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Unraveling the effects of import bans on domestic poultry production: a case study of Senegal

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Abstract

Senegal banned all imports of uncooked poultry meat in 2006 in response to Avian Influenza outbreaks in many exporting countries. This paper investigates the effects of the import ban on domestic chicken meat production and the performance of Senegal's broiler farms. To do so, we employ various comparative analyses at the farm and macro levels. We use the synthetic control method to estimate the effects on total production, which shows that Senegal's chicken meat production increased more than it would have without the import ban. This may imply, in line with the infant-industry argument, that the ban has had a positive impact on chicken meat production. In addition, we use a farm-level analysis to evaluate the performance of typical Senegalese broiler farms. The comparison with Ghana shows that Senegalese farms are performing better and have lower costs of production. An opening of the markets should only be implemented gradually, by replacing the ban with tariffs because local industries must have the opportunity to adapt to the competition of the international market step by step.

Keywords: Poultry meat, Import ban, Infant industry, Senegal, Trade

JEL Classification: Q12, Q18

Introduction

Poultry meat[1] is an important source of animal protein in Senegal. Although many Senegalese rely on marine fish for the majority of their animal protein intake, consumption of poultry meat, particularly chicken meat, is rapidly increasing (Arnoldus et al. 2021; Netherlands Enterprise Agency 2019). At the beginning of the 2000s, Senegal was one of many African countries that imported large quantities of frozen chicken meat to meet rising demand (Johnson 2011). However, this pattern didn't last for long. In 2006, Senegal banned all imports of uncooked poultry meat in response to widespread Avian Influenza outbreaks in many countries.[2]

[1] The most important type of poultry meat is chicken meat (in terms of production and consumption) in Senegal. Thus, we use the terms of "poultry meat" and "chicken meat" interchangeably throughout the paper.

[2] Please see Trade Map (https://www.macmap.org) for the underlying documents of the ban and for other trade restrictions of Senegal.

The poultry meat ban remains in place, shielding the poultry industry from Avian Influenza outbreaks as well as frozen chicken import competition. The ban is the most significant policy intervention in the poultry meat sector at the moment. As a member of the World Trade Organization (WTO),[3] Senegal cannot maintain a trade restriction indefinitely. Nevertheless, there have been instances where certain exemptions were granted under specific conditions. Notable examples include Switzerland, which has implemented import restrictions using seasonal Tariff Rate Quotas (TRQs) since 1990, Russia, which selectively banned certain markets since 2014, and the European Union (EU), which imposes seasonal bans on all countries except its member states (Goetz and Grethe 2009; Loginova et al. 2021; Loginova and Irek 2022). Thus, the country will have to lift the ban once the risk of outbreaks has passed. However, as an infant industry, it is not yet able to compete effectively with imported products. According to the infant-industry argument, protecting the Senegalese poultry sector may help domestic producers become more competitive in the long run. The empirical findings on this argument, however, differ between developing and developed countries. The industry's capacity for learning and the role of temporary protection in stimulating productivity have a substantial impact on the ultimate outcomes of trade protection measures (Melitz 2005). Considering this, the objective of this paper is to assess the effects of the import ban on poultry production in Senegal. The study aims to assess the implications of the ban and offer insights on strategies to bolster the industry during the post-ban period.

Despite the prolonged and contentious debate surrounding poultry meat imports, empirical studies investigating the effects of trade restrictions in West Africa, especially in Senegal, remain scarce. Recent research has focused on evaluating the potential impacts of poultry trade bans in other West African countries, such as Ghana, from both producer and consumer perspectives (Zamani et al. 2022; Knößlsdorfer and Qaim 2023). Furthermore, Boimah and Weible (2021) have assessed the impact of Senegal's poultry import ban from a consumer perspective using focus group discussions.

This study aims to contribute to the existing literature in three ways. Firstly, our analysis seeks to evaluate the effects of the total ban on poultry production in Senegal. While there are reports of domestic production progress following the ban (e.g., Killebrew et al. 2010), to the best of our knowledge, no empirical study has yet investigated the impact of the poultry import ban on Senegal's poultry production. Furthermore, our study examines the effects of the ban not only on the macro level of poultry production but also on different types of farms at the farm level. Thirdly, we employ an analytical framework that encompasses various stages of the poultry value chain. Although the different components of the framework are not directly integrated (i.e., hard integration), the results provide insights into effects at both the farm and macro levels.

To begin, we estimate the production trend in the absence of the trade ban to assess the effects of this policy intervention on poultry meat production using a data-driven Synthetic Control Method (SCM). This technique has recently gained significant attention in agricultural economics literature for assessing various agri-food policies (e.g., Olper et al. 2022; Luo et al. 2022). The SCM identifies comparable countries that can

[3] For more information please read: https://www.wto.org/english/tratop_e/markacc_e/qr_e.htm.

serve as a proxy for replicating Senegal's poultry meat production trade. Additionally, we examine how the ban on poultry meat imports may have influenced the performance of broiler farms in Senegal using the typical farm approach. Due to the lack of pre-ban farm data in Senegal, we compare Senegalese broiler farms with those from a country that would have been similar to Senegal if the ban had not been imposed. The combination of these two methods allows us to contribute to the understanding of the effects of the import ban at both macro and micro levels. The rest of the paper is organized as follows. "An overview of the Senegalese poultry meat sector" section provides an overview of the Senegalese poultry meat sector. "Trade restrictions and infant-industry protections" section reviews relevant literature on trade restrictions, specifically focusing on the infant-industry argument. In "Methods" section, the data of our analysis are discussed. "Data" section outlines the frameworks used to evaluate our hypothesis. The findings are then discussed in "Results" section, followed by a discussion in "Discussion and policy implications" section.

An overview of the Senegalese poultry meat sector

Although marine fish plays a large role in meat consumption in Senegal (about 70%), poultry meat is the second most important source of animal protein intake (FAOSTAT 2021). Typically, chicken meat is consumed weekly or at events and festivals (Arnoldus et al. 2021). Upper-income households who represent about 10% of the population are able to buy pre-packaged frozen and slaughtered chicken meat from modern supermarkets (Netherlands Enterprise Agency 2019). Overall, slaughtered chicken is increasingly available in large cities, such as Dakar. However, over 90% of Senegalese purchase poultry from open-air markets (Arnoldus et al. 2021).

Senegal's trade policy aligns with the objectives of the Economic Community of West African States (ECOWAS), which aims to foster economic integration through the establishment of a common internal market and external protection. To achieve this, the ECOWAS has implemented a Common External Tariff system. In the case of poultry meat, the tariff rate is set at 35%, representing the maximum rate under the ECOWAS Common External Tariff. However, Senegal's bound tariff, as defined by the WTO, must fall within the range of 15–30%. This presents a challenge for policymakers when the trade ban is lifted because they will need to address this inconsistency. To resolve such issues, negotiations are taking place among ECOWAS member states to find suitable solutions (WTO 2017).

Pre-ban period (before 2006)

Before the ban on poultry imports in 2006, Senegalese poultry production increased by 78% from 16 to 29 thousand tons. However, the sector significantly relied on imports to meet the domestic demand for poultry products, particularly from 2002 to 2005 (Fig. 1). For instance, imports constituted approximately 30% of domestic consumption in 2005. The applied tariff on chicken cuts underwent a series of reductions. Before 1998, the tariff stood at 55%, but it was gradually lowered to 30% in 1999, 25% in 2000, and finally to 20% in 2002. Our estimates indicate a slight increase in per capita consumption of

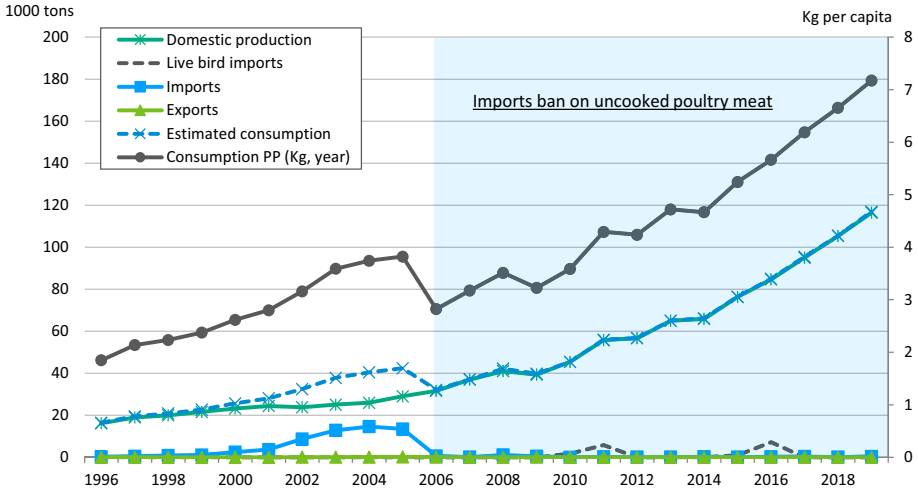


Fig. 1 Development of the Poultry Meat Sector in Senegal from 1996 to 2019 (in 1000 tons). *Note*: The domestic consumption is estimated based on imports + production − exports. To estimate the consumption per capita, we use data from various sources, including import and export figures extracted from UN Comtrade and domestic production data provided by FAO. The consumption per capita is calculated using the formula: Consumption = production + imports − exports. Additionally, we project the per capita consumption using population data provided by the World Bank. *Source*: Exports and imports are based on UN Comtrade (2021), HS code: 0207. Production data are retrieved from FAOSTAT (2021)

chicken meat increased from 2.2 kg per person in 1998 to 3.8 kg in 2005 (Fig. 1).[4] The domestic poultry industry perceived imports of frozen chicken as a threat, prompting poultry producers to advocate for protectionist measures. In 2002, the Senegalese government initially imposed a ban on frozen chicken imports in response to the situation. However, this ban was eventually lifted under the influence of importers and consumers (Boimah and Weible 2021). Nevertheless, in 2006, the government took a proactive measure by reinstating the ban on the import of live poultry, edible poultry meat and offal, and poultry products to safeguard against potential avian influenza outbreaks, which remain in effect to this day.

Post-ban period (after 2006)

Following the ban, domestic consumption of chicken in Senegal experienced a significant decline. During the post-ban period, domestic production significantly increased by 268% from 2006 to 2019. After 2006, almost no imports of poultry products and live birds took place, except for the years 2011 and 2016 (Fig. 1). Although not substantial, some poultry products from Senegal are exported to neighboring countries such as Gambia and Guinea Bissau (Boimah and Weible 2021). Despite the import ban, Senegal imports live birds in the form of day-old chicks for its local poultry production (Boimah and Weible 2021). Generally, this occurs when domestic hatcheries are unable to meet local demand, such as in 2011 and 2016. Under normal circumstances, domestic

[4] Although the FAO has not provided specific dietary guidelines for Senegal, it is worth noting that the country's estimated consumption of poultry meat is comparatively lower than the recommended levels observed in other West African countries, such as Ghana and Benin. For more information check: https://www.fao.org/nutrition/education/food-based-dietary-guidelines.

hatcheries import fertilized eggs which are hatched locally and then sold to broiler or layer farms (Killebrew et al. 2010). Since 2004, the number of domestic hatcheries has increased from 10 to 70 (Netherlands Enterprise Agency 2019). Based on our estimates, the per capita consumption of chicken meat has significantly increased from 3.51 kg per person in 2007 to 6.65 kg in 2019 (Fig. 1). However, it is still lower than the average for West Africa which is 14.8 kg per capita (Arnoldus et al. 2021).

Trade restrictions and infant-industry protections

This section reviews the current literature on trade restrictions (trade bans and tariff policies) and elaborates on the infant-industry argument in the agricultural sectors of African countries. An import restriction including a trade ban is prohibited for member countries according to the WTO. However, there are some exemptions under defined conditions such as safeguarding mechanisms, and human, livestock, and plant health-related issues (see GATT 1994 Article XI). Aiming at increasing self-sufficiency—through protecting domestic producers—and preventing animal disease outbreaks, import restrictions have drawn particular attention among West African policymakers (Akunzule et al. 2009; Johnson 2011; Naggujja et al. 2020).

Existing literature shows that the effects of an import ban vary from country to country. Trade restrictions along the value chain have different effects on producers and consumers. Implementing an import ban on key inputs for poultry production, such as maize, can result in a rise in production costs (Andam et al. 2017). These increased costs may then be transferred to the consumer, leading to higher consumer prices for chicken meat. Supporting this notion, Loginova and Irek (2022) found that domestic producer prices for livestock products experienced a significant increase in Russia following a trade ban. In the past, several African countries, including Nigeria, Ghana, and Senegal, have implemented partial or complete bans on chicken imports as part of their trade policies. In their study, Zamani et al. (2022) examined the effects of a partial import ban on the poultry sector in Ghana. This ban restricted imports from certain countries while allowing imports from others, which created the potential for trade diversion. The study found that the total imports of corresponding products in Ghana experienced only minor changes following the partial ban, due to a 'cushioning' effect. However, the researchers noted that a complete ban would increase domestic production by up to 250% and that large-scale farms are better positioned to increase production than small and medium farms. However, an import ban in Ghana would eliminate tariff revenues from poultry imports and the overall welfare in the country would decrease. Knößlsdorfer and Qaim (2023) evaluated the impact of import restrictions on Europe's chicken exports to Ghana, focusing on the welfare effects for different population groups. The findings suggest that implementing import restrictions, such as a 50% tariff or a complete ban, would lead to increased domestic chicken prices, negatively affecting consumption and overall welfare. In this line, Boimah and Weible (2021) assessed the effects of Senegal's poultry import ban on consumers. Their study reveals positive outcomes for the domestic poultry sector, including job creation and decreased chicken prices. However, the research also uncovered concerns from specific consumers who prioritize convenience, product diversity, and safety, as they felt neglected by the ban.

In Nigeria, the complete ban has led to a reduction in the per capita consumption of chicken meat from an annual average of 1.32 kg per person from 1995 to 1999 to an annual average of 0.85 kg per person from 2011 to 2015 (Andam et al. 2017). Furthermore, Andriamananjara et al. (2009) and Golub (2012) highlight the impact of poultry trade restrictions on an increased tendency to illegal trade (smuggle) frozen meat. In contrast to Nigeria, an inspection of time-series data shows that consumption in Senegal has increased as a result of the import ban (FAOSTAT 2021).

The effects of the protectionist policies in the poultry sector of Senegal can be explained by an infant-industry argument for the protection of import-competing industries. This argument has a long and overwhelmingly theoretical background in the literature (e.g., Baldwin 1969; Clemhout and Wan 1970; Bardhan 1971). The theory of infant-industry protection was first introduced at the beginning of the 19th century to justify safeguarding domestic production from international trade. After World War II, it became a fundamental aspect of the tariff policy debate in developing nations (Sauré 2007). However, in recent years, there has been a renewed interest in both the theoretical and empirical aspects of this argument (e.g., Harrison and Rodríguez-Clare 2010; Juhász 2018). Protecting an industry that may gradually lower its unit cost of production is the core hypothesis of the infant-industry argument (Buryi and Lahiri 2019). Under free trade, domestic industries often face challenges entering the market due to their higher average costs compared to foreign competitors, along with the presence of negative externalities (Baldwin 1969; Rask 1994). Thus, the domestic industry may necessitate a temporary period of protection, allowing it to lower its costs and become competitive with foreign firms. Once the industry achieves this goal without additional governmental protection, it can thrive in the open market (Rask 1994). Krueger and Tuncer (1982) and Rask (1994) argue that the cost reduction mechanism primarily occurs through technological advancement and economies of scale, which eventually fosters the development of domestic industries. This process is commonly referred to as "learning by doing" in the literature (Bardhan 1971). In contrast to traditional neoclassical models of international trade, learning-by-doing trade models show how protectionist measures can spur output expansion, boost productivity, and reduce prices (Harris et al. 2015).

Despite its long history, the most notable aspect of the infant-industry protection literature is that it has been argued almost entirely on theoretical grounds. Additionally, the empirical literature on this topic varies in its evaluation of the benefits of such protection (Buryi and Lahiri 2019). Tariff protection, according to Irwin and Davis (2003), did not accelerate U.S. industrialization and had large but temporary effects on production by shifting resources from trade-dependent industries to domestic infant industries. Buryi and Lahiri (2019) argue that when a domestic firm faces foreign competition, the protections can encourage research and development in product innovation. In this context, Lee (1997) and Juhász (2018) found evidence supporting the positive impact of temporary trade protection in fostering the development of infant industries, particularly through technological advancements. However, empirical studies of the infant industry contend that "in many developing countries, there is not much maturation of infants (Bell et al. 1984: p. 103). Turkey and India's experiences have shown that infant-industry protection does not

work for all countries (Bell et al. 1984; Bhagwati 1994). This evidence supports the hypothesis that protectionist policies reduce incentives for efficiency (Krueger and Tuncer 1982). Moreover, Melitz (2005) evaluated how the decision to protect an industry should depend on the industry's learning potential. The study suggests that protecting the infant industry in the form of a quota may induce higher welfare levels than tariffs and it may be preferred to a domestic production subsidy.

In the case of West African countries, the cost of domestic chicken products is high compared to imported products (Sumberg et al. 2017). Chicken meat prices in West African countries including Senegal, are not competitive at a free market price (Davids and Meyer 2017). According to the infant-industry argument, "*the sector requires a temporary period of protection or assistance during which its costs will fall enough to permit it to survive the international competition without assistance*" (Krueger and Tuncer 1982; p. 1143). According to this assumption, protectionism may benefit the Senegalese poultry sector as learning in the domestic sector may increase over time. Given WTO restrictions, the public sector can protect the infant industry using different policy instruments such as trade protections or subsidies to ensure later economic efficiency. In other words, public protections aim to support the infant industry at the early stages to create a reasonable rate of return when it is developed. Nevertheless, it raises the question of whether the long-term benefits outweigh the short-term costs of infant-industry protections.

The present empirical work attempts to find evidence to check the hypotheses of an infant industry in the Senegalese poultry sector. Thereby it contemplates that the policy implications of a ban policy may not be generalized based on the effects it had on other countries but should instead be analyzed in this specific local context.

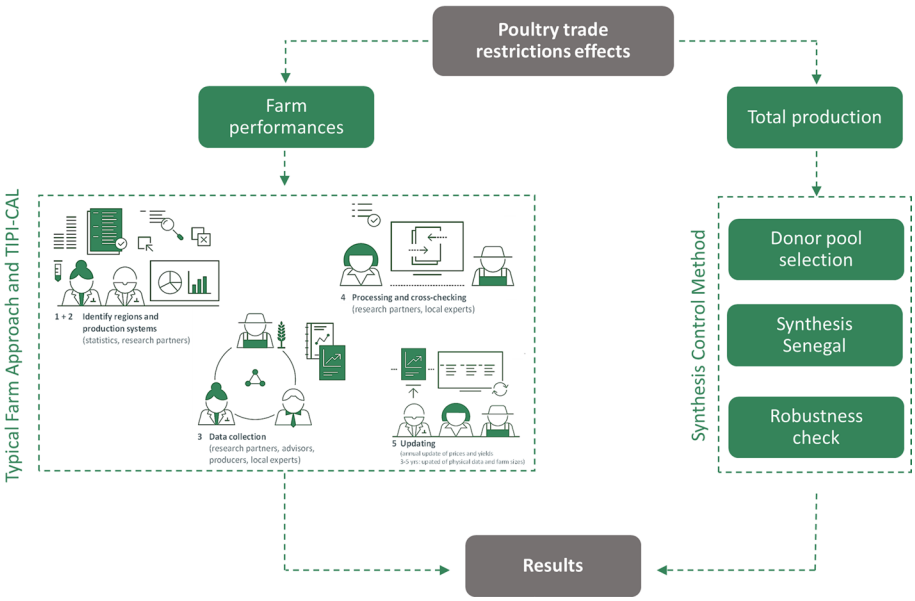


Fig. 2 The analytical framework of policy analysis. *Source*: Own presentation, TIPI-CAL box is taken from Chibanda et al. (2020)

Methods

Given the scope of our analysis and data availability, we employ a variety of methods to assess the effects of Senegal's poultry meat trade ban (Fig. 2). First, we use a data-driven Synthetic Control Method (SCM), as proposed by Abadie and Gardeazabal (2003), to estimate the effects of the trade ban on domestic production at the national level. Following the methodology outlined by Chibanda et al. (2020), we proceed to use the Technology Impact Policy Impact Calculations farm-level analysis model (TIPI-CAL) to compare the performance of different conventional broiler farm types in Senegal and Ghana. Through this analysis, we gain valuable insights into how the trade ban affects various types of broiler farms within these countries.

Comparative analysis: synthetic control method

When analyzing the effects of a total import ban on chicken meat in Senegal, a crucial question arises: How would the trajectory of total chicken meat production have developed after 2006 in the absence of the ban? To address this, the SCM estimates the effects of the import ban by creating a synthetic control country that closely matches Senegal's pre-ban outcomes. This approach has been extensively used to estimate the consequences of interventions in a variety of situations, including those involving trade, economics, and health-related issues (see e.g., Mohan 2017; Demko and Jaenicke 2018; Cole et al. 2020; Olper et al. 2022; Luo et al. 2022).

Dwelling on the method of Abadie et al. (2015), we use panel data with i = 1, ..., N units observed for t = 1, ...,T period. To be more precise, we split our sample into two periods$T = T_0 + T_1$, where T_0 denotes pre-intervention period, and T_1 is the post-intervention period,T_1. Denote the number of comparison countries by k + 1. The first country (i.e., treated unit) is affected by the import ban over the pre-intervention period$T_0 + 1, \ldots, T$, and the other K countries[5] are considered as the control samples. For each country k and time t, let $X^I_{k,t}$ be the outcome variable observed for the countries that did not experience a complete import ban in the post-intervention period, and $X^N_{k,t}$ be the outcome for the treated unit (i.e., Senegal) after it had adopted the complete ban. Thus, the net effect of the ban ($\rho_{j,t}$) for Senegal is defined by the gap between $X^N_{k,t}$ and$X^I_{k,t}$,

$$\rho_{k,t} = X^N_{k,t} - X^I_{k,t} \tag{1}$$

For the pre-intervention period, i.e., $t \leq T_0$, we assume $Y^N_{1,t} = Y^I_{1,t}$. Following Abadie et al. (2010), the potential effect of the intervention for the affected unit on our study (Senegal) in period $t > T_0$ is measured by,

$$\rho_{k,t} = X^I_{1,t} - X^N_{1,t} = X_{k,t} - X^N_{1,t} \tag{2}$$

Since $X^I_{1,t}$ is known, one can estimate the post-intervention trend of the variable of interest by estimating $X^N_{1,t}$ which is the outcome variable of Senegal where no intervention occurred. Abadie et al. (2010) apply the following linear factor model to estimate $X^N_{k,t}$.

[5] So-called "donor pool".

$$X_{k,t}^{N} = \beta_t + \theta_t Y_k + \delta_t Z_k + \varepsilon_{k,t} \tag{3}$$

where β_t denotes the time-variant fixed effect, Y_k is the observed variables, and Z_k is the unobserved variable affecting the variable of interest. $\varepsilon_{j,t}$ is the random error term with zero means. According to Abadie (2021), a weighted average of units in the donor pool may approximate the characteristics of the treated unit much better than any untreated unit alone. Given a set of weights for each untreated unit $W = \left(w_2, \ldots, w_{k+1}\right)'$, a synthetic control estimate of $X_{1,t}^{N}$ is given by,

$$\widehat{X}_{1,t}^{N} = \sum_{k=2}^{k+1} w_k X_{k,t} \tag{4}$$

where $\widehat{X}_{1,t}^{N}$ stands for the counterfactual domestic production of chicken meat. The weights (w_k) are nonnegative and sum up to one, i.e., $\sum_{j=2}^{k+1} w_k = 1$. The SCM is based on the idea that a weighted average of control units in the donor pool ($\widehat{X}_{1,t}^{N}$) represents a better counterfactual than a single unit (Demko and Jaenicke 2018; Ben-Michael et al. 2021). This method compares the actual trend with the "synthesis" version of poultry meat production while holding all other factors constant. The synthetic comparison country is chosen by determining w_k that minimizes the difference between the pre-intervention characteristics of the treated unit and a synthetic control (Abadie et al. 2015),

Since the SCM is not a randomization-based technique, formal statistical inference for the treatment effect cannot be calculated (Abadie et al. 2015). Empirical studies mainly use different types of placebo tests to examine the statistical significance of the synthetic control estimates (Demko and Jaenicke 2018; Luo et al. 2022). In the placebo test, the SCM is iteratively run for each country in the donor pool, and the distribution of these placebo runs is compared. Synthetic control estimate is robust when they are not similar to the placebo found for the treated country (Demko and Jaenicke 2018). We use Stata 17 to estimate the results.

The typical farm approach and TIPI-CAL model

The typical farm approach was employed to construct typical conventional broiler farms in both Senegal and Ghana. Ghanaian farms were chosen for comparison due to the following reasons: 1. Ghana is one of the comparison units in the synthetic Senegal donor pool. This point will be elaborated further in the following section. 2. Trade policies in both Ghana and Senegal are significantly influenced by the Economic Community of West African States (ECOWAS). Over the past decade, Ghana has been reliant on frozen chicken imports and has not experienced a complete ban on the poultry sector. We assume that Ghana provides similar characteristics of poultry production to the pre-ban trend in Senegal. The weight of Ghana in constructing the synthetic Senegal will be presented in the subsequent section.

Chibanda et al. (2020) and Lasner (2020) explain that a typical farm is a 'virtual' farm that represents a specific production system in a particular region. Therefore, a typical farm is not the same as a farm that exists in real life with unique particularities "individual farm" because the typical farm is constructed to have characteristics that represent

a production system. The typical farm approach is widely used in farm economic analysis and relies on the use of interviews, focus groups, and expert consultations to modify individual farm data to be more representative of a specific production system in a particular region (Chibanda et al. 2022; Siqueira and Duru 2016; Hagemann et al. 2011; Kress and Verhaagh 2019). The method is implemented through a series of steps known as the "*agri benchmark* Standard Operating Procedure" (Chibanda et al. 2020). The steps are listed below.

Step 1: Identification of broiler production hotspots

The most important region 'hotspots' in terms of broiler production were identified through a literature review.

Step 2: Identification of the most common conventional broiler production systems

The most prevalent broiler production systems were identified by conducting a literature review and consulting local experts (producers, researchers, and extension officers).

Step 3: Data collection

A two-phase data collection process was conducted. The first phase involved collecting farm data from individual producers. In this phase, broiler farms with characteristics representing the identified production systems were selected and data were collected from them through semi-structured interviews. In line with Chibanda et al. (2020), to ensure comparability, the same standard questionnaire was used to collect data from the individual farms in Senegal and Ghana. Due to limited data available on broiler farms in Senegal, we selected individual farms in the identified regions in collaboration with extension officers who work closely with producers. These professionals possess in-depth knowledge of the farms in their region, as they are often visiting them. Consequently, we were able to identify individual farms with characteristics aligned with the different production systems. The second phase of the data collection process entailed the construction of typical farms through the "typification" of the individual farm data. Chibanda et al. (2020) explain that the process of typifying individual farm data is characterized by replacing data that is particular to the individual farm with data that is representative of the production system in that region. For example, the individual producer may state that the mortality rate on the farm is 15%. While consultations with poultry experts knowledgeable of the production system and region will reveal that the most common mortality rate in the region is 5%. The typification of individual farm data can be accomplished through either focus groups or consulting poultry experts (Chibanda et al. 2020). In Ghana, the typification of individual farm data was performed through focus groups composed of producers, extension officers, and local researchers. In Senegal, the typification was conducted by consulting poultry experts in the regions where the individual farms are located. The output of the typification process were "typical farms" that represent a specific production system in a particular region.

Step 4: Processing and cross-checking

TIPI-CAL is a production and accounting model that enables the calculation of farm-level economic and physical parameters (Chibanda et al. 2020; Ndambi et al. 2008). In this study, the TIPI-CAL model was used to calculate broiler farm performance indicators and the costs of production of the six typical broiler farms. The performance indicators that were calculated include the feed conversion ratio (FCR) and the broiler farm economy index (BFEI). FCR is the most commonly used indicator

to measure feed-use efficiency in poultry production (Zampiga et al. 2021). Chibanda et al (2022) explain that the FCR is an indicator that measures the amount of feed used to produce a kilogram of meat. Therefore, the lower the FCR the more efficient the chickens are in terms of feed use. BFEI measures the overall broiler farm efficiency by combining several indicators (Singh et al. 2017). A BFEI value of 2 and above indicates good overall farm management. The formulas used to calculate the two indicators are shown below:

$$\text{FCR} = \frac{\text{Cumulative feed intake}\,(\text{kg})}{\text{Total weight gain}\,(\text{kg})} \tag{5}$$

$$\text{BFEI} = \frac{\text{Average live weight}(\text{kg}) \times \%\ \text{livability}}{\text{FCR} \times \text{growing period}(\text{days})} \tag{6}$$

The TIPI-CAL model classifies production costs into two categories: factor costs and non-factor costs. According to Chibanda et al. (2022), factor costs comprise the following components:

(1) Land-related costs, encompassing land rental expenses and the opportunity cost of owning land.
(2) Labor-related costs, which include the cost of contract labor and the opportunity cost of family labor.
(3) Capital-related costs, consisting of interest paid on liabilities and interest paid on own capital as an opportunity cost of capital.

On the other hand, non-factor costs encompass all other expenses (including depreciation) related to veterinary services, feed, energy, day-old chicks, fuel, lubricants, water, buildings, insurance, and more.

Step 5: Updating

The Ghanaian typical farms were updated in 2022 to enable comparisons with the Senegalese farms. There was an update for data on prices and costs, while other data was unaltered (e.g. farm size, labor input, and performance indicators).

Data

Donor pool selection

We adopt various characteristics to select comparison countries in the donor pool, following Abadie et al. (2010). We include countries whose pre-ban chicken meat production trends closely resemble Senegal's as comparative units. To ensure the stability of weights over time, we specifically choose countries with data available for the entire research period in the dataset. Second, to provide the most accurate comparison group for Senegal, the donor pool is limited to African nations because they are more likely to have comparable levels of development. Additionally, we exclude countries with similar trade ban policies, retaining only African countries that were not subject to the poultry ban starting in 2006. After removing missing observations and outliers, our donor pool consists of 33 countries.

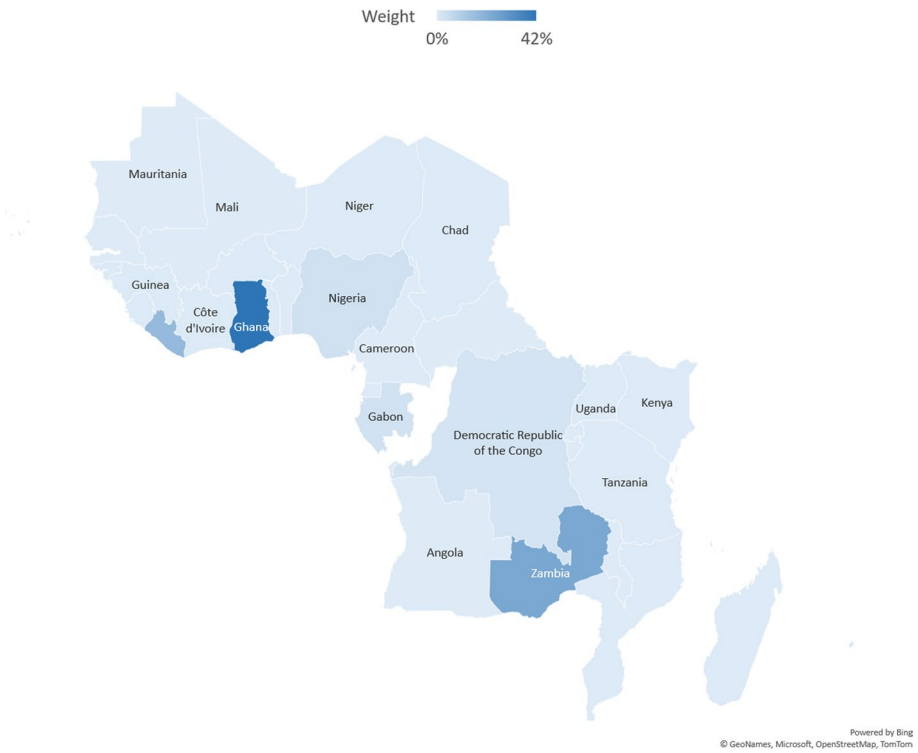


Fig. 3 Composition of synthetic Senegal's donor pool. *Source*: Own elaboration using Microsoft Office

The panel data are taken from the FAO and World Bank data set from 1980 to 2019. In the present analysis, chicken meat production represents the outcome variable. The second type of data is a set of summary statistics[6] which must be available for every donor unit (Hollingsworth and Wing 2022). Given data availability, real GDP, urban and rural populations, maize production (as the main feed ingredient) as well as imports of chicken meat, are considered to be summary statistics. For our research design, the inclusion of these variables and databases is essential since it enables us to acquire a lengthy pre-intervention period, i.e., 26 years.

Our estimates imply that synthetic Senegal's chicken meat production is primarily reflected by a weighted average of Ghana, Zambia, Liberia, and Congo (Fig. 3).[7] All other comparison countries in the donor pool obtain zero or negligible weights. An important assumption in the counterfactual analysis is the concept of "parallel trends", which posits that the trends in outcomes before the intervention are similar between the treated and comparison groups. To assess this, we compare the simple average of comparison countries with synthetic Senegal. Figure 4 illustrates the alignment of the synthetic Senegal chicken meat production trend with that of the equally weighted average of control countries. As observed, the simple average does not function as a suitable control group for Senegal, whereas the pre-treatment trend of synthetic Senegal closely follows

[6] In the literature, these are usually referred to as predictor. Following Hollingsworth and Wing (2022), we use the phrase summary statistics since it more clearly illustrates the role these values have in the procedure.

[7] "Appendix I" presents the detailed information on country weights.

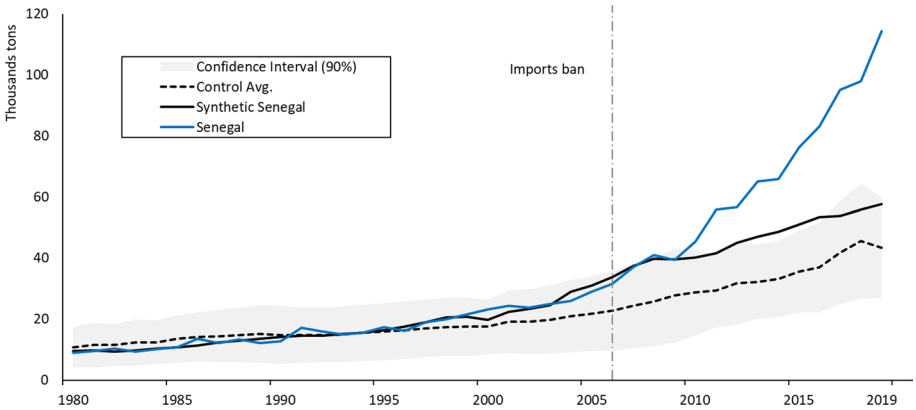


Fig. 4 The trend of the simple average of donor countries in comparison to synthetic Senegal. *Source*: Own calculation using FAO data and Stata 17

the actual chicken meat production in Senegal. This suggests evidence supporting the reliability of our results. Furthermore, we perform a standard robustness check in the following sections.

Typical farm data

The data used to construct the typical farms were collected from Senegal and Ghana. As already mentioned, we first identified the most important regions in both countries. Dakar and Thiès were identified as the most important broiler production regions in Senegal. In Ghana, Greater Accra, Kumasi, and Dormaa were identified as the most important regions. In both countries, small-scale, medium-scale, and the large-scale integrated broiler production systems were identified. One "individual farm" was selected to represent each production system in each country. The individual farms were selected through consulting extension officers in the regions where each production system is more prevalent. Therefore, a total of three individual farms were visited in Ghana and three farms in Senegal. However, in Senegal, a large-scale integrated broiler farm was not selected for the individual farm data collection because during the data collection period (January 2022) there were suspected cases of the highly pathogenic H5N1 bird flu in Senegal. Consequently, large-scale farms were not accepting farm visits. Hence, instead of selecting a large-scale farm for the individual farm data collection, one small-scale and two medium-scale farms with slightly different characteristics and from different regions (Dakar and Thiès) were selected. The interviews gathered data on farm buildings and equipment, labor input and wages, overhead costs, feeding periods and quantities, performance data (mortality rate, weight gains, etc.), and costs.

The individual farms were then typified to in order to constrict typical farms that represent a specific production system in a particular region. In Ghana, the individual farm data was typified through the use of focus groups. A total of three focus groups were held, one for each of the three identified production systems. In Senegal, the individual farm data was 'typified' by replacing the farm particularities with typical information that was provided by poultry experts (agricultural officers and researchers) knowledgeable of the production systems and regions. Therefore, a total of three typical farms representing the most common broiler production systems in the main production regions

Table 1 Characteristics of the typical conventional broiler farms in Ghana and Senegal

Farm name	Ghana			Senegal		
	GH_3k	GH_12k	GH_27k	SN_9k	SN_36k	SN_38k
Production system	Small scale	Medium scale	Large scale integrated	Small scale	Medium scale	Medium scale
Location	Accra	Dormaa	Kumasi	Thiès	Dakar	Thiès
Chickens sold/year	3613	12,086	27,000	8527	35,263	37,571
Feed source	Informal feed mills	Formal and informal feed mills	Operate their own feed-mills	Commercial feed-mills	Commercial feed-mills	Operate their own feed-mills
Origin of day-old chicks	Imported from the Netherlands	Imported from Ivory Coast	Hatchery belonging to the farm	Chicks are sourced from local hatcheries	Chicks are sourced from local hatcheries	Chicks are sourced from local hatcheries
Marketing channels	Sells live birds: individuals, live bird markets	Sells live birds: live bird markets. Rarely, the birds are slaughtered and sold to fast-food shops	Slaughters its birds and sells them to retailers and restaurants	Live chickens: traders (bana-banas), individuals, and small restaurants	Chickens are either slaughtered on the farm or sold as live birds	Chickens are often slaughtered on the farm and sold to bana-banas

Source Own survey and calculations.

were constructed for each country. The typical conventional broiler farms from Senegal were constructed in March 2022. While in Ghana, they were constructed in March 2020 and then later updated (see Step 5) in April 2022 to enable a comparison with the Senegalese farms.

The typical farms were named according to their respective country codes and the total number of broilers they produce annually (in thousands), which are—GH_3k, GH_12k, GH_27k, SN_9k, SN_36k, and SN_38k (see Table 1). Although similar production systems were identified in Senegal and Ghana, the Senegalese typically produce a larger number of birds per year. For instance, the typical small-scale conventional broiler farm in Ghana (GH_3k) produces 3613 birds per year while the typical small-scale farm from Senegal produces 8527 birds per year. Although the farm sizes are measured in terms of chickens sold per year, broiler production involves several cycles within a year. The TIPI-CAL calculations are adjusted to account for these multiple production cycles.

The typical farms are generally located in large cities (Accra, Kumasi, Dakar, Thiès) with the exception of Dormaa. However, Dormaa is an important production region in Ghana because it is at the border between Ghana and the Ivory Coast. Poultry traders from the Ivory Coast come to Dormaa to purchase birds at farmgate.

Results

Comparison of broiler farm economics in Senegal and Ghana

The farm economic analysis was conducted to gain insights on how the poultry import ban might have affected the performance of broiler farms in Senegal. As shown in the previous section, Ghana was chosen for the comparative analysis because it is one of the main countries in reproducing the pre-ban trajectory of chicken meat in Senegal. Additionally, Senegal and Ghana have similar conventional

broiler production systems, making them comparable. Therefore, we assume that the performance of Ghanaian typical farms closely reflects how Senegalese farms would have performed without the ban.

Comparison of broiler farm performance

Table 2 shows that typical broiler farms from Senegal (SN_9k, SN_36k, SN_38k) are more efficient than those from Ghana (GH_3k, GH_12k, GH_27k) in terms of the FCR and the BFEI. Medium-scale farms from Senegal (SN_38k and SN_36k) have FCR values of 1.78 and 1.61, respectively which are comparable to that of broiler farms in key broiler meat exporting countries like the USA (FCR=1.83) and the Netherlands (FCR=1.58) (van Horne 2018). However, the typical small-scale farm from Senegal (SN_9k) has a high FCR value of 2.06 which is more comparable to the Ghanaian farms. The farms from Senegal also have higher BFEI values than Ghanaian farms, indicating more efficient farm management. The Senegalese typical farms also have lower mortality rates, and shorter feeding periods, and run more production cycles per year. The efficient farm performance of the Senegalese farms can be attributed to the use of high-quality feed, chicks, and good husbandry (Arnoldus et al. 2021). While the poor farm performance of the Ghanaian typical broiler farms can be attributed to the use of poor-quality inputs (poor-quality feed from informal feed mills and poor quality domestically hatched day-old chicks), long production cycles of fast-growing broiler breeds, and poor animal husbandry practices.

Table 2 Comparison of broiler farm performance indicators

Indicators	Ghanaian farms*			Senegalese farms		
	GH_3k	GH_12k	GH_27k	SN_9k	SN_36k	SN_38k
Feed conversion ratio (FCR)	2.43	2.08	2.33	2.06	1.78	1.61
Broiler farm economy index (BFEI)	1.90	2.01	2.03	2.43	2.67	3.42
Feeding period (days)	63.00	45.50	42.00	38.00	40.00	35.00
Mortality at farm level (%)	2.88	4.08	10.00	5.00	5.00	3.50
Number of cycles per year	3.72	3.00	3.00	6.00	6.20	6.10

*We assume that the performance of Ghanaian typical farms closely reflects how Senegalese farms would have performed without the ban in 2021. Source: Own survey and calculations

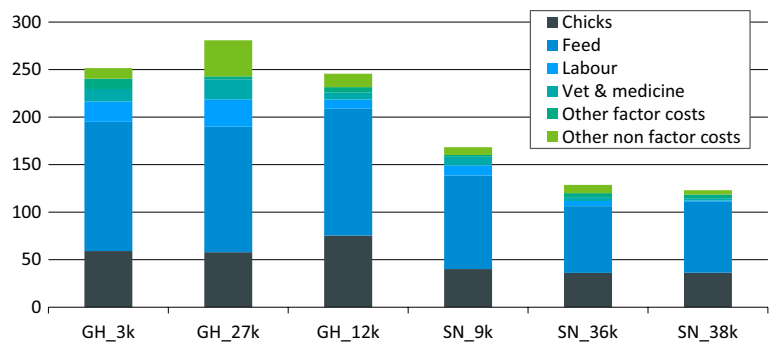


Fig. 5 Comparison of production costs (€/100 kg live weight). *Source*: Own calculations

Comparison of production costs

Figure 5 shows that production costs are higher in Ghana than in Senegal.[8] For instance, a comparison of the production costs of typical small-scale broiler farms from Ghana (GH_3k) and Senegal (SN_9k) shows that the costs of production for GH_3k are 40% higher than that of SN_9k. A comparison of those for medium-scale farms (GH_12k, SN_36k, and SN_38k) shows that the costs of production for GH_12k are 63.8% higher than that of SN_36k and 66.7% higher than that of SN_38k. The costs of production for the typical broiler farms in Ghana are generally higher because of higher feed, day-old chicks, and veterinary costs. More specifically, GH_3k and GH_12k have higher day-old chick costs because they are rearing imported day-old chicks that are more expensive. In contrast, the typical Senegalese farms are all using locally hatched chicks that are more affordable. Chibanda et al. (2022) explain that some broiler producers in Ghana prefer to rear imported day-old chicks from Europe and the Ivory Coast because the locally hatched day-old chicks are of low quality. There are many factors that can account for the differences in feed costs. However, at the farm level, the main factor is feed use efficiency. As shown in Table 2, the Senegalese farms are more efficient in feed use (FCR values), therefore, the farms use less feed to produce a kilogram of meat in comparison to the Ghanaian farms. This implies that they spend less on feed per kilogram of meat produced. It is important to note that the typical small-scale farm in Senegal (SN_9k) has higher costs compared to the medium-scale farms (SN_36k and SN_38k). Consultations with small-scale farmers revealed that they cannot negotiate for lower feed and day-old chick prices. In contrast, larger farms can negotiate lower prices because they buy in bulk.

Complete ban and total chicken production

This section presents the results obtained from the SCM experiments, in which we explore the effect of the import ban on total chicken meat production in Senegal. To assess the reliability of our analysis, one can measure to what extent the synthetic control matches the characteristics of the treated unit in the pre-intervention period. As "Appendix II" shows, synthetic Senegal closely reproduces the pre-treatment characteristics of Senegal during the pre-ban period.

Figure 6 represents the trend of synthetic chicken meat production and its actual trend in Senegal. Overall, the results imply that synthetic Senegal accurately reproduces the actual trend of chicken meat production as well as summary statistics for the pre-intervention period. Following the import ban in 2006 treated unit and synthetic Senegal trends deviated noticeably, which is interpreted as the effects of the intervention. As shown, the volume of production increased significantly in the domestic production of synthetic Senegal. The difference is more obvious in the post-2008 period. According to the infant-industry theory, the lag from 2006 to 2009 may be related to the time it took the Senegalese producers to take advantage of the import ban, i.e., the learning curve, and to extend production capacities. Thus, the broiler

[8] "Appendix IV" provides the average production cost for each farm type.

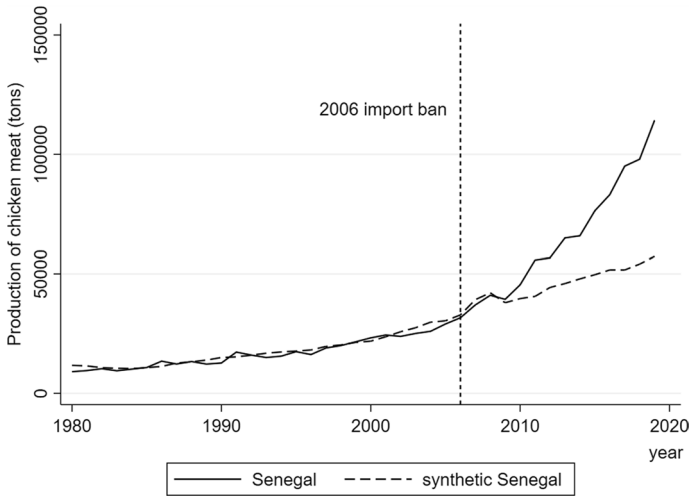


Fig. 6 Actual chicken meat production of Senegal versus synthetic Senegal. *Source*: Own calculation using Stata 17

producers in Senegal took three years to adapt to the new situation and increase their production.

As previously mentioned, the difference between the actual trend and its synthetic version may be regarded as the effect of the ban policy. Thus, we can project the trajectory of production in the absence of an import ban. The import ban enforced over the study period raised domestic production by an average of 20 thousand tons per year from 2006 to 2019 (see Fig. 7). In other words, the policy interventions caused production to increase by 151% during the study period. This highlights the positive

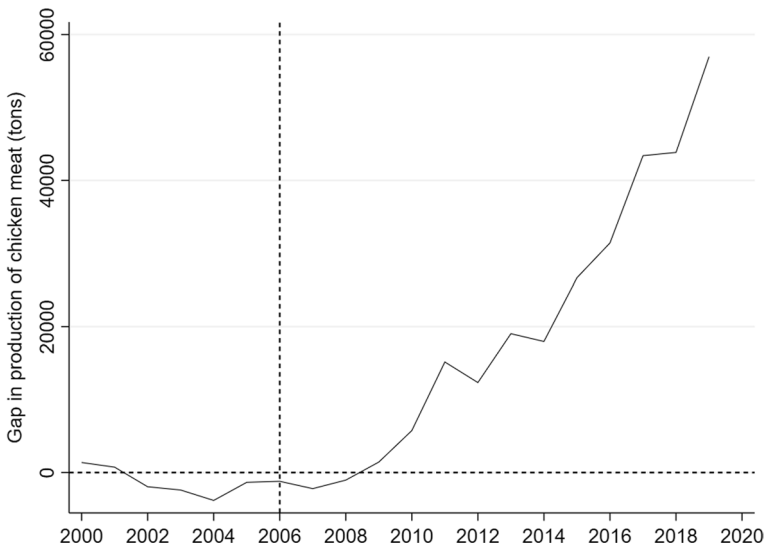


Fig. 7 Gap in chicken meat production between actual trend and synthetic Senegal. *Source*: Own calculation using Stata 17

effects of the import ban on the performance of Senegalese poultry producers. This indicates the positive impact of the import ban on the performance of Senegalese poultry producers, potentially demonstrating productivity improvements through learning by doing, as suggested by the infant-industry theory. To evaluate this hypothesis, in the following section, we will conduct a comparative farm-level analysis of broiler producers in Senegal and Ghana.

To ensure the reliability of our empirical analysis, we conduct robustness checks. Thus, we conduct a number of standard robustness checks to examine the reliability of the results obtained from our main analysis. Following the literature (Abadie et al. 2015), we first conduct a "placebo" test to assess whether the 2006 import ban had a unique effect on chicken meat production in Senegal compared to other countries in our donor pool. To conduct the intentionally-false placebo test, we create a synthetic control group for all countries in our donor pool and analyze pre- and post-treatment levels of domestic chicken meat production as if each country had an import ban in 2006. The quality of the synthetic controls' fit to the pre-intervention evolution of the outcome variable (i.e., chicken meat production) in Senegal is assessed using the root mean square prediction error (RMSPE). "Appendix II" presents the ratios between the post and pre-intervention RMSPE values for Senegal and all other countries. The analysis shows that Senegal exhibits the largest post/pre RMSPE ratio among comparative countries, providing evidence of the statistical significance of our findings.

Because our donor pool includes 33 control units, the probability of obtaining a post/pre-Proposition 99 RMSPE ratio as large as that of Senegal's is less than 4%. Next, we explore the sensitivity of our estimates to different summary statistics, donor pools, and policy interventions. Here, we examine three separate changes to our estimates: first, we remove each independent variable one by one and check whether the results change. We also examine the impact of using different starting years and countries in our analysis. As "Appendix III-A" shows, the results remain consistent when using different control variables or measures. In a similar process, we perform the analysis using different starting years as reference points for the policy intervention. However, as "Appendix III-B" presents, our results remain robust when using different starting years for the analysis.

Discussion and policy implications

Economists generally concur that liberalizing agricultural trade often leads to improvements in global food security and standards of living (Rutten et al. 2013). However, some research suggests that temporary trade protectionist measures, while initially assisting infant industries in developing countries, can ultimately impair the competitiveness of the sectors they aim to safeguard (e.g., Krueger and Tuncer 1982; Bhagwati 1994). Our analysis lends credence to the infant-industry argument in Senegal. By employing the Synthetic Control Method, we find that Senegal's chicken meat production grew more than it would have in the absence of the import ban. This suggests that the ban had a favorable effect on chicken production, particularly noticeable after a period of three years, possibly indicating a gradual adjustment of domestic producers to the new trade situation.

Comparing the performance and production costs of typical farms in Senegal and Ghana reveals that Senegalese farms outperform their Ghanaian counterparts while incurring lower production costs. These findings suggest that the complete ban led to improved farm performance, as we assume that the Ghanaian farms represent what the Senegalese farms would have been like if a complete ban had never been imposed. These results are intriguing because, based on the general economic arguments highlighted earlier, one would expect the Ghanaian farms to be more competitive (with better farm performance and lower costs of production) since they are operating in a more open market. However, these findings can be explained within the context of the infant-industry argument. The basic theoretical premise of the infant-industry argument is that a domestic "infant" industry may require protection if it is not competitive compared to more established foreign competitors. Therefore, the theory suggests that the domestic industry will require time under protection to become competitive. Additionally, the findings indicate that poultry meat production in Senegal goes through a 'learning by doing' phase, which is expected when an infant industry is initially protected. This supports the idea that the protection offered by the ban allowed Senegalese producers to develop their capabilities and competitiveness over time.

It is important to clarify that the purpose of this paper is not to advocate for the use of poultry meat import bans as a sound or necessary economic policy. Instead, the paper aims to understand how the poultry meat ban has affected production in Senegal. Furthermore, considering Senegal's membership in the WTO, the ban cannot be maintained indefinitely. Thus, this paper also aims to explore pathways for the future liberalization of the poultry meat trade. Within this context, Senegalese policymakers may be considering how to lift the ban while still ensuring good farm performance. Melitz (2005) suggests that countries protecting an industry they deem to be an "infant" industry should gradually reduce the level of protection as the industry's learning progresses. In this light, the Senegalese government may gradually open the market to sustain the competitiveness of the local product. This could involve replacing the ban with tariffs that are then gradually reduced over time. However, policymakers face a new dilemma because the bound tariff rate for Senegal is only 25%, which might not offer sufficient initial protection required for the gradual process of removing protectionist measures. Moreover, this bound tariff rate is also lower than the ECOWAS Common External Tariff. Policymakers should thus find a suitable solution to address this inconsistency during the period after the import ban. The international community should support a solution within the framework of the WTO to resolve this issue. Additionally, the farm-level findings revealed that typical small-scale farms in Senegal are not performing as well as larger farms and also have higher production costs. As the country considers gradually reducing protectionist measures, policymakers should implement targeted interventions to support smallholder broiler producers. These interventions could involve providing training on poultry husbandry practices to enhance knowledge about proper feeding techniques and biosecurity measures, ultimately reducing mortalities. Producers in Senegal should be proactive in addressing the lifting of the import ban on poultry. While the ban has had a positive impact on domestic poultry meat production, it is essential

for producers to take steps to maintain and enhance their productivity. To achieve this, producers could consider the following:

- Quality Improvement: Producers should prioritize maintaining high-quality standards in poultry production to strengthen their competitiveness in the domestic market. Consumer support for local products is more likely when they are perceived as superior in quality.
- Cost Reduction Strategies: Identifying opportunities to minimize production costs without compromising quality is crucial. This may involve optimizing feed formulation, exploring alternative energy sources, or streamlining supply chain operations.
- Capacity Building: Investment in training and skill development for the workforce is essential. A well-trained and motivated workforce is vital for achieving increased productivity and maintaining product quality in the poultry industry.
- Direct payments: These payments are intended to alleviate the financial burden on producers and aid in their adaptation to new market conditions, particularly when trade protectionist policies are lifted. The main objective of these direct payments is to ensure stability in the supply of broilers, and they can be customized to address the specific needs of the sector. To achieve this, the support can be tailored to compensate farmers who may experience profit losses due to the changes in trade policies (Mann and Lanz 2013). Moreover, the introduction of a feed subsidy policy could serve as an additional effective tool for supporting domestic poultry growers post-ban. This policy would assist producers in maintaining competitiveness by reducing production costs, ultimately leading to lower consumer prices (Andam et al. 2017).

Furthermore, it is crucial for future studies to assess and compare the competitiveness of Senegalese broiler farms with major poultry exporters such as the USA, Brazil, and the EU. Such comparative studies will provide policymakers with valuable insights into the appropriate timing and rate for reducing protectionist measures.

Lastly, it is important to acknowledge that this study has certain limitations. First, the farms included in the farm economic analysis were not selected through a stratified or random sampling process, meaning they may not be statistically representative of the broader population of farms. The inclusion of farms in the study was based on expert consultations, including interviews and focus groups, which provide insights into specific farm types in particular regions but may not encompass the diversity of all farms within the country. Therefore, while the study findings offer valuable insights, they should be interpreted with caution and may not be generalized to all farms in the country. Moreover, the poultry sector is viewed in isolation and no consideration is given to whether subsidies or protection in other sectors would have a better overall impact on the economy. Another potential limitation is the exclusive comparison between Senegal and Ghana. While the selection of Ghana for comparison is justified by its data proximity, it does not rule out the possibility that other nations may have achieved more favorable results.

Appendix I

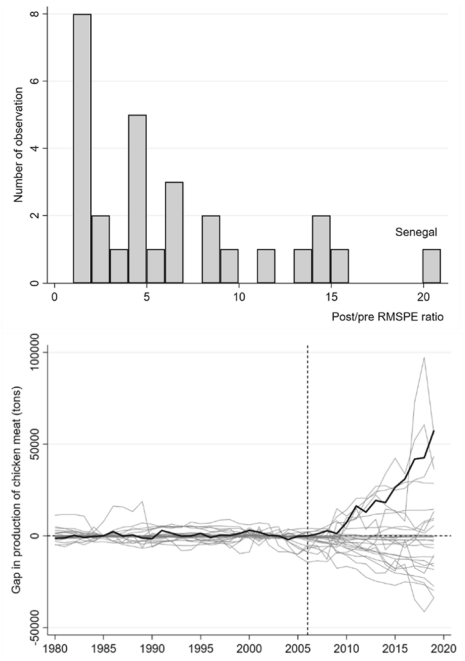
See Table 3.

Table 3 Country weights in synthetic Senegal

Country	Weight (%)
Angola	0.1
Benin	0.0
Burkina Faso	0.1
Burundi	0.1
Cabo Verde	0.1
Central African Republic	0.5
Chad	0.1
Comoros	0.1
Congo	14.1
Côte d'Ivoire	0.3
Democratic Republic of the Congo	0.7
Equatorial Guinea	0.1
Gabon	0.2
Ghana	41.8
Guinea	0.2
Guinea-Bissau	0.1
Kenya	0.0
Liberia	7.8
Madagascar	0.1
Malawi	0.1
Mali	6.5
Mauritania	0.1
Mauritius	4.8
Mozambique	0.2
Niger	0.1
Nigeria	3.0
Rwanda	0.1
Seychelles	0.1
Sierra Leone	0.3
Togo	0.2
Uganda	0.1
United Republic of Tanzania	0.1
Zambia	18.1

Appendix II

See Fig. 8.



Note: The left panel presents the pro/pre RMSPe ratio for all countries in the donor pool. As shown, Senegal has the largest ratio. The right panel shows the distribution of gaps between the actual trend and synthetic of all units in the donor pool. The solid black line in the right graph denotes synthetic Senegal.

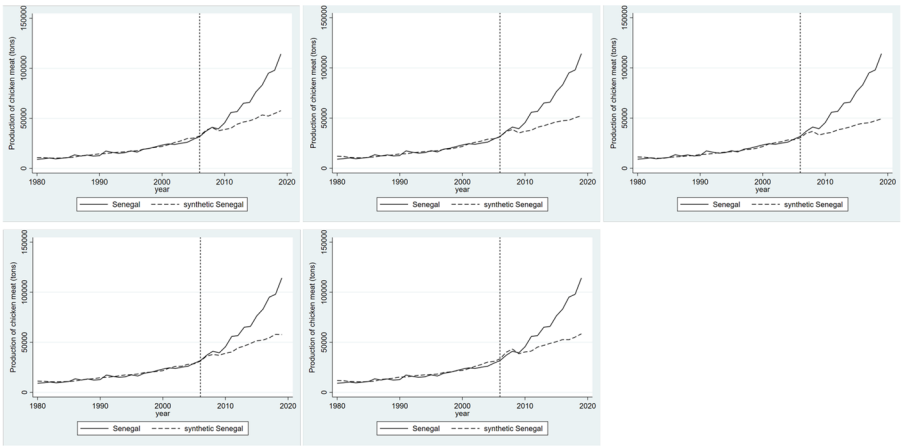
Source: Own calculation using Stata 17.

Fig. 8 Placebo test results.

Appendix III

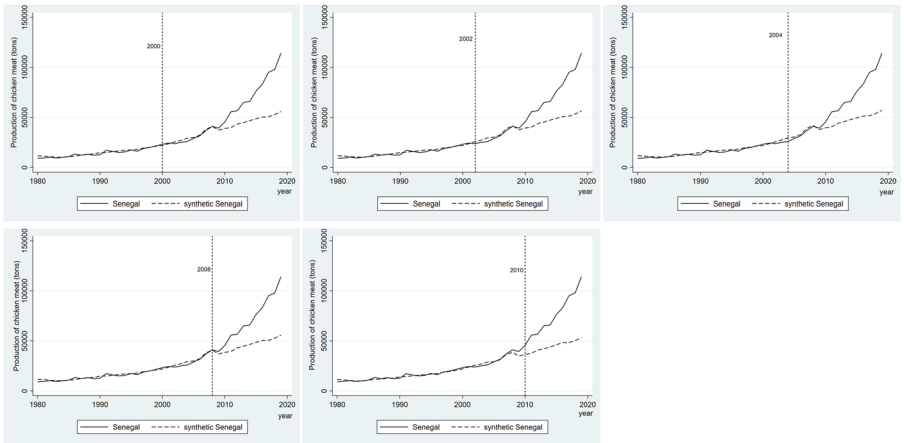
See Fig. 9.

A) Results of the SCM using different summary statistics



Source: Own calculation using Stata 17.

B) Results of the SCM using different starting years



Source: Own calculation using Stata 17.

Fig. 9 Robustness check.

Appendix IV

See Table 4.

Table 4 Comparison of production costs (EUR /100 kg live weight)

	GH_3k	GH_27k	GH_12k	SN_9k	SN_36k	SN_38k
Total costs	251.53	282.19	247.57	168.32	122.95	123.10

Source Own calculations

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Author contributions
OZ: Conceptualization, Investigation, Data curation, Formal analysis, Methodology, Software, Roles/writing-original draft, Visualization, Validation. CC: Investigation, Data curation, Formal analysis, Methodology, Roles/writing-original draft, Visualization, Validation. JP: Funding acquisition, Supervision, Formal analysis, Resources, Writing—review and editing, Project administration.

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Availability of data and materials
Data are available upon request.

Declarations

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

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