	••	••
Use of nest boxes (nesting)	•••	•	•	•	n.d.
Use of perches (perching)	•••	••	••	••	••
Foraging behavior	•••	••	••	•	•
Dustbathing behavior	•••	••	••	••	••
Air quality	•	••	••	•••	•
Water intake	•	•	•	•	••
Movement	•••	••	••	•	•
Disease	•	•	•	•••	•••
Skeletal heath	•••	••	••	••	•

Legend: level of welfare threats: • low (or positive); •• medium; ••• high; n.d.—no data. Source: elaboration based on [14,18,23].

2.3. Economic Aspects

Intensive production methods based on cage rearing brought economic benefits to the egg industry [2,5,6]. However, the current debate regarding a total ban on cages in the EU takes place against the backdrop of the transition from conventional to enriched cages, which has recently incurred high costs. Many farmers are concerned about the prospect of additional capital expenditures to switch to non-cage systems [15,29].

Cost-intensity analyses of various production systems conducted in the past [30], cited in [4] and more recently [31], indicate that, in general, the key determinant of egg production costs is the available space for the hens. Elson's research [30] cited in [4], for example, demonstrated that increasing the average area for a bird from 450 cm^2 to 560 cm^2 resulted in a 5% increase in production costs, and expanding it to 750 cm^2 added another 10 percentage points. A similar cost increase was associated with switching from a cage system to a two-tier aviary with a stocking rate of 12 birds/m^2. According to more recent data [31], the cost of egg production compared to the enriched-cage system is approximately 17% higher in barn/aviary systems and approximately 30% higher in free-range systems. It is also worth noting that the cost increases in alternative systems can be linked to a deterioration in feed conversion, which leads to higher feed costs [3,24,32–34]. Moreover, providing more space and freedom of movement may also lead to reduced yields [15].

2.4. Legal Context

One of the first legal acts that changed hen housing conditions in the EU was the Convention on the Protection of Animals Kept for Farming Purposes introduced by the Council of Europe of 1976 [4,16]. The ratification of this convention by the EU Member States led to, inter alia, the introduction of Directive 86/113/EEC [35], called "Welfare of battery hens". This directive regulated the minimum number of drinkers per cage, feeder space, and floor area per hen in conventional cages.

Based on the guidelines of this directive, a report on scientific progress in research on the welfare of hens in various housing systems was published in 1992 [36]. This report highlighted severe welfare disadvantages for hens [36]. It marked the beginning of preparations to phase out battery (conventional) cages. Adopted on 15 June 1999, Council Directive 1999/74/EC [10] established minimum standards for the welfare and protection of laying hens. This directive has become a key regulation in the EU egg sector. A crucial provision of this regulation was the phase-out of battery cages by 2012. According to this regulation, from 2003 on, all new cages had to provide at least 750 cm^2 per hen (550 cm^2 until 2003), a nest box, a perch, and a litter area for scratching and pecking. Since 2012, all cages in use had to meet these requirements.

In addition to the ban on unenriched cages since 2012, Council Directive 1999/74/EC also establishes minimum standards for the protection of laying hens [36].

Following discussion on the 'End the Cage Age' initiative, the European Parliament called on the Commission to propose a revision of Council Directive 98/58/EC [37], aiming at phasing cages out in the EU egg sector, possibly by 2027. The European Commission [12] underscored that several Member States have already introduced total (Austria, Luxembourg) or partial bans on cages (France, Germany, Czechia, Wallonia (Belgium), Slovakia) between 2025 and 2030.

Some legislative action to improve the welfare of laying hens is also being taken in other parts of the world, although existing bans in New Zealand, Canada, and certain US states, for example, apply to conventional cages. Thus, it can be concluded that the EU is a global leader in promoting solutions for the welfare of hens.

2.5. Other Aspects

Indoor systems involve a higher risk of disease transmission within the farm, while outdoor access may introduce additional sources of infection [15]. Animals kept outdoors face additional threats, such as exposure to diseases from wild birds [38].

Another aspect is the environmental impact of various agricultural production technologies. Different hen-housing systems and manure management practices can lead to varying emission levels. Cage systems fare better in this regard, as they generate a relatively lower environmental burden per production unit (ecoefficiency) due to their high efficiency [21,39]. However, this solution is less socially acceptable in developed countries, as it scores lower in the social dimension of sustainability. On the other hand, alternative egg production systems result in higher prices, which may reduce the economic accessibility of this product for lower-income segments of society. Consumers from lower-income segments will likely demonstrate a higher acceptance of cages [40,41].

2.6. Current Situation in Transition to Alternative Housing Systems in the EU

The EU belongs to the world's important hen egg producers, accounting for approximately 7.5% (6.47 million tonnes) of global production in 2021. China is the global leader in the sector with a production volume of almost 30 million tonnes (Figure 1). Egg production in EU countries has remained at a similar level for several decades, while global egg production has increased several times during this period, primarily due to increased production in China.

The largest egg producers in the EU include France (14.2%), Germany (13.7%), Spain (12.5%), Italy (11.5%), the Netherlands (10.3%), and Poland (7.9%) (see Figure 2). The remaining 21 countries collectively account for approximately one-third of EU egg production [42].

The structure of laying hens by housing system varies significantly in EU countries (Figure 3). Some countries in the EU are moving away from the cage system, such as Sweden, Germany, the Netherlands, Denmark, and France, while other European countries, including Austria, Luxembourg, and Switzerland (not an EU Member State), have banned cage systems already. On another side of the scale is a relatively large group of countries where the share of hens kept in cages exceeds 60%. These are mostly Eastern or Southern European countries (Figure 3).

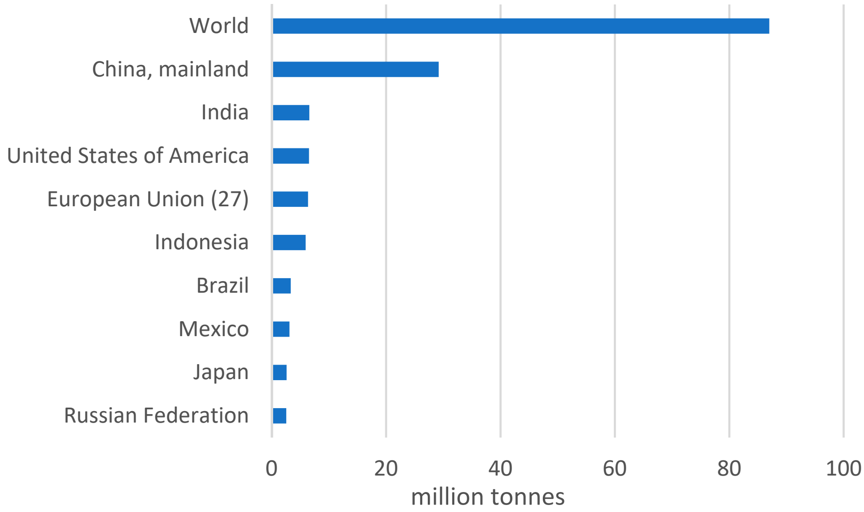

Figure 1. Global hen egg production in 2022 (million tonnes). Source: Own elaboration based on FAOSTAT statistics.

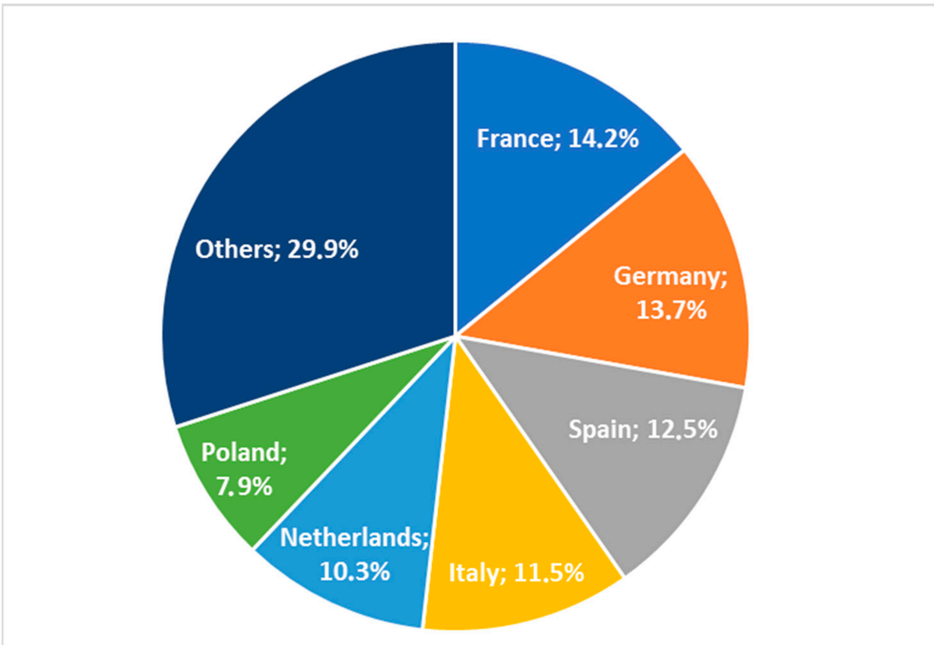

Figure 2. Structure of egg production in the EU by countries in year 2022. Source: Own elaboration based on DG AGRI statistics.

The transition to alternative hen-housing systems is an on-going process, and in some countries, it is accelerating. Based on the literature review and observations of market changes, it can be concluded that the pace of transformation in the laying hen sector is the result of the interaction of many factors that collectively determine its current and future state. These factors can be grouped into four basic categories: social, market, technological, and political (see Figure 4).

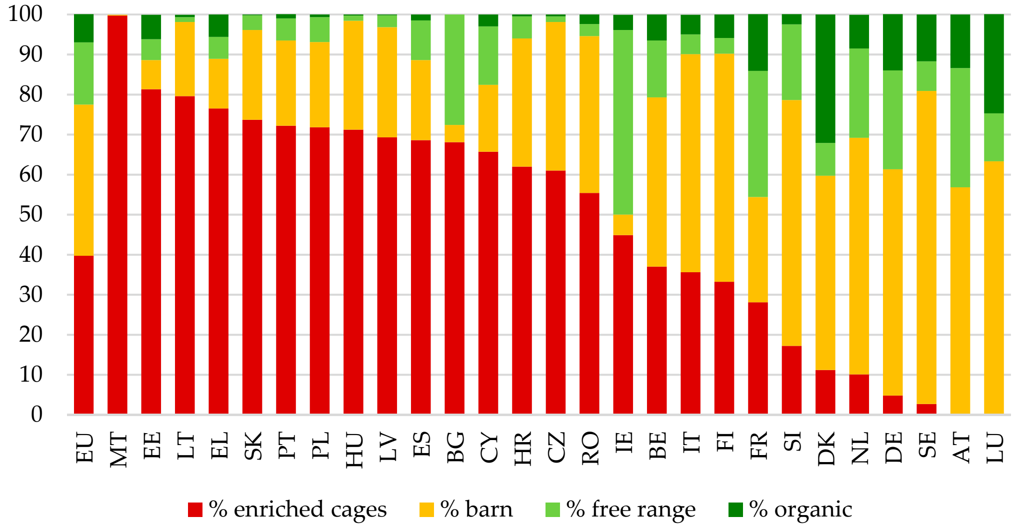

Figure 3. Structure of laying hens in EU countries by housing system. Source: Own elaboration based on DG AGRI statistics [42].

Figure 4. Factors determining changes in EU hen sector. Source: own elaboration.

In brief, long-lasting pressures from animal welfare organizations and supporters result in positive reactions from individual consumers [43] and, more recently, retail chains and food processors. At the same time, science and technological advancements enable a smooth, relatively effective switch of the sector to alternative hen-housing systems, largely induced and strengthened by EU policy makers' regulative activities.

3. Materials and Methods

3.1. Conceptual Framework and Sources of Data

The farm-level consequences of the proposed ban on the use of enriched cages for housing laying hens were analyzed using the following conceptual framework (Figure 5).

The impact assessment was carried out in three stages (Figure 5). In the first stage, assessments were performed for a sample of farms based on the results of a farm survey with input from the literature review and poultry experts. The costs of transformation to alternative systems calculated at this stage were then fed into the CAPRI model (The Common Agricultural Policy Regional Impact (CAPRI) model is a global partial equilibrium model for the agricultural sector with a focus on the European Union. It has been designed for ex ante impact assessment of agricultural, environmental, and trade policies [44]), which supplied the second stage farm-level assessments with parameters, mainly the egg yields, prices, and production volume, determined for a market equilibrium after the full transition. The methodology of CAPRI estimation for this study was published by Potori et al. [45]. Due to brevity, we refrain from presenting the CAPRI methodology here. Finally, the results of the assessments for the sample of farms were aggregated to the EU-27 sector level.

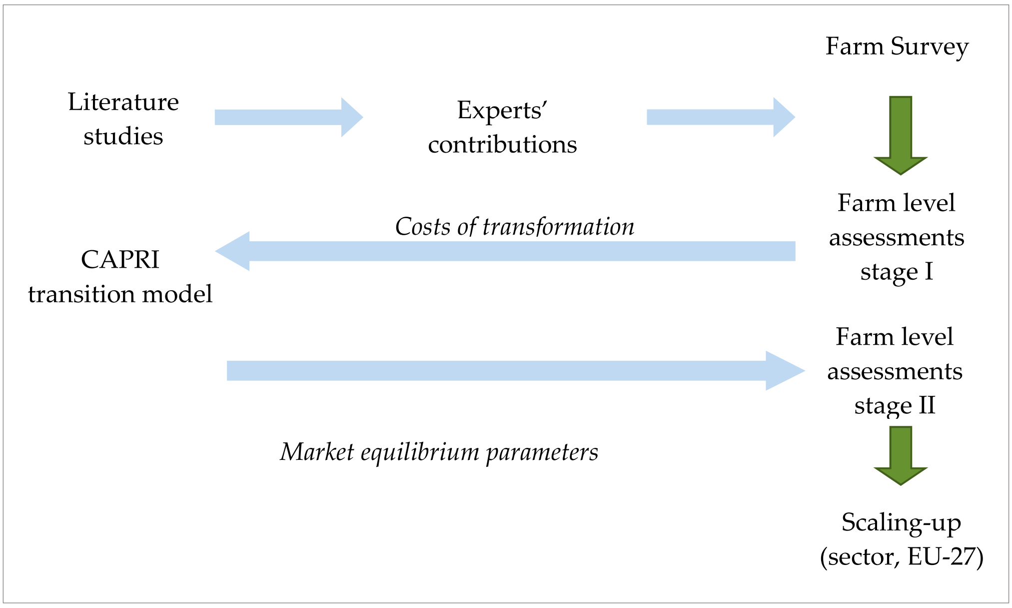

Figure 5. Conceptual framework for farm-level assessments. Green arrows indicate step to next stages of analysis, blue arrows transfer of information. Source: own elaboration.

The primary data source for the farm-level assessments was the Farm Survey conducted in 2021 across several EU countries, representing both "old" and "new" Member States. Only countries with a share in the total number of hens in EU-27 exceeding 2% and/or keeping at least 10% of hens in enriched cages have been considered in the analysis. The questionnaire was delivered through farmer organizations and conducted in the following countries (in brackets is the share of the lying hen population in the EU-27 [42]).

- West-EU:—France (12.8%), Spain (12.5%), Italy (10.8%), Portugal (2.7%), Greece (1.2%), Ireland (1.0%);
- East-EU:—Poland (13.6%), Hungary (2.0%), Romania (2.4%), Czechia (2.0%), Bulgaria (1.4%), Slovakia (0.8%), Latvia (0.9%), Croatia (0.6%), Estonia (0.2%).

The survey questionnaire was designed to cover the following sections:

- General information about the egg production sector: number of hens, mortality rates, types of housing for hens, and employment;
- Production related data: yields, volume of sales, the distribution of eggs in size classes, and the breakdown of egg sales for consumption and industrial use;
- Inputs: feed, pullets, bedding materials, energy, water, etc.;
- Financial data: prices and costs (e.g., veterinary expenses, other services);
- Farmers' declarations on their likely choice of an alternative hen-housing system after the introduction of the ban. An "exit" option from egg production was also provided.

Convenient sampling methods were employed in the survey process. Farmers were contacted by researchers or farmer organizations. We are convinced that the sample reflects quite well the structures of the laying hen sector, and the tests made for a number of indicators show that the results do not differ significantly from what can be found in the literature. Different approaches were utilized for data collection, including an online questionnaire completed by individual farmers and face-to-face and telephone interviews.

In addition to the survey data, information was also gathered from experts' opinions, farmer organizations, and statistics related to egg production.

Four housing systems were taken into consideration:

- Enriched Cages—as the baseline and alternative systems to replace the still-existing enriched cages;
- Voliera (Barn eggs);
- Free-Range;
- Organic.

The farm-level impacts were aggregated to the EU-27 level. The results were weighted based on the structure of the laying hen flock in the EU Member States and the percentage of hens kept in different housing systems.

3.2. Transition Scenarios and Structure of Farms/Hens after Transition

The key assumption was that the transition period for switching from the existing cage system to alternative hen-housing systems would conclude in 2035, whereas 2021 was chosen as the reference year. The four scenarios reflect the anticipated reactions of the farmers using cages to the ban. It influences the likely reallocation of hens to different housing systems, depending on the preferences declared in the Farm Survey, including the option to "exit" from egg production.

The number of hens shifted to alternative housing systems, reflecting the farmers' declarations, was reduced due to the requirement of lower densities of hens per square meter in the respective systems.

The scenarios are described below:

Scenario S1—"Extreme Exits"

In cases where farmers declared resignation from continuing egg production, the respective number of hens was moved out of the sample. It was further assumed that there would be no new entrants, and the "exited" hens would not be acquired by farmers continuing production. The remaining hens from the sample kept in cages in 2021 were moved to alternative housing systems (Voliera, Free-Range, Organic) in proportions calculated based on the preferences declared in the survey.

Scenario S2—"No Exits"

This scenario creates another extreme situation, assuming that all farmers continue production despite exit declarations from the survey. Consequently, all hens kept in cages in the base year 2021 were moved into alternative systems. This scenario serves as a reference for other, more likely alternative scenarios.

Scenario S3—"Modified Exits"

It was very likely that negative emotions drove exit declarations of some farmers due to a lack of acceptance of the proposed regulations. Thus, the survey exit declarations were modified, assuming that the final decisions of the farmers would be more rational, resulting in a lower number of exits than initially declared in the survey.

To estimate the probability of exits, a linear interpolation was used for all farms in the sample, taking into account three criteria simultaneously:

- The flock size: for less than 25,000 hens, the probability of exits was assumed at 100%, and for more than 120,000 hens—0%;
- Farmers' age: for less than 45 years—probability 0%; for older than 60 years—probability 100%;
- The existence of a successor (% of likelihood): if no successor—the probability 100%, and succession is confident—the probability of exit 0%.

The estimated overall probability of exit from the egg production sector by individual farms was calculated by multiplying the presented above partial probabilities.

If the overall probability was 100%, such farms and flocks were excluded from production. The probability of exits within the 1–99% range determined the proportion of hens moved out of production from the respective farms in the sample.

Scenario S4—"Market Equilibrium"

In this scenario, which can be considered a variant of S3, egg production and egg prices were set at the market equilibrium levels estimated in the CAPRI model [46]. The equilibrium was reached with the drop of egg supply by 2.0% and drop in demand by 0.6%. It suggests a low demand price elasticity and results in a moderate price increase. Based on the CAPRI model results, it was assumed that the producer price increases by 3.5%, and the consumer price increases by 1.5%. According to the CAPRI model, the production of eggs will not be affected by imports in this scenario. The EU egg sectors' exports exceed imports, and considering a relatively low decrease in egg production, the EU still remains the net exporter of eggs. Exits were planned at the level as in the S3 Modified Scenario. However, to achieve the CAPRI estimated production of eggs, in addition to the cage replacements, investments in new capacities were considered, allowing for the CAPRI egg production level to be reached. Despite a small drop in egg production, investments in new buildings are required to compensate for the potential exits of small-scale producers and assumed yield decreases in alternative housing systems.

The transfer of hens from cages was adjusted to the estimated likelihood of exits, also considering reduced stocking density in alternative systems. Exit assumptions for two extreme scenarios were made as follows: $S1_{exits}$—100% of exits as declared by farmers, and $S2_{no\text{-}exits}$—zero exits. The estimation procedure for the Scenarios $S3_{modified}$ and $S4_{market\ eq}$ was presented in the description of the S3 scenario.

Following this procedure, the final structure of farms and hens in alternative systems after the transition was estimated. The number of hens remaining in production after estimated exits was adjusted, accounting for lower densities assumed for alternative systems.

3.3. Key Indicators and Parameters Used in Farm-Level Assessments

The gross margin, which represents the difference between the value of production and direct costs, is used to assess the financial impacts of the ban on cages. The value of production encompasses the revenues generated from the sale of eggs and slaughtered end-of-lay hens. On the other hand, direct costs include the expenses related to feed, labor, the purchase of one-day chicks, other materials, and services (including veterinary care). Depreciation resulting from necessary investments, such as equipment replacing cages in all scenarios and investments in new buildings in Scenario S4 ("Market Equilibrium"), was also taken into account.

Fixed 2021 prices were used to calculate the financial results. This approach allows for us to isolate the assessment of impacts resulting from the transition to alternative housing systems due to the ban on cages, regardless of the long-term trends in price and cost fluctuations.

The technical parameters related to productivity and inputs in the gross margin calculations reflected differences between cage and non-cage production systems. The assumptions were based on contributions from poultry experts (researchers, advisors, and members of farmer organizations) and a literature review (Table 2).

Table 2. Basic technical parameters for gross margin calculations (enriched cages = 100).

Parameters	Justification for the Change	Housing System		
		Barn (Voliera)	**Free-Range**	**Organic**
Feed consumption per hen	Increased mobility (reduced density, access to outdoor space)	102.2	104.3	108.7
Price of feed	Certified feed in organic production	100	100	135
Average weight of eggs	-	100	95	95

Table 2. *Cont.*

Parameters	Justification for the Change	Housing System		
		Barn (Voliera)	Free-Range	Organic
Yield of eggs (number/hen/year)	-	97	85	85
Higher mortality rates	Mobility, risk of diseases (FR, organic)	102	103.9	103.9
Veterinary costs per hen	As above	100	111	111
Energy costs per hen	Lower density (less hens)	117.6	142.8	142.8
Labor costs per hen	Additional input of labor, deteriorating working conditions	122.1	127.6	133.2
Price of pullet	Adaptation to the housing system	100	110	125
Price of eggs	Market relations *	109	135	170

Source: own elaboration. * Derived from average prices calculated for the set of EU countries noted in [47].

4. Results

4.1. Characteristics of the Sample

The parameters characterizing the sample of farms are presented in Table 3. The farms in the sample were grouped into clusters based on geographic location (Eastern and Western EU) and flock size, which was categorized as small (below 30 thousand hens), medium (30–100 thousand hens), and large (above 100 thousand hens).

Table 3. Basic characteristics of the sample.

Farm Cluster	Number of Farms	Total Number of Hens ('000)	Number of Hens/Farm	Egg Yield per Hen	Number of Fully Employed per '000 Hens
East-EU	108	11,525	106,711	303	0.110
West-EU	63	13,893	220,516	306	0.075
Sample	171	25,418	148,639	304	0.090
Small (<30 k)	57	659	11,558	308	0.192
Medium (30–100 k)	48	2979	62,052	301	0.090
Large (>100 k)	66	21,780	330,000	305	0.087

Source: own elaboration.

These characteristics reveal significant differences between the sample clusters. The flocks of hens in the West-EU are approximately twice as large as those in the East-EU. This is mainly due to the prevalence of small farms in some of the new member states from Eastern and Central Europe (such as Poland, Hungary, Romania), where the consolidation of the livestock sectors is less advanced.

The number of employees per thousand of hens shows a clear correlation with average flock sizes. A very high value of this indicator suggests an excessive amount of labor in the smallest farms, which can impact labor efficiency and, ultimately, financial results.

Egg yields did not exhibit significant deviations, remaining highly comparable across the sample. This consistency can be attributed to the highly standardized technology of egg production.

Table 4 presents the likely choices of alternative hen-housing systems after the ban on cages, which is a key parameter for the assessments.

In the survey, the majority of respondents declared their intention to transition to Voliera (Barn) with 45.03% choosing this option. However, almost an equal percentage of farmers (42.11%) selected the "exit" response. The high number of farmers considering exit can be explained, to some extent, by the likely frustration of producers who invested in enriched cages 11 years ago and are now facing new, radical changes and costly investments.

Table 4. Transition decisions as declared by farmers: % of farms, (% of hens).

Farm Cluster	Voliera (Barn)	Free-Range	Organic	Exit	Total
East-EU	45.37 (49.5)	11.11 (14.6)	1.85 (1.5)	41.67 (34.4)	100.0
West-EU	44.44 (66.3)	11.11 (12.9)	1.59 (0.1)	42.86 (20.7)	100.0
Sample	45.03 (58.7)	11.11 (13.7)	1.75 (0.7)	42.11 (26.9)	100.0
Small (<30 thousand)	24.56 (29.2)	5.26 (5.6)	3.51 (3.9)	66.67 (61.3)	100.0
Medium (30–100 thousand)	56.25 (55.0)	14.58 (16.7)	0.00	29.17 (28.3)	100.0
Large (>100 thousand)	54.55 (60.1)	13.64 (13.5)	1.52 (0.7)	30.30 (25.6)	100.0

Source: own elaboration.

There are also rational reasons for this choice, as the "exit" option was mainly selected by small-scale producers (66.67% in the cluster of farms with flocks below 30 k hens), often nearing or already past retirement age and without a successor. Some producers mentioned in their comments that they see no chance of achieving a return on investment in the remaining years of their professional activity. Relatively few respondents indicated free-range and organic as their choices.

If the farmers' declarations were confirmed in reality, the share of hens (values in brackets in Table 4) transitioning to alternative systems and exiting corresponds with the percentage of responses. However, the distribution is slightly different due to the uneven number of hens in individual clusters of farms. On average, in the sample, 26.9% of hens would exit production, assuming there were no new entrants to the sector and no capacity-expanding investments by those farmers who chose to stay in business.

The combined effect of exits and the reduced density required in alternative systems would be even more profound. However, by modifying the number of exits, as explained in the methodological section, the transition of hens still kept in enriched cages to the barn, free-range, and organic systems occurs in proportions of 81.5%–17%–1.5%, respectively.

4.2. Impact of the Ban on Enriched Cages on the EU Egg Production Sector—Aggregation Results for EU-27

Table 5 presents the number of hens in different housing systems and egg production in the EU-27 in the year 2021.

Table 5. Number of hens and egg production in the EU-27—2021 baseline.

Countries	Number of Hens	Enriched Cages	Barn	Free-Range	Organic	Total
East-EU	millions	67.4	22.5	3.8	0.9	94.6
	share %	71.2	23.8	4.0	1.0	100.0
West-EU	millions	101.4	111.4	44.5	24.0	281.3
	share %	36.0	39.6	15.8	8.5	100.0
EU	millions	168.8	133.9	48.3	24.9	375.9
	share %	44.9	35.6	12.8	6.6	100.0
Countries	Egg Production	Enriched Cages	Barn	Free-Range	Organic	Total
East-EU	thousand tonnes	1256	408	57	13	1734
West-EU		2015	2148	714	374	5251
EU		3260	2510	753	377	6900

Source: own elaboration.

In 2021, approximately two-thirds of all laying hens in the EU-27 were in the Western EU countries; the remaining third were in the Eastern new Member States. The distribution of hens between housing system differed noticeably with the majority of hens in the East-

EU still kept in enriched cages (71.2% against 36% in the West-EU). As a result, more hens in Western EU countries transitioned to alternative systems.

The proportions in the egg production structure were similar. Figure 6 presents the changes in the number of hens after transitioning all hens from enriched cages to alternative systems in the year 2021.

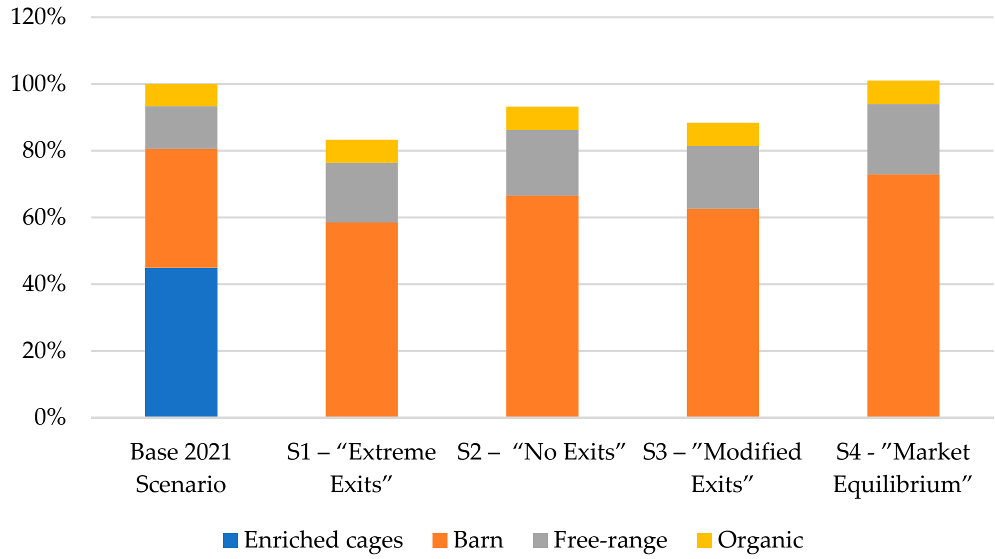

Figure 6. Aggregated impacts of the ban on enriched cages—hens in housing systems and transition scenarios (2021 baseline = 100%). Source: own elaboration.

Unsurprisingly, Scenario S1 ("Extreme Exits") seriously drops the number of hens. As in all other scenarios, this effect is reinforced by the required reduction in hen stocking rates. In Scenarios S2 and S3, the number of hens remains below the 2021 baseline. Only in Scenario S4 ("Market Equilibrium"), which is based on the volume of production and egg price levels generated with the CAPRI model, does the number of hens reach and even slightly exceed the 2021 reference.

The distribution of hens in the respective housing systems remains very similar across all scenarios.

Since egg yields were very similar across different countries and farm types, egg production, as shown in Table 6, is closely tied to the variations in the number of hens within the respective scenarios.

Table 6. Production of eggs aggregated to the EU-27 level (thousand tonnes).

Scenario/Housing System	Enriched Cages	Barn	Free-Range	Organic	Total
2021 baseline	3260	2510	753	377	6900
S1—"Extreme Exits"	0	4154	1057	396	5607
S2—"No Exits"	0	4688	1153	398	6239
S3—" Modified Exits"	0	4427	1106	396	5929
S4—" Market Equilibrium"	0	5232	1265	415	6912

Source: own elaboration.

Figure 7 presents the structure of egg production in different housing systems and geographic regions under the "Market Equilibrium" Scenario.

Considering the initial 2021 situation and the likely transitioning decisions reported by surveyed farmers, barn eggs are expected to dominate total egg production, accounting for approximately 80% on average. In the East-EU countries, the share of barn eggs surpasses the EU average, while the share of organic eggs (1.6%) is considerably lower compared to 8.5% in the Western EU countries. This distribution may shift in favor of free-range and organic eggs over time, contingent upon farmer declarations, consumer preferences for premium-priced eggs, and market dynamics. However, the proportions may change in the long-term depending on market conditions and consumer behavior.

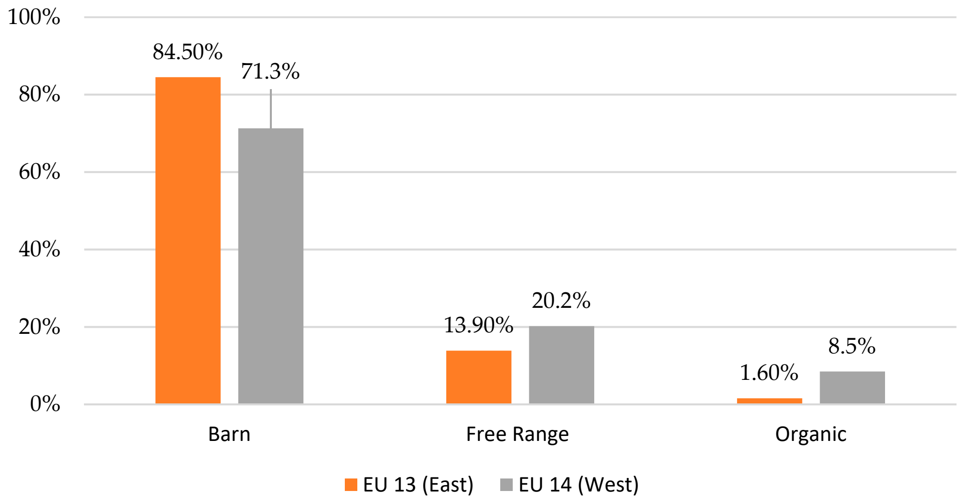

Figure 7. Structure of egg production in the "Market Equilibrium" Scenario from alternative systems. Source: own elaboration.

4.3. Financial Consequences of the Ban on Enriched Cages

Several factors impact the financial consequences of transitioning to alternative egg production systems, which we measured in our study using gross margin. Lower productivity from unit area (m^2) due to reduced densities and lower yields compared to cages has a negative effect on the value of production despite higher average prices. On the cost side of the gross margin equation, depreciation on the value of additional equipment replacing existing cages is a significant factor in all scenarios. Additionally, depreciation resulting from investments in new buildings for hens in the "Market Equilibrium" Scenario is the main cost-increasing factor. Furthermore, the higher cost of feed, pullets, and labor per unit of production in alternative systems relative to enriched cages results in increased average production costs after the transition.

The values of gross margins from different housing systems are presented in Table 7.

Table 7. Gross margins from different housing systems and scenarios.

Scenario	Enriched Cages	Barn (Voliera)	Free-Range	Organic	Mean
		EUR/kg Eggs			
2021 baseline	0.127	0.138	0.145	0.164	0.135
S1—"Extreme Exits"	-	0.160	0.171	0.200	0.165
S2—"No Exits"	-	0.138	0.145	0.164	0.141
S3—" Modified Exits"	-	0.148	0.156	0.179	0.152
S4—" Market Equilibrium"	-	0.070	−0.143	−0.239	0.012
		Ratio: Enriched Cages = 1.0			
S1—"Extreme Exits"	1.00	1.26	1.35	1.57	1.30
S2—"No Exits"	1.00	1.09	1.14	1.29	1.11
S3—" Modified Exits"	1.00	1.16	1.23	1.41	1.19
S4—" Market Equilibrium"	1.00	0.54	−2.09	−2.82	0.10

Source: own elaboration.

Gross margins in all housing systems of the alternative Scenarios S1–S3 are noticeably higher compared to enriched cages. This is despite higher costs and lower productivity per square meter due to premium prices strongly favoring alternative systems (mainly free-range and organic) in the base year 2021 (see Table 2). Notably, the gross margins in Scenario S1 ("Extreme Exists") are significantly higher than those in Scenario S2 ("No Exits"). This is because the farms discontinuing egg production in Scenario S1 are generally smaller and less-effective.

The "Market Equilibrium" Scenario results in a significantly lower gross margin due to two main factors:

- Average egg prices are, as simulated with the CAPRI model, much lower compared to the 2021 price levels from alternative scenarios in the base year 2021;
- Depreciation resulting from investments in additional buildings for hens, which are required to reach the CAPRI model market equilibrium, is increased.

Figure 8 presents the value of estimated necessary investments. Transforming the remaining farms with enriched cages will necessitate a substantial investment effort. In Scenarios S1–S3, where expenditure is only required to equip existing buildings with new equipment, the investment value will range from EUR 2 billion (S1) to approximately EUR 2.6 billion (S2). The value of investments in the "Market Equilibrium" Scenario would increase to over EUR 3.2 billion, encompassing investments in additional buildings as well.

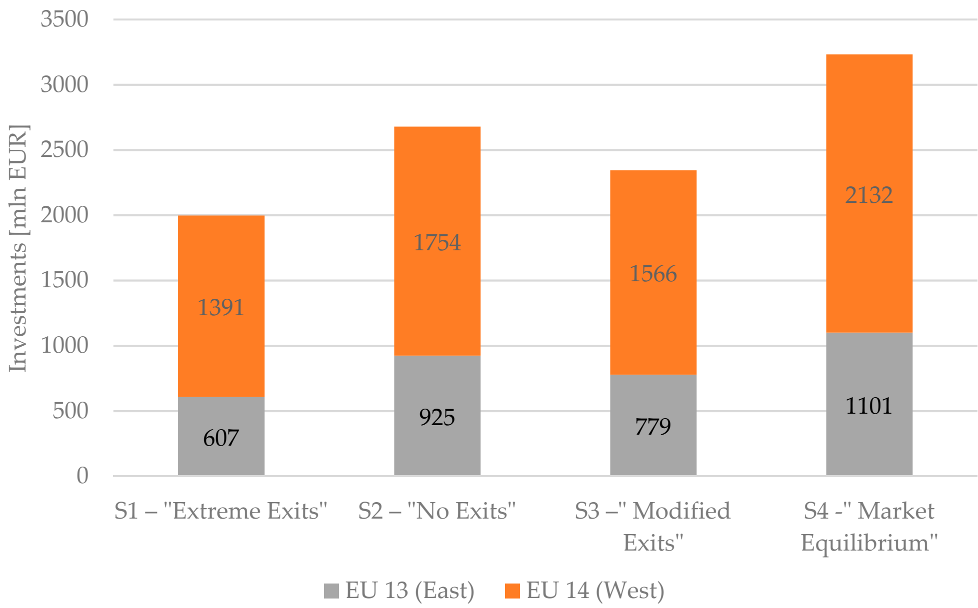

Figure 8. Investments in buildings and equipment in respective scenarios (million EUR in 2021 prices). Source: own elaboration.

It should be emphasized that the investment outlays were estimated at 2021 prices. Considering the inflation processes observed in the period 2022–2023 and the probable high levels of energy and raw material prices in the following years, transition investments would pose a significant burden for the sector affected by the ban on enriched cages.

5. Discussion and Conclusions

When assessing the merits and demerits of various hen-housing systems, it is crucial to recognize the diverse and sometimes conflicting assessments found in the literature. Rakonjac et al. [48] argue that the disparities in research findings are often attributed to various factors that can influence these systems' performance. These factors include genotype, age, diet, and numerous components of the feeding environment. For example, while most studies indicate higher egg production in conventional cage systems compared to alternative housing systems, some reports suggest no significant difference in egg production by hens [22].

Furthermore, research results concerning egg quality can be inconclusive. Castellini et al. [27] point out that caged eggs may have poorer quality parameters. However, other studies, including those by Dikmen et al. [3], Kraus et al. [49], and Matt et al. [50], propose that alternative systems do not necessarily outperform enriched cages when it comes to egg quality. Therefore, although alternative systems provide greater freedom of movement, the effects of housing these systems on the health of hens, performance, and product quality often remain a contentious topic in the literature.

The process of transitioning away from cage systems for laying hens, initiated in the early 1990s, is an ongoing endeavor in the EU countries. Some of these, including Austria and Luxembourg, have eliminated enriched cages, while others, like Germany and Sweden, have restricted their use. Additionally, there are plans by the European Commission to implement a ban on keeping laying hens in cages.

At the turn of 2021/2022, this ban affects 44.9% of the 375.9 million hens. The analysis based on data from the Farm Survey and expert knowledge indicates that the ban's impacts will vary depending on how the producers using cage systems react and the specific scenario of further transformation. For this analysis, four scenarios were constructed.

The first two scenarios, "Extreme Exits" (S1) and "No Exits" (S2), are less likely and serve as reference points. They assume no new investments to increase the current capacities of the sector. Similarly, the "Modified Exits" (S3) Scenario envisions no new investments, but it assumes that farmers from small farms without successors who are nearing or exceeding retirement age may withdraw from production. In each of these scenarios, egg production decreases in proportion to the changes in the number of farms continuing to operate.

Conversely, the "Market Equilibrium" (S4) Scenario, which presents a more realistic outlook, envisions that egg production in the EU will remain at the 2021 level unless there are no significant deteriorations in business conditions in this sector. However, unlike other scenarios, Scenario S4 requires substantial investment in additional capacities. Due to the relative decline in the average price of eggs from alternative systems in the "Market Equilibrium" Scenario compared to the constant prices in 2021 as assumed in the remaining scenarios, the profitability of egg production will deteriorate.

Adhering to the theory of diffusion of innovations [51], this also signifies that the beneficiaries of this transformation will remain primarily early adopters who have already embraced the change in the initial phase of the diffusion curve. As innovation implementation progresses through its initial phases (innovators, early adopters, early majority), the scale of implementation steadily increases, reaching 50% of the market share by the end of the "early majority" phase. This potentially leads to cumulative benefits, although their growth rate decreases after the "early adopters" phase.

However, as the scale of implementing alternative hen-housing systems has already surpassed the peak established by the "early majority" phase, farmers who transition in the future will find themselves in the subsequent phases of the innovation diffusion curve, namely the "late majority" or even "laggards". For these producers, any financial gains may dwindle as the supply of eggs from alternative systems continues to expand. This awareness and the risk of costly investments might be among the factors fueling opposition to the European Commission's plans, particularly among farmers who currently keep laying hens in enriched cages.

At the same time, the critical question arises whether it is imperative to introduce a legal obligation to phase-out enriched cages at the current stage of transitioning in the sector. Implementing such a ban on cages could accelerate the demise of small-scale producers, further consolidating the sector. From a market perspective, these changes may lead to a relative increase in egg prices, potentially impacting less affluent consumers. It is worth noting that prior research has not conclusively demonstrated an improvement in animal welfare, health, and egg quality [1,3,15,21–25,49,50], a point emphasized by producers reluctant to abandon enriched cages.

Perhaps the best approach is to let market mechanisms drive this issue, although this would be harmful to small-scale producers as would the planned ban on cages. Statistical data analysis indicates that European farmers are gradually transitioning to alternative hen-housing systems. This shift is partly due to changes in national legislation related to animal welfare and, to a significant extent, the influence of the market, trade organizations, and, more recently, food processors, which are actively contributing to this transformation.

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