Impact of Tobacco Use and Prevention Laws on Regional Cigarette Sales: An Analysis of Provincial Disparities and Convergence Patterns in Spain

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Abstract

This paper aims to examine regional disparities in cigarette sales that occurred after the implementation of two laws regulating the sale and use of tobacco products in Spain. These laws became effective in December 2005 (Act 28/2005) and December 2010 (Act 42/2010). Furthermore, it provides a framework for studying spill-over effects pertaining to cross-border strategies that may alter how frontier regions react to the implementation of the laws. Provincial official data from January 2005 to December 2010 for legal cigarette sales has been divided into two distinct periods based on these regulatory changes. We apply Phillips and Sul's club convergence test for absolute and within-group convergence. Our findings indicate that although the 2010 law helped to reduce disparities across provinces, there was no complete convergence, meaning that the impact of the law was not uniform across all regions, especially in frontier regions with France and Gibraltar. However, we observe evidence of convergence within groups of similar entities, and the number of these groups decreased over time. This outcome highlights several interesting insights. Firstly, it supports what previous studies have established, indicating that the 2010 law was more restrictive than the one in 2005. Secondly, the effectiveness of these regulations can vary in border regions due to different laws in neighboring countries, resulting in unintended consequences that can reduce the impact of tobacco control policies, a result that is also in line with the literature. Finally, it is important to have harmonized regulations to ensure greater effectiveness in controlling tobacco use.

Keywords Public policy, Smoke-free legislation, Taxation, Regional disparities, Spill-over effects, Convergence test

Introduction

In the global context, many laws have been passed in different countries to control tobacco usages, with cigarette smoking being the most common form of tobacco use worldwide. In this regard, taxes play a crucial role and have been implemented in several countries as a mechanism for reducing tobacco smoking [1]. They not only help to offset the healthcare expenses that arise due to diseases caused by their consumption, thereby increasing healthcare cost savings [2], but they aim to discourage their consumption by making them more expensive. Therefore, policies and programs to reduce the demand for tobacco products are highly cost-effective, according to WHO's report [3].

Economic analyses have long emphasized the crucial role of comprehensive tobacco control policies, particularly those that integrate pricing measures and advertising bans, in reducing tobacco consumption. Research highlights that such economic strategies are

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Galiano *et al. Health Economics Review*   (2025) 15:44

Page 2 of 13

essential for influencing tobacco demand, especially among price-sensitive populations [4]. An extensive number of studies have explored the impact of cigarette's prices and taxes on reducing smoking rates or encouraging quitting [5–9]. Geboers et al. [10] identified the cost of tobacco as one of the most reported reasons for quitting smoking. Some empirical studies have quantified around the world the negative effect of price increases through taxes on smoking prevalence [9, 11–16]. Most of these studies disaggregate the results by population groups, as they tend to respond differently to changes in prices [7, 8, 17]. A specific population group where price plays a crucial role is youth; in this group, price plays a fundamental role in preventing the initiation of tobacco use. Tobacco price increases are widely recognized as one of the most effective measures to reduce youth smoking initiation. Higher prices deter young individuals from starting to smoke, as they are often more price-sensitive compared to adults. Policies that significantly raise the cost of tobacco not only reduce smoking prevalence but also prevent potential smokers from initiating the habit, creating long-term public health benefits. The 2012 U.S. Surgeon General's report [18] on youth prevention and the 2014 report [19] marking fifty years of progress highlight the pivotal role of price increases in curbing tobacco use among young people. Similarly, the World Health Organization's (WHO) MPOWER framework [20] underscores the importance of pricing policies as a cornerstone for preventing youth initiation and promoting tobacco control globally.

However, taxes on tobacco products may not always be effective in deterring people from consuming tobacco. Some consumers may opt for cheaper brands when tobacco prices rise, to minimize costs [10, 21, 22]. Others may switch to other forms of tobacco use, such as roll-your-own (RYO) cigarettes [23, 24]. Several studies have shown that such price-minimizing strategies are quite common. According to a study conducted by Guindon et al. [25], a significant number of smokers in Canada, France, and the United Kingdom buy cigarettes from low or untaxed sources. Specifically, more than 10% of smokers in these countries admitted to purchasing their cigarettes from such sources. These measures are more common among subgroups that are more sensitive to price [10] and among low socio-economic status (SES) smokers [17]. It is important to reduce price differences between products and locations to discourage prize-minimizing behaviors [10, 21]; if not, smokers will behave in contrast to the negative price elasticity of demand for tobacco products that the empirical literature supports [16, 26, 27].

Another way to avoid paying high prices is by purchasing cigarettes from countries where the prices are lower. These behaviors cause cross-border regions to diverge in tobacco sales [28]. Merriman [29] warns about the risk of non-uniform taxes and provides evidence demonstrating a significant increase in the probability of non-compliance and tax evasion among Chicago and its neighboring jurisdictions. These findings are supported by conclusions from the CDC's report on illicit trade [30], which emphasize that state-level excise tax disparities create incentives for cross-border purchases and tax avoidance. The report further highlights the need for harmonized taxation policies to address these issues effectively. It is worth noting that cross-border cigarette purchasing is more prevalent in European regions bordering countries with lower cigarette prices [31, 32].

In addition to price and taxation policies, targeted marketing by the tobacco industry plays a critical role in shaping tobacco consumption patterns. Marketing strategies often exploit demographic, socioeconomic, and geographic factors, thereby exacerbating existing disparities. Findings from the U.S. Surgeon General's report (2024) [33] on disparities emphasize the industry's role in driving these inequities through targeted promotion and marketing behaviors, a phenomenon that has relevance beyond the U.S. context.

The implementation of tobacco uses and prevention laws may face challenges due to price differentials between neighboring countries. This can be explained because, in border areas, nearby countries may resort to cross-border strategies to take advantage of the lower tobacco prices in their neighborhood countries. This could lead to changes in tobacco sales behavior in the frontier regions, resulting in a divergent effectiveness of tobacco use and prevention laws among territories. However, although cross-border sales can partially undermine the impact of price increases, they do not eliminate the critical role that pricing plays in reducing tobacco consumption. Strategies such as tax harmonization, minimum pricing policies, and enhanced enforcement can mitigate these effects. Furthermore, research suggests that individual cross-border purchasing behaviors often diminish over time due to the inconvenience associated with such practices [34]. Price increases are one of the most effective tools for reducing tobacco consumption. However, evidence suggests that socio-economic factors influence how individuals respond to these measures. Licht et al. [35] demonstrated that lower-income populations are more likely to engage in price-minimizing behaviors, such as switching to cheaper brands or purchasing tobacco in bulk, in response to price increases. This highlights the importance of considering socio-economic disparities when designing and evaluating tobacco

control policies. Spain has a geographical location (bordered by France, Portugal, and the United Kingdom, considering the proximity of some regions to Gibraltar) that provides an intriguing opportunity to examine these divergences at border areas. So, this paper offers a framework to provide more evidence about the existence of spill-over effects related to crossing-border strategies because of price and tax differentials in border countries.

Tobacco use and prevention laws are another type of regulation that includes the ban on tobacco advertising, promotion, and sponsorship, the establishment of smoke-free environments in public places, and the creation of programs to help individuals quit smoking. These laws have been found to be more effective in reducing tobacco sales and consumption. Fichteberg and Glantz [36] have quantified the effects of regulating smoke-free workplaces and compared them to those achieved through tax increases. Similarly, Kasza et al. [37] analyzed the impact of tobacco marketing regulations, and Van Hoof et al. [38] perform the same analysis for the case of alcohol. These studies show that the measures resulted in significant reductions in the use of these products compared to tax increases.

The Spanish Government has enacted two tobacco use and prevention laws in December 2005 [39] and December 2010 [40], to regulate tobacco sales, supply, consumption, and advertising. While policies may influence behavior upon introduction to the public debate, our analysis focuses on the effective dates (December 2005 and December 2010) when the laws were enforced, and population-wide behavioral changes were expected. The purpose of these laws is to reduce tobacco sales and promote public health. The regulations require health warnings with images of tobacco products, the establishment of smoke-free environments in all public and workplace areas, and the creation of programs to help individuals quit smoking. The effectiveness of implementing control measures to ensure smoke-free environments in Spain has been demonstrated in a study by Galán et al. [41].

A group of studies in Spain have discovered that different regions in the country respond differently to certain economic situations, particularly in the context of tobacco consumption. One study by Martín-Álvarez et al. [42] found that the impact of the business cycle on tobacco consumption varies depending on the region. Another study by Almeida et al. [43] showed that in some regions, the demand for tobacco is not price-inelastic in the long term. Additionally, Almeida et al. [44] discovered that regions bordering countries with high price differentials, such as Gibraltar and France, tend to have clusters of low and high per capita tobacco consumption, respectively. These findings suggest that each region's response

to tobacco control measures is unique and should be considered accordingly.

Our research is focused on analyzing the differences in cigarette sales among the different regions of Spain. We will use data at the provincial level to determine how the implementation of tobacco use and prevention laws has affected sales. This is the first study to investigate the response to tobacco use and prevention laws in Spanish provinces, and into evaluate the potential effects of strategies that involve crossing borders.

Legislative framework
Spanish's Tobacco laws after their inclusion in WHO-FCTC
In 2005, Spain became a party to the WHO Framework Convention for Tobacco Control (FCTC), a global treaty aimed at reducing tobacco use and exposure. The FCTC [45] has had significant implications for Spain's policy environment, particularly in shaping its interactions with the tobacco industry and fostering cross-border collaboration with neighboring countries. By committing to this treaty, Spain adopted international standards for tobacco control, including measures to reduce tobacco consumption, restrict advertising, and promote public health. These commitments complement the domestic regulatory framework and provide an important context for understanding the broader impact of tobacco control policies implemented in Spain.

Following this commitment, two main laws regulate the consumption, sales, and advertising of tobacco products were implemented: Art 28/2005 [39] and Art 42/2010 [40]. The Ley 28/2005 [39] marked a significant milestone in Spain's tobacco control efforts, establishing the first comprehensive regulations on the consumption, supply, and advertising of tobacco products. This law aimed to reduce tobacco use through measures such as restricting smoking in certain public spaces and regulating the promotion and marketing of tobacco, laying the groundwork for future, more stringent legislation. Particularly, the tobacco uses, and prevention law enacted in December 2010 introduced significant measures aimed at reducing tobacco consumption and promoting public health. The Art 42/2010 [40] expanded on previous regulations by implementing stricter restrictions on smoking in public and workplace environments, as well as broader limitations on advertising, promotion, and sponsorship of tobacco products. Additionally, while the law did not directly mandate an increase in tobacco taxes, it operated in conjunction with fiscal policies that influenced the affordability of tobacco products during this period.

These measures, coupled with enhanced retail regulations and penalties for non-compliance, sought to create a more comprehensive framework for tobacco control. Moreover, Spain's position as a party to the WHO FCTC

Galiano *et al. Health Economics Review*   (2025) 15:44

Page 4 of 13

[46] influenced the alignment of its domestic policies with international standards, shaping its interactions with neighboring countries such as France and Portugal, where differing regulatory environments may have affected cross-border tobacco sales. Understanding the intersection of these policies is critical for interpreting the observed regional disparities and convergence patterns in cigarette sales.

The implementation of these laws had a notable impact on tobacco prices, the retail environment, and promotion practices. While neither law directly mandated tax increases, their enforcement coincided with fiscal policies that indirectly raised tobacco prices, primarily affecting cigarettes but also other tobacco products, such as roll-your-own tobacco [47]. Additionally, enhanced retail regulations included measures such as stricter licensing requirements, regular inspections, and penalties for noncompliance, which were primarily directed at retailers and distributors [38]. Although Spain did not implement a comprehensive track-and-trace system during this period, the combination of fiscal and regulatory measures aimed to reduce illegal trade and improve pricing enforcement [48]. Advertising and promotional activities were significantly curtailed, limiting the tobacco industry's ability to market its products, and further reinforcing these regulatory efforts [27].

Another critical factor influencing the effectiveness of tobacco control policies is the targeted marketing strategies employed by the tobacco industry. For instance, research demonstrates that comprehensive advertising bans are critical to reducing tobacco consumption, whereas partial bans have little or no impact [49]. Additionally, targeted marketing disproportionately affects vulnerable populations, such as adolescents, contributing to disparities in tobacco use behaviors [50]. These targeted marketing practices represent a critical environmental factor that shapes how regulatory measures translate into real-world outcomes, influencing the observed regional disparities in cigarette sales.

The role of advertising in shaping tobacco consumption patterns has been extensively studied, highlighting its significance as a driver of demand and its potential to undermine tobacco control policies. Lancaster and Lancaster [51] demonstrate that tobacco advertising expenditures are strongly correlated with increased demand, particularly among vulnerable populations such as adolescents. Their analysis underscores the necessity of comprehensive advertising bans to effectively reduce consumption, as partial restrictions often lead to a redirection of industry spending towards alternative marketing channels. Quentin et al. [52] further reinforce this conclusion through a systematic literature review, showing that comprehensive advertising bans are consistently associated with significant reductions in tobacco consumption over time. In contrast, partial bans yield minimal effects, as the tobacco industry adapts to regulatory gaps. These findings highlight the critical importance of implementing and enforcing strict advertising restrictions as part of broader tobacco control policies to mitigate the influence of marketing on consumption patterns and regional disparities.

Spain's laws, particularly Act 42/2010 [40], imposed significant restrictions on tobacco advertising and sponsorship. However, enforcement challenges in specific regions, especially near border areas, may undermine these policies. These strategies are often tailored to specific geographic regions, exploiting variations in demographic, socioeconomic, and regulatory contexts to maximize sales and circumvent restrictions [53]. In Spain, the geographic diversity, coupled with disparities in cross-border regulations, has provided opportunities for the tobacco industry to focus its promotional efforts on regions where enforcement might be less stringent or where access to lower-cost products is facilitated by neighboring countries. Studies have shown that the tobacco industry adjusts its marketing tactics based on regional consumption patterns and regulatory environments, often intensifying promotional efforts in areas with higher tobacco demand or weaker advertising restrictions [54, 55].

Following the results in Blecher [54], in developing countries, weaker enforcement mechanisms, limited resources, and significant informal markets often allow the tobacco industry to circumvent regulations and sustain high levels of tobacco consumption through targeted marketing strategies. In contrast, developed countries tend to implement stricter enforcement of advertising bans and higher tobacco taxes, which are more effective in reducing consumption. However, even within developed countries, regional disparities persist, particularly in border regions where cross-border trade and varying levels of enforcement can weaken the overall effectiveness of tobacco control measures. This distinction is particularly relevant for Spain, where geographic and regulatory diversity creates opportunities for the tobacco industry to exploit regions with less stringent enforcement or access to lower-priced products, highlighting the need for harmonized and robust policy implementation across all regions.

Impact of border state policies on regional tobacco sales

The effectiveness of Spain's tobacco control policies cannot be fully understood without considering the regulatory environments of its neighboring regions—France, Portugal, and Gibraltar (UK). These border states exhibit significant variations in tobacco control measures,

particularly regarding taxation, advertising restrictions, and enforcement practices, which can influence cross-border trade and consumption patterns in adjacent Spanish regions.

France has consistently ranked among the top European countries in tobacco control, as measured by the Tobacco Control Scale [34]. The country has implemented comprehensive policies targeting both marketing and pricing. High excise taxes have been a cornerstone of French tobacco control, contributing to significant increases in cigarette prices and reductions in smoking prevalence. Strict advertising bans and comprehensive smoke-free laws further limit the tobacco industry's ability to promote its products [56]. Moreover, France employs advanced enforcement mechanisms, such as the Codentify track-and-trace system,[1] to combat illicit trade and ensure compliance with tobacco control measures [48].

Portugal has adopted a less aggressive approach to tobacco control compared to France and Spain. While the country has ratified the FCTC and introduced some smoke-free regulations, it has been slower to implement comprehensive advertising bans or significant increases in tobacco taxes, resulting in more affordable products for consumers [48, 57, 58]. Portugal's focus has been primarily on creating smoke-free environments rather than targeting marketing practices or pricing strategies. This regulatory gap contributes to cross-border trade in regions like Galicia, where consumers seek cheaper tobacco products.

Gibraltar (UK) represents a unique case due to its low-tax regime and minimal restrictions on tobacco advertising and promotion [59]. Tobacco products in Gibraltar are significantly cheaper than in Spain, and enforcement mechanisms are relatively weak, making it a hub for cross-border purchases and potentially fueling illicit trade. While Gibraltar has implemented some smoke-free policies in line with the UK's commitment to the FCTC, its overall regulatory framework remains limited compared to its neighbors [48, 60].

These differences in border state policies highlight the need for harmonized tobacco control measures across the region to mitigate the influence of cross-border trade and ensure the effectiveness of Spain's domestic regulations. Understanding the interplay between Spain's policies and those of its neighbors is critical for interpreting the regional disparities observed in cigarette sales and consumption patterns.

The Table 1 summarizes the key tobacco control measures implemented by Spain and its neighboring regions, emphasizing differences in pricing, marketing restrictions, smoke-free regulations, and enforcement mechanisms.

Data and methods

The data utilized in this study has been sourced from the Trade of Tobacco Commission of Spain. This data provides a monthly overview of legal cigarette sales in each of the 48 Spanish provinces[2] from January 2005 to December 2021 (9,792 observations). Data has been divided into two distinct periods based on the regulatory changes that occurred in Spain in December 2005 and December 2010 (Act 28/2005 and Act 42/2010) [39, 40]. The first period, from January 2005 to December 2010, encompasses 3,456 observations (48 provinces with 72 months), while the second period, from January 2011 to December 2021, includes 6,336 observations (48 provinces with 132 months).

When the effect of a particle law is analyzed, it is important to distinguish between the introduction, enactment, and effective dates of these policies. The introduction date refers to when the policy is first presented to the public or legislative body, which can influence behaviors through public debate. The enactment date marks when the policy becomes law, while the effective date is when enforcement begins, and population-wide behavioral changes are expected. This study focuses on the effective dates of these laws—December 2005 and December 2010—when they officially came into force and their enforcement began.

These breakpoints we have chosen ensure consistency with the enforcement periods and capturing the impact of the regulations during their implementation phase since we are considering data starting from the months immediately following the effective dates of the laws.

Our study employs the club convergence test developed by Phillips and Sul [61, 62]. This non-linear and time-varying factorial model represents a significant advancement in club detection, since it allows for heterogeneity and identifies diverse temporal trajectories on the objects under study, in our case, the legal sales of cigarettes by region. This method identifies convergence clubs based on individual object characteristics, improving accuracy. Previous methods relied on defining a reference object and external methods to classify other objects, which can be less efficient. By deriving the different clubs from

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[1] Codentify is a track-and-trace system developed by Philip Morris International to monitor tobacco products through unique codes. While intended to combat illicit trade, it faces criticism for lacking independence from the tobacco industry. Article 8 of the FCTC Protocol mandates independent systems, making Codentify's alignment with these standards controversial.

[2] If we divide Spain into provinces, there are a total of 48 provinces, excluding the island, Canary Islands and Baleares. The provinces are grouped into 17 Autonomous Communities, excluding the autonomous cities of Ceuta and Melilla.

Galiano *et al. Health Economics Review*   (2025) 15:44

Page 6 of 13

Table 1 Comparative analysis of border state policies

Country	Price and Taxes	Marketing Restrictions	Smoke-Free Policies	Enforcement Measures	References
Spain	Indirect price increases through fiscal policies; higher than Portugal and Gibraltar (2010)	Comprehensive advertising bans under Act 42/2010	Expanded smoke-free regulations in 2010 to include all enclosed public spaces	Penalties for non-compliance; no comprehensive track-and-trace system	[34, 40, 57]
France	High excise taxes; significant price increases since early 2000s	Strict advertising bans since early 2000s; aligned with FCTC standards	Comprehensive smoke-free laws covering most public and private spaces since the early 2000s	Track-and-trace system (Codentify) implemented in 2010; Strong enforcement mechanisms	[34, 48, 56]
Portugal	Lower taxes compared to Spain and France; moderate increases after 2010	Partial advertising restrictions: slower implementation compared to Spain and France	Incremental implementation of smoke-free laws; less comprehensive than Spain and France	Weaker enforcement mechanisms compared to Spain and France	[48, 54, 57]
Gibraltar (UK)	Minimal taxes; significantly lower prices than Spain and neighboring countries	Minimal restrictions; weak enforcement of advertising bans	Limited smoke-free regulations; aligned partially with UK commitments to FCTC	Limited enforcement; contributes to illicit trade into Spain	[48, 59, 60]

Galiano *et al. Health Economics Review*   (2025) 15:44

Page 7 of 13

the endogenous characteristics of each object, our model enhances the reliability and extrapolation of the different clubs found [63].

To start with the estimated model, Phillips and Sul [61, 62] proposed a modification in the data decomposition of the variable under study. Being X the variable data under study, is broken down in the following way:

$$X_{it} = g_{it} + a_{it}$$

where g_{it} includes the common component, so that, it is the systemic part that affects the entire variable, and a_{it} is the transitory component in time.

To have the heterogeneity of time in the variable under study, the resulting equation is:

$$X_{it} = \left(\frac{g_{it} + a_{it}}{\mu_t} \cdot \mu_t \right) = b_{it} \cdot \mu_t$$

This a factorial formulation that separates the proper parts of the object from the common ones, b_{it} is the path to a common state determined by μ_t. The estimation of b_{it} is essential for checking the converge of the different objects, but some additional restrictions are imposed to b_{it} before its estimation.

In turn, to build a statistical test for convergence, Phillips and Sul [61]. assumed the following parametric estimation of b_{it}:

$$b_{it} = b_i + \frac{\sigma_i \xi_{it}}{L(t) t^\alpha}$$

Where b_i is defined to be invariant in time; the parameter ξ_{it} is a time-dependent and standard normal independent and identical distributed random variable; $L(t)$ is a slowly varying function in time that $L(t) \to \infty \, when \, t \to \infty$; and α is the convergence ratio.

The hypothesis test for convergence would be:

$$H0 : b_i = band \; \alpha \geq 0$$

$$H1 : b_i \neq band \; \alpha < 0$$

If the null hypothesis is not ruled out, there may be different trajectories for the objects, including divergence.

Additionally, Phillips and Sul [38, 39] proposed to study the existence of convergence between objects by estimating the following model by ordinary least squares (OLS):

$$log \frac{H_1}{H_t} = -2\log(\log t) = \alpha + \beta \log t + u_t; \, t = [rT], [rT] + 1, \ldots, T.$$

In this equation, $H_t = N^{-1} \Sigma_{i=1}^{N} (h_{it} - 1)^2$, and $\frac{H_1}{H_t}$ is the variance ratio of the cross-section; β represents the speed of convergence of the b_i parameter; $-2\log(\log t)$ is a penalty function that improves the performance of the test under the alternative hypothesis; r has a positive value on the interval (0,1) to discard the first observation block from the estimation, finally, $[rT]$ is the enter part of rT. Phillips and Sul [39]. suggested using $r \in (0.2, 0.3)$ for samples of small size ($T < 50$) because of Monte Carlo simulations.

The null hypothesis of convergence is contrasted by applying the one-tailed t-test at a significance level of 5%, rejected at this level if $t_{\beta <} - 1.65$. The test is robust to heteroscedasticity and autocorrelation (HAC) to inequality $\alpha > 0$ (using the estimate $\beta = 2\alpha$).

The log-t test would serve to contrast the convergence of clubs for the entire sample. If this test is rejected, Phillips and Sul [59, 60] proposed repeating the procedure by applying a four-step grouping. Regarding the number of resulting clubs, and as a solution to this problem, Phillips and Sul [60], developed an algorithm for merging the clusters formed with the previous algorithm. This would enable the detection of clubs close to each other by running the log-t test comparing the clubs one by one with the rest of the clubs. Following the same criteria as above, if $t < -1,65$, these clubs will not converge. But, if $t > -1,65$, the clubs will converge, and they will form a new club.

Results

In this section, we present the results of our analysis. To accomplish our objective, we utilized R Version 4.0 and the ConvergenceClubs package [63].

By applying the Log(t) test statistics we determine if there was global convergence in the two periods considered and on the whole sample. The results of the Log(t) test statistics are presented in Table 2, which provides all the necessary information to determine whether the null

Table 2 Log (t) test statistics for cigarette sales by provinces, 2005–2021

Period	Number of provinces	Test	β	Standard error	t-Statistic	*p*-value
2005–2021	48	log t	-1.453	0.088	-16.484	0.000
2005–2010	48	log t	-0.483	0.012	-41.396	0.000
2011–2021	48	log t	-0.568	0.001	-454.413	0.000

Galiano *et al. Health Economics Review*   (2025) 15:44

Page 8 of 13

hypothesis of overall convergence can be rejected in each period.

The regression analysis shows that the slope coefficient for cigarette sales in Spain by province is -1.453, -0.483, and -0.568. The standard errors are 0.088, 0.012, and 0.001, respectively, accounting for heteroscedasticity and autocorrelation. Therefore, we reject the null hypothesis of overall convergence for any significance level. These results suggest that cigarette sales in Spain by province diverge, meaning that we reject the idea of absolute convergence.

After rejecting absolute convergence, we used a clustering algorithm to examine whether there was within-group convergence. This analysis was done over the two sub-periods (2005–2010 and 2011–2021). The results are displayed in various tables and figures. Tables 2 and 3 illustrate different clubs, and for each club, the corresponding estimations of β (where β = 2α is the scaled coefficient of the club's speed of convergence, and α is the estimated speed of convergence for any club following

Phillips and Sul [61]. In all instances, the t-statistic the existence of within-club convergence.

The number of clubs found varies depending on the period being considered. Our findings reveal a shift in club composition (Fig. 1), with a notable decrease in the number of clubs. From 2005 to 2010, three convergence clubs were observed, while from 2011 to 2021, the regions were grouped into two clubs. This reduction in the number of clubs indicates that from 2011 to 2021, the sales of cigarettes have a more uniform behavior than from 2005 to 2010, where regions were grouped into three clubs. This result supports what is established in the previous literature [64], indicating that Act 42/2010 was more restrictive than Act 28/2005.

The algorithm's application to the pre-2011 period (Table 3 and Fig. 2) identified two provinces as divergent (Girona and Cádiz). Girona is situated in the northeast region of Catalonia and Cádiz is in the southwest of Andalucía. Both are border provinces with France and Gibraltar, respectively. Applying the clustering algorithm

Table 3 Convergence club process in cigarette sales by province, 2005–2010

| Club	Number of provinces	β	Standard error	t-value	*p*-value	Name of the provinces
1	3	1.17	0.080	14.550	1	Lleida, Guipúzcoa, Navarra
2	19	0.167	0.160	10.405	1	Balears (Illes), Huelva, Alicante/Alacant, Huesca, Almería, Badajoz, Murcia, Cáceres, Jaén, Ciudad Real, Cuenca, Albacete, Cantabria, Ávila, Palencia, Asturias, Teruel, León, Soria
3	24	0.038	0.028	1.354	0.912	Tarragona, Málaga, Granada, Valencia/València, Toledo, Castellón/Castelló, Zaragoza, Córdoba, Guadalajara, Burgos, Salamanca, Rioja (La), Segovia, Madrid, Valladolid, Zamora, Coruña (A), Vizcaya, Ourense, Lugo, Sevilla, Barcelona, Álava, Pontevedra
Divergent	2					Girona, Cádiz
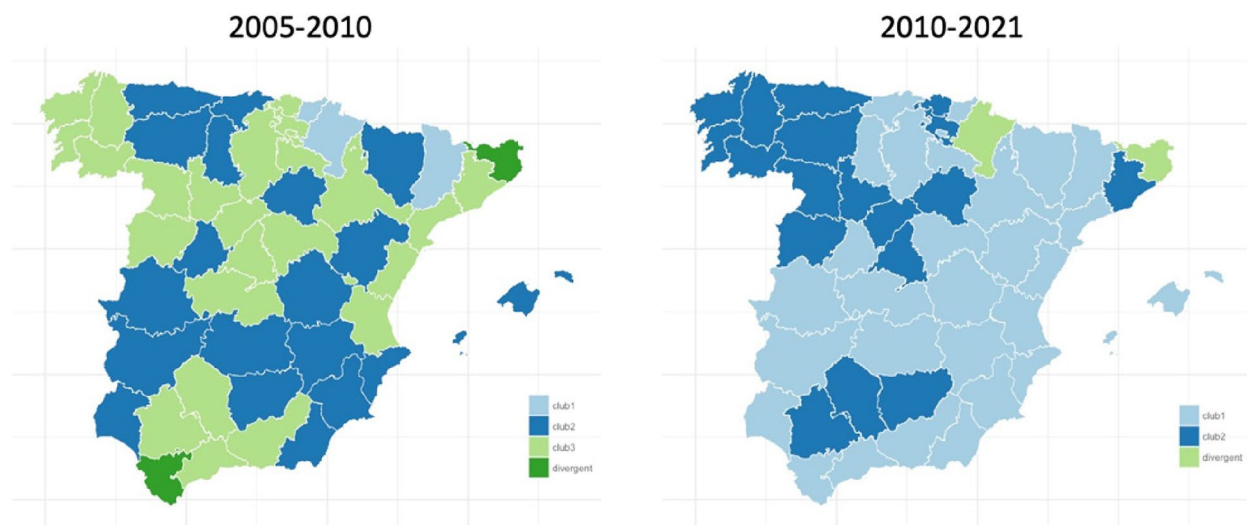
Fig. 1 Geographical distribution of the clubs found

Galiano *et al. Health Economics Review*   (2025) 15:44
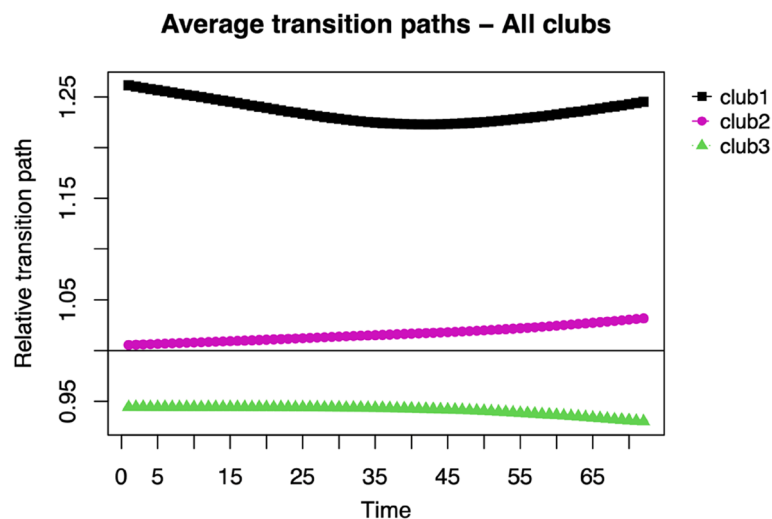
Page 9 of 13

Fig. 2 Convergence transition paths and speed in cigarette sales, 2005–2010

to test for subgroup convergence to the second subperiod from 2011 to 2021 (Table 4 and Fig. 3) two provinces are also identify as divergent (Girona and Navarra). Navarra is positioned in the north of Spain, and it is also a border province with France. Our analysis has found that Girona is divergent in all the sub-periods examined. Additionally, Navarra and Cádiz also show divergences in some periods with respect to the rest of the provinces. It is important to note that all these regions are border provinces with France and Gibraltar, as illustrated in Fig. 1. These results are consistent with previous research, which suggests that there exists regulatory distortions and inefficiencies in these border countries [40, 48, 49].

The analysis shows that regions bordering France, Portugal, and exhibit significant differences in tobacco sales dynamics, driven by proximity to distinct regulatory and fiscal contexts. Specifically, the provinces of Girona and Cádiz showed divergent behavior before 2011, while Girona and Navarra exhibited it after 2011. These

variations do not necessarily imply a generalized increase in sales in all border regions but rather reflect how the tobacco control policies of neighboring countries differently affect behaviors in these areas.

Our findings suggest that the effectiveness of tobacco use, and prevention laws varies in border regions compared to non-border areas. This could be due to the influence of foreign customers crossing the Spanish border to buy tobacco products, leading to significant changes in sales behavior. A major contributing factor could be the higher price differential for cigarettes in these countries compared to Spain. This is in line with recent studies that emphasize the importance of cross-border strategies and collaboration in tax legislation to address price differentials between regions [25, 28, 29].

The analysis performed focuses on assessing the impact of specific tobacco control laws on regional cigarette sales and convergence behaviors, with the timing of these policies being a critical factor. The periods analyzed are

Table 4 Convergence club process in cigarettes sales by province, 2011–2021

Club	Number of provinces	β	Standard error	t-value	*p*-value	Name of the provinces
1	28	0.170	0.012	13.630	1	Almería, Cuenca, Castellón/Castelló, Cádiz, Huesca, Huelva, Albacete, Toledo, Guadalajara, Alicante/Alacant, Balears (Illes), Murcia, Cáceres, Ciudad Real, Teruel, Tarragona, Zaragoza, Ávila, Granada, Badajoz, Cantabria, Rioja (La), Valencia/València, Burgos, Palencia, Málaga
2	18	0.015	0.012	1.242	0.893	Asturias, León, Jaén, Segovia, Soria, Zamora, Valladolid, Coruña (A), Ourense, Vizcaya, Lugo, Córdoba, Salamanca, Sevilla, Álava, Madrid, Pontevedra, Barcelona
Divergent	2					Girona, Navarra

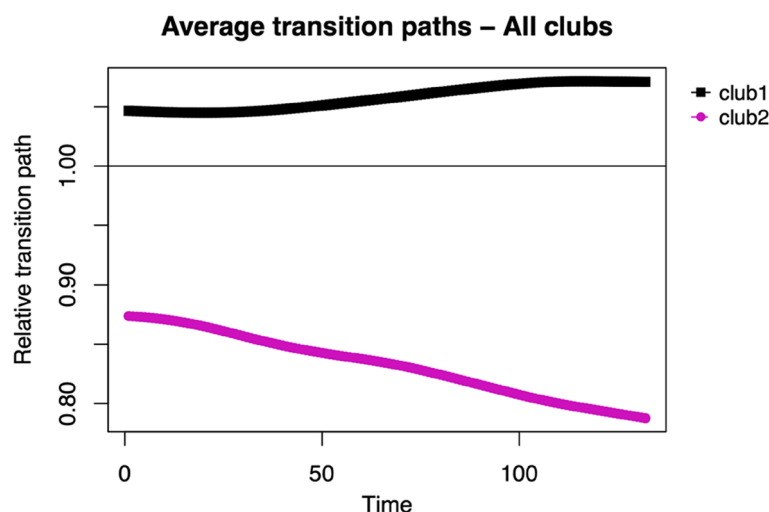## Average transition paths – All clubs

Fig. 3 Convergence transition paths and speed in cigarette sales, 2011–2021

directly tied to the dates of implementation of these laws, as they represent the actual moments when the regulations came into effect and began to influence behavior. Altering the timing of the analysis would distort the results and contradict the study's objective, which is to demonstrate that the selected dates and periods have a tangible impact on the convergence patterns observed across the units of analysis. By maintaining the chosen temporal framework, we ensure that the analysis accurately captures the effects of these policies and their role in shaping regional disparities.

This justifies the decision not to introduce sensitivity analyses of the results. Additionally, the methodology employed in this study follows a well-established framework used in similar academic research analyzing regional disparities and convergence patterns. Notably, articles such as [65–67] employing this methodology do not include sensitivity analyses, as the robustness of the results is inherently tied to the assumptions and structure of the convergence models used. The selected methodological approach ensures consistency with the existing body of literature and highlights the reliability of the findings without requiring additional sensitivity testing.

Discussion

This paper aims to examine regional disparities in cigarette sales that occurred after the implementation of two laws regulating the sale and use of tobacco products in Spain. These laws were introduced in December 2005 (Act 28/2005) and 2010 (Act 42/2010). Furthermore, it provides a framework for studying spill-over effects pertaining to cross-border strategies that may alter how frontier regions react to the implementation of the laws. Provincial official data from January 2005 to December

2021 for legal cigarette sales has been divided into two distinct periods based on these regulatory changes. We apply Phillips and Sul's club convergence test for absolute and within-group convergence.

One strength of this study is the use of Phillips and Sul's club convergence test, which allowed for a detailed analysis of convergence patterns within groups of similar provinces. This method provided a nuanced understanding of how tobacco sales converged over time.

Our findings indicate that although the 2010 law helped to reduce disparities across provinces, there was no complete convergence, meaning that the impact of the law was not uniform across all regions, especially in frontier regions with France and Gibraltar. However, we observe evidence of convergence within groups of similar entities, and the number of these groups decreased over time. This outcome highlights several interesting insights. Firstly, it supports what previous studies have established, indicating that the 2010 law was more restrictive than the one in 2005. Secondly, the effectiveness of these regulations can vary in border regions due to different laws in neighboring countries, resulting in unintended consequences that can reduce the impact of tobacco control policies, a result that is also in line with the literature.

At the provincial level, we found that the laws implemented did not result in an overall convergence or standardization of the market, indicating a geographical factor. We observe a convergence within certain subgroups of provinces and, interestingly, this convergence did not occur in some border regions.

- *Regions bordering France (northern Spain, such as Navarra and Girona):* The stronger tobacco control measures in France incentivize cross-border

Galiano *et al. Health Economics Review*   (2025) 15:44

Page 11 of 13

purchases into Spain, creating a more pronounced impact in regions bordering France. France's robust tobacco control measures—high excise taxes, strict advertising bans, and comprehensive enforcement—create a significant price disparity with Spain. As a result, French consumers often cross into Spain, particularly in regions like Catalonia, to purchase cheaper tobacco products. This explains the more pronounced impact observed in regions bordering France, as the flow of cross-border purchases into Spain is driven by these economic incentives. Otherwise, the density of populations, economic activities, and transport accessibility in border regions further amplifies these patterns. For instance, Catalonia's proximity to major French cities facilitates the flow of consumers, while the lower economic disparities along the Spanish-Portuguese border mitigate similar effects. Higher prices in France and may influence sales behavior in neighboring areas.

- *Regions bordering Portugal and Gibraltar (southern Spain, such as Cádiz):* Gibraltar's minimal taxes and weak advertising restrictions create a hub for low-cost tobacco products. This not only incentivizes cross-border purchases from Spain but also fuels illicit trade. However, given Gibraltar's small size, its impact is localized and does not significantly distort the broader regional patterns observed in Spain.
- Portugal's relatively lower taxes and weaker enforcement of advertising bans make it an attractive destination for price-sensitive consumers. Consequently, the cross-border flow of tobacco products is more likely to move from Spain into Portugal rather than the other way around. This dynamic reduces the observable impact of Spain's tobacco control measures in regions bordering Portugal. This analysis underscores the importance of harmonized policies across neighboring regions to mitigate cross-border trade and enhance the effectiveness of domestic tobacco control measures. Moreover, our results are consistent with previous literature, which suggests that regulatory distortions can result in inefficiencies when laws are applied at the national level [47, 68, 69].

We highlight that tobacco use and prevention laws, when examined in the context of the evolution of tobacco sales, play a pivotal role in creating a convergence path among regions, underscoring their significant impact on tobacco control. However, the impact of these regulatory changes can be markedly different in border regions, primarily due to the unique challenges posed by neighboring countries with varying regulatory laws, thereby highlighting the complexities of cross-border tobacco control. When regulatory distortions occur in neighboring countries, they can trigger spillover effects that distort the way people respond to the laws in nearby provinces, potentially undermining the effectiveness of tobacco control policies and necessitating the need for harmonized regulations. This can potentially reduce the effectiveness of tobacco control policies and cause unintended consequences.

Conclusion

This research highlights the pivotal role of tobacco use and prevention laws in shaping regional convergence in tobacco sales in Spain. Despite the positive impact of the 2010 law in reducing provincial disparities, border regions exhibited unique challenges due to cross-border effects. Policymakers should consider these complexities to ensure the effective implementation of tobacco control measures.

The results contribute to the growing body of literature using club convergence to evaluate the impact of tobacco control policies on consumption patterns [65–67], emphasizing the need for harmonized measures to reduce regional disparities.

Our results have important policy implications. They suggest that while national tobacco use and prevention laws can create a convergence path among regions, their impact can be markedly different in border regions due to the unique challenges posed by neighboring countries with varying regulatory laws. This highlights the need for harmonized regulations to enhance the effectiveness of tobacco control policies.

For future research, it would be interesting to study the effectiveness of the tobacco use and prevention laws in eliminating the spillover effect found in this research. To accurately measure the reduction of tobacco prevalence rates in a specific region, tobacco consumption should be used instead of sales. This method would help to eliminate the impact of cross-border sales and tax avoidance on the analysis of the effectiveness of national policies. By analyzing consumption data, it would be possible to remove the effect of foreign sales and obtain a more precise assessment of policy outcomes.

Galiano *et al. Health Economics Review*   (2025) 15:44

Page 12 of 13

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate.

Not applicable.

Consent for publication.

Not applicable.

Competing interests

The authors declare no competing interests.

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