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Sustainable mobility and alternative fuel vehicles.
How can public policy sell you a new car?

Niccolò Donati
UNIVERSITY OF MILAN

Abstract

To solve issues related to sustainable mobility, and in particular to the sale of alternative fuel vehicles (AFVs), public policy has to produce a change in the behaviour of citizens. Scholarly research has mainly investigated the causal power of policy instruments individually, while few studies address how interactions of different types of policy instrument can causally affect individual behaviour. Building on the policy design literature, a specific combination of positive and negative inducements can put in motion a mechanism that can change individual behaviour desirably, by narrowing the possible choices of the policy takers to a single and clear behavioural pattern. In order to test whether the interaction effect takes place, we will analyse the policy mixes adopted by five Italian regions to reduce environmental pollution in the period 2000-2005. Qualitative comparative analysis will be used to identify which combinations of policy instrument were more effective in inducing environmental-friendly consumer behaviours.

1. Introduction

In some of the most iconic science fiction movies from the 1980s, the future giant cities of Earth were depicted as densely populated and perpetually battered by acid rains. During the 1980s, acid rain was a frequent and worrisome event, partly resulting from nitrogen oxide (NO_x) emissions, mostly stemming from consumer behaviours – particularly traditional cars' emissions (Hendrey 1985, Newbery et al. 1990). Eighties science fiction concocted many elements to lend credibility to this future dystopia: among them, governments' failure, overpopulation, and individual egoism, resulting in path dependency and reliance on heavily pollutant transport and industrial production. Notwithstanding the fatalism that surrounded this issue in popular culture, in reality, public policy was extremely effective in curbing NO_x emissions: in OECD countries, NO_x fell by 50 percent during the 1990-2020 period (OECD 2020). This was achieved thanks to a mix of taxation and new regulations which changed consumer and producers' behaviours, by both imposing new standards (compulsory catalytic converters on new cars) and incentivizing the conversion of old vehicles (Gunningham and Sinclair 1999: 59).

Acid rains are a distant memory; today's science fiction dystopias depict our future as either a barren or a frozen world resulting from climate change. 'Fleet inertia' could once again be relevant in bringing into existence this future scenario: for instance, passenger cars and vans alone contribute to 14.5% of total EU GHGs emissions (European

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Contact Author: Niccolò Donati, University of Milan, Milan
E-mail address: niccolo.donati@unimi.it

Commission 2022). Can we replicate the success obtained with NO_x reduction? The public policy solution to this problem is more complex since it requires more radical behavioural adaptation. One crucial measure that could contribute to GHG reduction would be to gradually substitute internal combustion engine vehicles (henceforth traditional vehicles) with alternative fuel vehicles (henceforth alternative vehicles). Alternative vehicles generally have higher purchase costs than traditional vehicles (Morfeldt et al. 2021). These costs are generally offset during the life cycle of a vehicle, with many alternative vehicles having lower total costs of ownership than the traditional vehicles (Rusich and Danielis 2015). In the short run, however, purchase costs may push people towards preferring traditional vehicles. Hence, public policy is once again paramount in speeding up the substitution of traditional vehicles with less-pollutant alternative vehicles.

The EU started to take action in this policy field after the Treaty of Amsterdam. The AutoOil Programme II, backed by Directive 98/79/EC, put forward a strategy to meet the Kyoto Protocol obligations by incentivising the use of alternative fuels for private transport. In each member state, these measures were implemented by different tiers of government in accordance with the principle of subsidiarity. In Italy, Legislative Decree 351/99 established a national framework for creating measures aimed at air quality preservation. Decree 500/99 allocated financial resources to create, both at the national and the regional level, sustainable mobility measures, including incentives for fuel-efficient vehicles (Nespor and De Cesaris 2009). Italian regions experimented with different policy mixes to improve air quality and also push the sales of alternative vehicles.

In this research, we will look at the policy instruments adopted by five Italian regions in the context of Decree 351/99. The regions were selected from among the northern Italian regions with more than two million residents. In this way, we are able to compare regions with a similar socio-economic composition and administrative capacity. The resulting sample is composed of Lombardia, Piemonte, Toscana, Veneto, and Emilia-Romagna. Provided that different policy instruments can achieve the same goal and considering that the combination of instruments can be more effective than the adoption of individual policy instruments, the comparison between the five regions will help us understand what principles should be taken into account when designing a policy aimed at solving the problem of fleet inertia. Our operational hypothesis is that a combination of repressive instruments (regulations) and stimulative instruments (financial incentives) can create a policy which is more effective in changing individual (consumer) behaviours.

The current literature on alternative vehicles offers some preliminary answers to our research question: we will look at them in Section 2. However, there are research gaps: Section 3 introduces a research puzzle that is hard to explain with the current findings of the literature on alternative vehicles policy. We then look at the literature on policy design and how research on the complementarity of policy mixes can provide useful guidance in designing an effective system of incentives as regards alternative vehicles. Section 4 will discuss the research design. Section 5 will compare the policies of the five Italian regions when first designing their alternative vehicle incentives during the 2000-2004 period. In the conclusions, we will be taking stock of the research findings in light of the existing literature.

2. Literature review

The development of alternative fuel vehicles is considered to be key in creating a sustainable energy policy and fighting climate change (Romm 2006). However, the alternative vehicles economic sector is one with relevant market barriers and failures. These principally consist of: i) financial barriers, including increased costs for consumers; ii) technical barriers, such as the low density of refuelling and charging facilities; iii) regulatory barriers, including regulatory gaps; iv) the public acceptability of alternative vehicles, related to subjective and intersubjective conditions that influence the decision to buy an alternative vehicle (Browne *et al*. 2012).

Since these market barriers *de facto* hinder the capacity of alternative vehicles to gain a foothold in the market, it is advisable to tackle these barriers through specific policy initiatives aimed at making alternative vehicles competitive with traditional vehicles (Leiby and Rubin 2004). In this regard, any such policy should take into account consumers' attitudes towards AFVs. The first influencing factor is the purchasing price of alternative vehicles. In this regard, many researchers have focused on subsidies and taxation as a means to reducing the price gap between alternative and traditional vehicles. When there are market failures, subsidies can play an important role by ensuring sustainable sales thresholds to alternative vehicles producers, thus 'tipping' the market back into 'a successful trajectory' (Shepherd *et al.* 2012). The second influencing factor is the price of petrol: the cheaper petrol is, the harder it is to sell alternative vehicles, even if alternative fuels have generally lower prices. According to some literature, this factor is even more relevant than government incentives on alternative fuels purchase: the incentives would have a weaker effect than the relative price of fuels on the sale of alternative vehicles (Diamond 2009, Beresteanu and Li 2011). According to Yeh (2007), both competitive alternative fuel prices and alternative vehicle subsidies play a role in enabling the 'wide adoption of natural gas vehicles'. Natural gas retail fuel price should be below '40-50% gasoline and diesel price' to be competitive. With regard to subsidies, they should keep 'the payback period at 3-4 years'. The two measures need not be adopted in conjunction, but in absence of one of the two, the alternative vehicles market cannot develop (Yeh 2007). A second way in which fiscal policy can improve the competitiveness of alternative vehicles is by taxing traditional vehicles. In this regard, Browne *et al.* (2012) suggest taxing negative externalities 'such as GHG emissions' (see also Gass *et al.* 2014). In the French case, alternative vehicle incentives and traditional vehicle disincentives are deployed at the same time, through a 'bonus-malus' system: 'high CO_2 emitting cars pay a malus, while desirable non-emitting cars receive a bonus' (Kerster *et al.* 2018). In terms of instrument settings, Shepherd *et al*. found 'a modest 6.8% increase in [conventional vehicles] operating costs' in terms of both increased fuel duties or external increases in oil prices (2012).

The traditional-alternative vehicles price differential is not the only factor playing a role in tipping consumers' choice in favour of alternative vehicles. According to Petschnig *et al*. (2014) there are three other factors that can significantly influence buying attitudes: i) compatibility, i.e., the capacity to retain previous driving habits; ii) relative advantage, i.e., the unique advantages offered by alternative vehicles compared to those offered by traditional vehicles; iii) cultural norms and preferences, especially those related to ecology.

In this section, we will address the first two dimensions. Concerning compatibility, one key dimension is the refuelling infrastructure: the absence of an adequate number of refuelling stations can dissuade consumers from buying alternative vehicles, in consideration of the necessity to change previous driving habits (Sierzchula *et al*. 2014, Yeh 2007, Egnér and Tosvik 2018). In this regard, the presence of adequate refuelling infrastructure is considered a necessary condition for the development of the market: in its absence, consumers will not buy alternative vehicles regardless of other considerations (such as generous incentives). In this regard, the necessary ratio of alternative-fuel refuelling infrastructure to the total number of refuelling stations is between 10 and 20% (Greene 1998, Nicholas *et al.* 2004). A second way of conceptualising alternative fuels infrastructure is in terms of 'sufficient' levels of coverage: the ratio which facilitates (instead of simply enabling) the commercialisation of alternative vehicles. In this respect, Melaina and Bremson (2008) found that the sufficient level of refuelling infrastructures in urban centres with a density of 2000 people per 2.6 square kilometers is 0.5 stations per 2.6 square kilometers. Concerning the second dimension, the relative advantage of alternative vehicles *vis-á-vis* traditional vehicles, the literature has focused, in recent years, on non-financial incentives as a way to make alternative vehicles more appealing – in terms of status, rather than from an economic standpoint (Holtsmark and Skonhoft 2013). Examples of non-financial incentives are special lane access, preferential parking, exemptions from driving bans (Hardman 2019).

3. Research gaps and puzzle

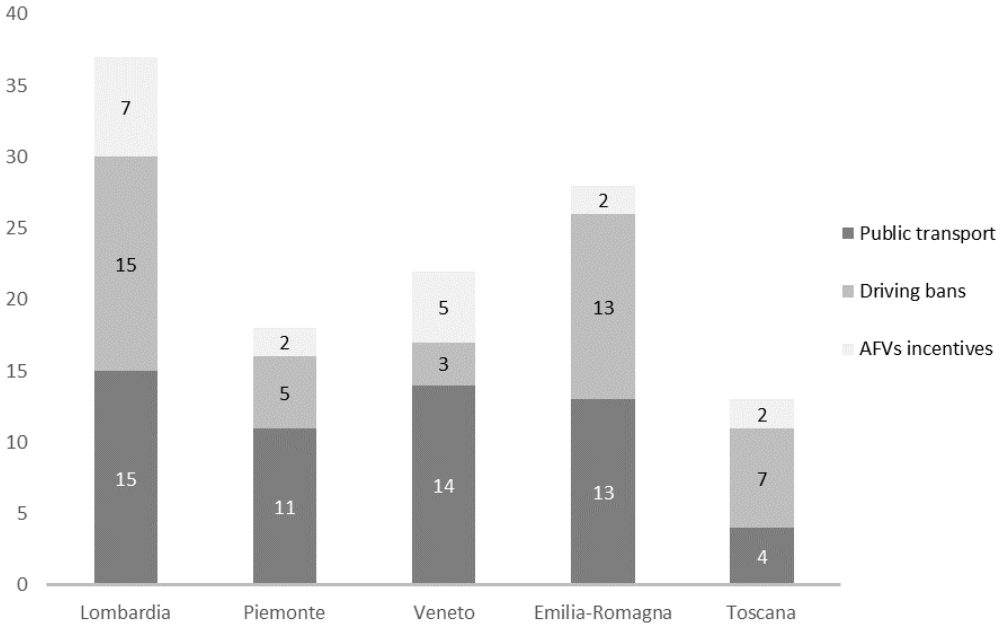
When examining the existing literature on alternative vehicles policies, policy instruments are rarely considered in combination. Even when policy mixes are explicitly addressed, the potential interaction effects between different types of policy instruments are seldom explored. Furthermore, when such interactions are studied, the consistency between observed outcomes and different policy mixes is not thoroughly measured. To shed light on this research gap, we will analyse the sales of alternative fuel vehicles in five Italian regions during the period 2005-2009. While the cases and operationalisation will be described in Section 4, we will utilize some of the data to illustrate the research puzzle in the context of the literature reviewed in the previous section.

Figure 1 illustrates the number of mobility-related measures adopted by each of the five Italian regions during the 2000-2004 period, aggregated by type of intervention. The majority of measures pertain to driving bans, while financial incentives to purchase alternative vehicles constitute a significant share of the policy measures adopted by the regions. Lastly, the category of 'transport policy measures' includes all initiatives aimed at altering the hierarchy between transportation modes, encouraging the use of public transport, walking, and bicycles instead of private cars (Banister 2008).

Each of these types of measure aimed to reduce the use of traditional vehicles for transportation. Various causal pathways could be envisioned to achieve this outcome, such as decreasing private transport through incentivizing public transport usage or increasing the adoption rate of alternative vehicles by either offering direct incentives or disincentives for traditional vehicles. Each solution complements the intended policy goal, and low rates of alternative vehicle adoption do not necessarily imply a failure in

the policy. Nevertheless, an increase in AFV sales can be deemed a sufficient solution for the policy problem at hand and thus a relevant outcome.

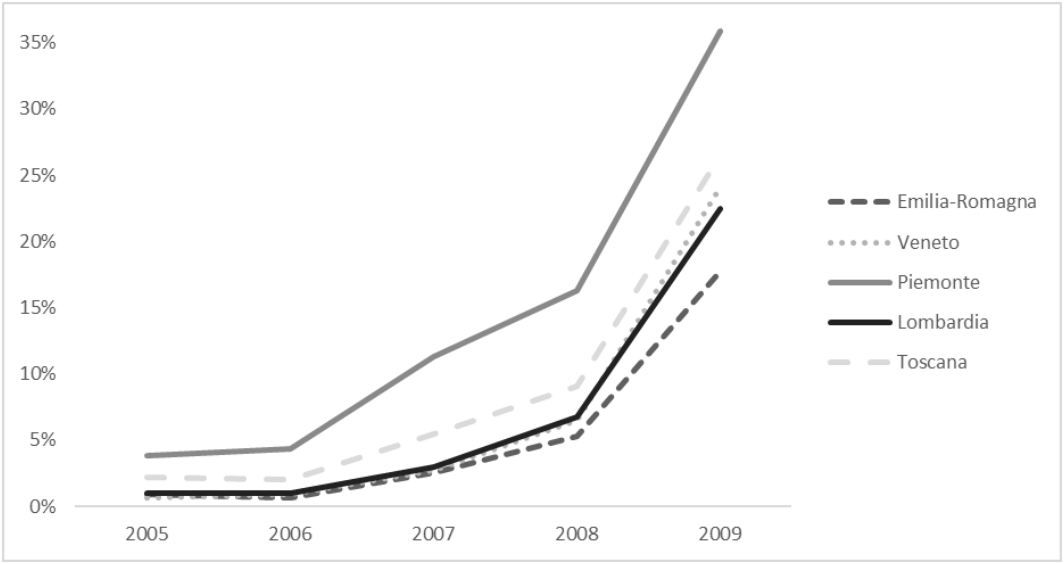
Figure 1. Number of mobility-related measures adopted during 2000-2004 (source: regional official gazettes, own elaboration)



Source: regional official gazettes, own elaboration.

Figure 2 depicts the percentage of alternative vehicles in total car sales during 2005-2009 (source: ACI 2010, own elaboration). Throughout the considered period, the sales of new AFVs followed a similar trend in all five regions.

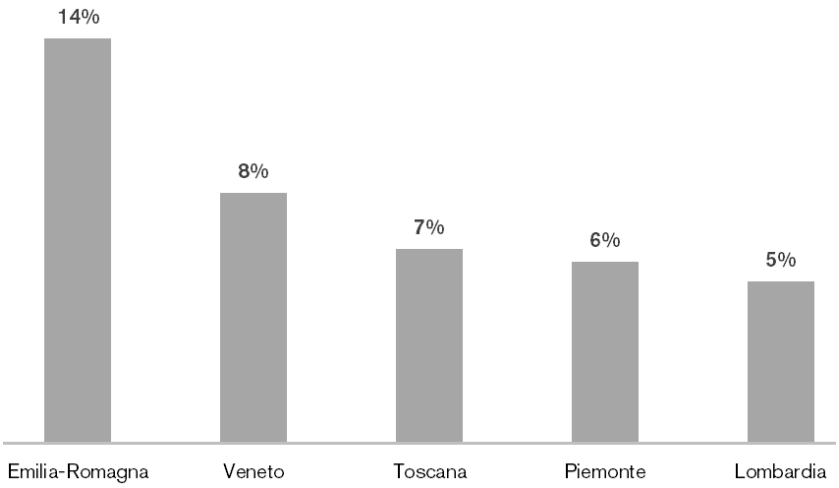
Figure 2. Percentage of alternative vehicles in total car sales during 2005-2009



Source: ACI 2010, own elaboration.

At the end of the 2005-2009 period, Emilia-Romagna emerged as the best performing region in terms of alternative vehicle sales over the total number (Figure 3).

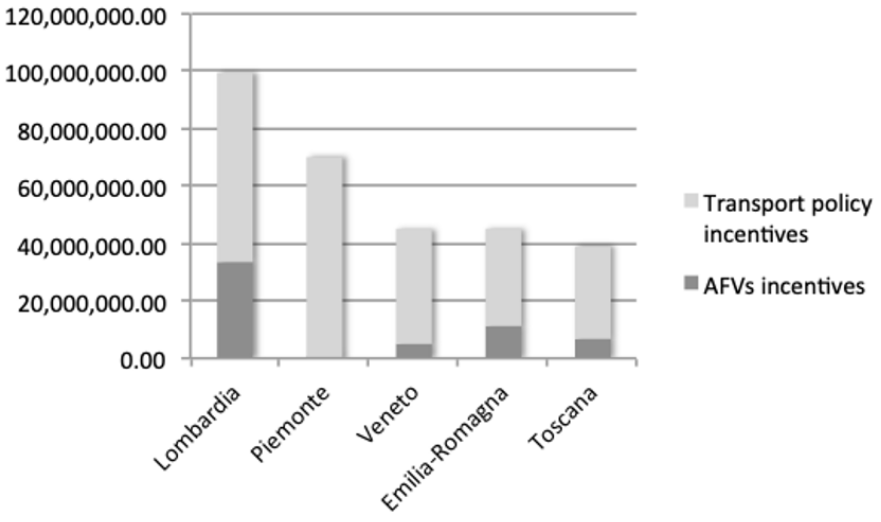
Figure 3. Percentage of alternative vehicles in total car sales during 2005-2009



Source: ACI 2010, own elaboration.

The literature we reviewed would suggest first focusing on the incentives adopted by each region: the higher the financial incentives, the higher the sales of alternative vehicles. However, research data present a different picture (Figure 4). Among the regions considered, Lombardia provided the most generous incentives (both in relative and absolute terms) during the 2000-2004 period; however, it performed poorly in terms of alternative vehicle sales during the 2005-2009 period. In contrast, Piemonte outperformed Lombardia, even though it did not offer financial incentives to purchase AFVs during the 2000-2004 period.

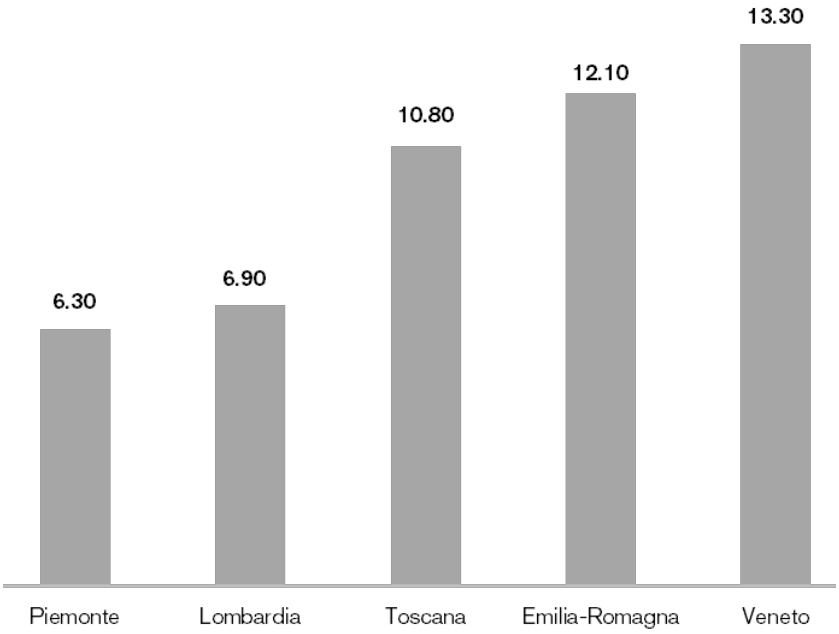
Figure 4. Funds for alternative vehicle incentives over total incentives for transport policy during 2000-2004, millions of euros



Source: regional official gazettes, own elaboration.

A second intuitive explanation considers the existing refuelling infrastructure (Yeh, 2007). Numerous empirical studies have demonstrated that to develop a mature AFVs market, the number of alternative-fuel refuelling stations (AFRSs) must constitute at least 10-20% of gas/diesel refuelling stations (Nicholas et al., 2004). Figure 5 displays the AFRSs ratio for the five regions. The 10% threshold appears to apply to the two worst-performing regions, Lombardia and Piemonte. Moreover, three of the best-performing regions, Emilia-Romagna, Toscana, and Veneto, also boast an AFRSs ratio above the 10% threshold. However, the refuelling infrastructure alone does not seem capable of explaining the varying performances of these three regions. Specifically, Veneto has a more favourable AFRSs ratio than Emilia-Romagna, yet its sales of alternative vehicles are significantly lower.

Figure 5. Percentage of alternative vehicles over total car sales during 2005-2009



Source: ACI 2010, own elaboration.

4. Analytical framework: causal mechanisms and policy mixes

In the previous section, we demonstrated that a theory solely based on the effects of individual policy instruments could not adequately explain the variations in outcomes between the five Italian regions. A more robust explanation may lie in the different combinations of policy instruments (and their relative settings) adopted by these regions. The interaction between policy instruments can create complex effects; in other words, the aggregate effects of the policy mix may surpass the sum of its individual parts. To better elucidate the observed outcomes, we must first attempt to conceptualise how this interaction operates, which can be achieved by unveiling the causal mechanisms at play.

According to Gerring (2010), causal mechanisms can address the question of 'how X causes Y' by specifying the causal chain that leads from X to Y. Another distinguishing feature of the mechanistic understanding is the 'interest in the theoretical process whereby X produces Y,' involving a 'transmission of what can be termed causal forces

from X to Y' (Beach and Pedersen 2011: 25). Bechtel and Richardson (1993) and Glennan (1996) consider mechanisms as 'systems of interacting parts'. Considering how these parts interact means viewing mechanisms not merely as isolated components but rather as the 'wheel-work' or agency by which an effect is produced (Hernes 1998: 78). The nature of these interactions is the subject of debate: on one hand, Machamer et al. (2000) characterize mechanisms as 'entities and activities organized in a way that they are productive of regular changes from start or set-up to finish or termination conditions'. On the other hand, a substantivalist position does not consider activities ontologically distinct from entities. In this regard, changes in the properties of the mechanism, in terms of the presence or absence of entities, can explain the mechanism's productivity. The latter perspective is particularly suitable for our analysis, enabling us to conceptualise each policy instrument as distinct entities while also understanding the effectiveness of various mixes of instruments. Consequently, mechanisms will be conceptualised as 'systems of interacting parts,' where the interacting parts are distinct entities. The resulting causal model needs to be expressed in the following form (Beach and Pedersen, 2011):

$$\boldsymbol{X}\ [(\boldsymbol{e1}\ \rightarrow)\ *\ (\boldsymbol{e2}\ \rightarrow)\ *\ (\boldsymbol{e3}\ \rightarrow)\ ]\ \boldsymbol{Y}$$

In other words, X causes the outcome Y through the mechanism composed of entity$_1$ in conjunction with entity$_2$ and entity$_3$.

4.1. Policy instruments and mixes

Our pragmatic choice to not take activities into account is justified as it would be impractical to observe how policy instruments are productive of causal effects at the individual level in the case at hand. The activities of each entity can only be inferred and tested for congruence. However, as we have discussed, the existing literature on alternative vehicle policies mostly focuses on the effects of single policy instruments without considering their combination effects. To overcome this limitation, we can examine policy instruments at a different level of abstraction, focusing on the features that make them work in a certain way regardless of the policy field.

For instance, an incentive can take various forms and be employed across different policy sectors; however, its fundamental properties that make it an 'incentive' will remain unchanged. Conceptualizing policy instruments can be approached in several ways, starting from different assumptions about their 'ontology' (Hood, 2008). Studies on policy instruments generally analyse them as 'institutions', i.e., forms of organization available to the government (Hood, 1983; Salamon, 2002), or through an 'institution-free approach', focusing on the behavioural effects of these instruments (Schneider and Ingram, 1990; Bertelmans-Videc, Rist, and Vedung, 1998). In recent years, the literature on policy design has revisited the concept of policy mix and the combinatory effects of policy instruments (Grabosky, 1994; Gunningham and Sinclair, 1999; Howlett, 2014). Meta-theories on policy instruments and mixes, using both institutionalist and more 'freewheeling' approaches, have started to investigate various policy fields (e.g., Schaffrin et al., 2014; Capano et al., 2020).

Due to our research question, we are primarily interested in the behavioural effects of policy instruments and how policy design can enhance (or hinder) their effectiveness. As Schneider and Ingram (1990: 514) note, 'public policy almost always attempts to get

people to do things that they might not otherwise do; or it enables people to do things that they might not have done otherwise.' This can be achieved in various ways, with coercion being the most direct method. As such, most studies classify policy instruments along a continuum from the lowest to the highest degree of coercivity. However, the effectiveness of a policy does not necessarily relate to the coerciveness of its instruments. Policy instruments are generally combined with others, creating policy mixes where different instruments enhance each other's effects, resulting in either complementarity (Gunningham and Sinclair 1999) or 'incoherent pluralism,' where new policy instruments are added 'on top of or alongside existing ones', creating a pattern of layering (Capano and Lippi 2013).

4.2. The give-and-take approach

According to Van der Doelen (1998: 131), coercive policy instruments are considered the most effective, but they often lack political legitimacy. Consequently, they are rarely employed in isolation and are instead combined with other instruments to enhance policy acceptability. Van der Doelen's typology distinguishes three types of policy instrument: the least coercive are based on 'education', followed by 'engineering' (economic incentives), and then 'enforcement' (regulations), which are the most coercive. Additionally, Bressers (1988) notes that the degree of coercion can also depend on the settings of the policy instrument; for instance, economic incentives like levies may exert more constraint than regulations. To address this complexity, Van der Doelen introduces a second dimension to the typology, distinguishing between stimulative and repressive forms of policy instruments based on 'the extent to which the use of the instrument by the individual is optional'. Consequently, a stimulative policy instrument enables individuals to take certain actions, while a repressive policy instrument restricts their choices. For example, in the case of economic incentives, a subsidy encourages individuals to take a specific course of action, whereas a levy discourages them. However, in both cases, the fundamental properties of the economic incentive remain unchanged, and individuals still retain their freedom of choice, despite the altered attractiveness of various alternatives due to the repressive nature of the instrument. Table 1 provides an illustration of the complete typology.

Table 1. Stimulative and repressive forms of policy instruments

	Stimulative	**Repressive**
Education	Information	Propaganda
Engineering	Subsidy	Levy
Enforcement	Contract	Order/prohibition

Source: Van der Doelen 1998.

The give-and-take strategy involves combining stimulative and repressive instruments to create policy mixes with complementary effects. While repressive instruments are generally more effective in restricting certain policy options, stimulative instruments can influence policy-takers to move in a desired direction. When both types of

instruments are combined, they can address different aspects of a common policy issue, leading to increased policy effectiveness (Gunningham and Sinclair, 1999).

An example can illustrate this point more clearly. In 1985, the Netherlands implemented a policy to promote eco-friendly cars. They introduced subsidies to encourage the sale of cars equipped with catalytic converters. At the same time, the tax rates on conventional cars were increased as a repressive measure to discourage the purchase of non-ecologic vehicles. The policy employed the repressive instrument of taxation to disincentivize buying non-ecologic cars, while the stimulative subsidies made the purchase of eco-friendly cars more appealing. The combination of these two instruments made the policy more precise and effective in directing consumers towards eco-friendly options. As a result, the adoption of eco-friendly cars increased.

Based on this example, our main hypothesis is that by deploying both incentives (encouraging the purchase of alternative vehicles) and regulations (disincentivizing the use of traditional vehicles) together, the policy will be more effective in promoting sales of alternative vehicles. The combination of these instruments can target various aspects of the policy issue, thereby encouraging consumers to opt for alternative vehicles over traditional ones and leading to a higher uptake of alternative vehicles on the market.

4.3. Model of causation

The causal mechanism to be tested, based on the give-and-take approach, is as follows:

$$\boldsymbol{X}\ [(\boldsymbol{e1\ incentives}\ \rightarrow) * (\boldsymbol{e2\ regulations}\ \rightarrow) * (\boldsymbol{e3\ alternative\ fuels\ infrastructure}\ \rightarrow)\ ]\ \boldsymbol{Y}$$

Table 2 presents the causal model ('truth table') that results from the three causal conditions ('entities') present in the causal mechanism and described in the previous two sections: stimulative measures, repressive measures, and capacity measures. When considering two states (0 = absent, 1 = present), there are 8 possible combinations. Each row of the model identifies a different combination of the three causal conditions. Based on the literature on policy instruments, we can develop plausible expectations regarding the effect that each combination will have on the outcome, which is the sale of alternative vehicles.

Capacity measures should be considered a necessary condition: with an ASFRs percentage lower than 10% of the existing refuelling infrastructure, an alternative vehicles market will not develop (Yeh 2007). Hence, when combinations 2, 4, 6, 8 occur, we should observe low or non-existent sales of alternative vehicles. Repressive measures should be effective even when stimulative measures are absent, but without combining them, the effects on the outcome could be weaker. A disincentive towards buying traditional vehicles without incentives towards buying alternative vehicles could also lead individuals to adopt different modes of transport (e.g., public transport) since the behavioural pattern created by the policy mix does not strongly discriminate between one mode of transportation or the other. Conversely, stimulative measures without repressive measures can also lead to a lower adoption of alternative vehicles, as there will be fewer reasons to buy an alternative vehicle instead of a traditional vehicle

Table 2. Truth table for the causal analysis

Incentives	Regulations	Infrastructure	
1	1	1	Give-and-take approach with infrastructural capacity
1	1	0	Give-and-take approach without infrastructural capacity
1	0	1	Enabling approach with infrastructural capacity
1	0	0	Enabling approach without infrastructural capacity
0	1	1	Coercive approach with infrastructural capacity
0	1	0	Coercive approach without infrastructural capacity
0	0	1	Laissez-faire approach with infrastructural capacity
0	0	0	Laissez-faire approach without infrastructural capacity

Source: own elaboration.

5. Operationalisation

5.1. Scope condition

Regarding the scope condition, the causal model introduced in Section 3 will be investigated in relation to a subset of northern Italian regions having a resident population of over 2 million. This approach allows us to establish a plausible ceteris paribus concerning the economic wealth of individuals and the region's size. By selecting regions that are comparable on these two dimensions, we can avoid distortions due to differing levels of both purchasing power and administrative capacity. This criterion led us to choose a group of five regions: Lombardia, Piemonte, Veneto, Emilia-Romagna, and Toscana. The timeframe in which the implementation of the policy is studied is 2000-2004, and the outcome will be observed in the five subsequent years, from 2005 to 2009. The assumption is that a five-year period is sufficient to observe how the regional policy mix impacted the sale of alternative vehicles in the selected regions. While different policy instruments may impact people's behaviour in different ways, thus having different timeframes, the timeframe of the analysis should allow the reader to appreciate the overall effects of the policy mixes of the five regions.

During the period of implementation, the five regions exploited the flexibility allowed by national law (see the introduction) to implement policy mixes with different policy instruments and settings. As shown in Section 2, regions introduced economic incentives on top of the alternative vehicles incentives already granted by the national policymaker. During the 2000-2004 period, in terms of direct repressive measures, only a compulsory certification for traditional fuel vehicles (the 'bollino blu') was introduced. This certification, however, showed minimal variation between the regions. Moreover, given the small fee related to the certification (7 to 12 euros), it would be difficult to anticipate meaningful effects on the sales of alternative vehicles. New regulations, nonetheless, were introduced in 2000-2004, along with the economic incentives: driving restrictions were mandated in cities with a population of more than 50,000 as an emergency measure to counter spikes in air pollution. These measures were complementary to alternative vehicles economic incentives: while they targeted traditional

vehicles, banning their circulation on given days, these restrictions did not apply to alternative vehicles.

This type of measure, implemented either by design or by chance in conjunction with incentives to buy alternative vehicles, meets the condition of validity laid down by Gunningham and Sinclair (1999): it targets a different aspect of a common policy issue. According to the theory, the simultaneous presence of driving restrictions that target traditional vehicles and incentives to buy alternative vehicles should create complementarity, enhancing the overall precision and effectiveness of the policy. On the one hand, the driving restrictions of traditional vehicles act as repressive measures, making traditional vehicles less attractive to potential buyers and current users. This alone is not sufficient to push alternative vehicle sales, as traditional vehicle users could resort to different modes of transportation, such as public transport (which was incentivized in the same years as well). However, in conjunction with positive incentives towards purchasing alternative fuel vehicles, the probability of preferring this option increases, ceteris paribus.

5.2. Operationalization of variables: raw measures

To test the causal model developed in Section 3, we compiled a comprehensive dataset of all sustainable mobility measures implemented by the five regions during the period 2000-2004. Due to the absence of thematic collections in the regional official gazettes during that period, we performed manual data collection, focusing on Regional Council laws and Regional Government decrees. Ensuring the dataset's exhaustiveness involved a two-phase approach. In the first phase, we conducted a thorough search of the Journals using a set of 18 predefined keywords[1]. This allowed us to identify a first bulk of laws containing sustainable mobility measures. The second phase consisted in analysing the laws and decrees collected, searching for normative references to other laws and decrees missed during research by keywords. Grey literature produced by the five regions during the 2000-2004 timeframe was used to cross-check the list of legislative acts to be included in the dataset. The legislative acts were then analysed to catalogue the measures contained therein. Each measure was catalogued following the Van der Doelen typology. The resulting dataset included all the permissive and restrictive measures adopted by the regions related to alternative vehicles policy. A third condition, as we have discussed, concerns the alternative fuel infrastructure, which consists in the ratio between alternative fuel and traditional fuel refuelling stations present in each region. We used data included in the annual report of Unione Petrolifera (2003) to reconstruct the alternative fuel infrastructure ratio for each region. Finally, the outcome consisted in the percentage of alternative vehicles over the total of new vehicles sold throughout the 2005-2009 period. To reconstruct the outcome, we relied on the 'Autoritratto' dataset produced annually by the Automobile Club Italia (ACI) which contains the number of new vehicles registered each year per each Italian region.

[1] The keywords are: 'aria', 'inquinamento', 'qualità', 'atmosferico', 'particolato', 'PM10', 'trasport*', 'traffico', 'riscaldamento', 'caldaie', 'impiant*', 'permess*', 'limit*', 'monitoraggio', 'polveri', 'mobilità', 'sostenibile', 'risanamento'.

In the context of our study, we have identified four causal conditions to investigate the impact of policy instruments on the adoption of alternative vehicles:

1) Incentives: this causal condition encompasses the positive economic incentives introduced by the regions to encourage citizens and private companies to purchase new alternative vehicles during the period 2000-2004. To gauge the relative strength of these incentives compared to other alternative transport measures (e.g., incentives to strengthen public transport), we measured the ratio of alternative vehicle incentives to the overall budget allocated for sustainable transport.
2) Regulation: this causal condition is a measure of the stringency of driving restrictions implemented by each region to mitigate air pollution caused by non-alternative vehicles during the period 2000-2004. To proxy the coerciveness of these regulations on individual behaviour, we measured the total number of hours of driving restrictions enforced during the 2000-2004 period.
3) Alternative fuel infrastructural capacity: this causal condition quantifies the ratio between the number of alternative fuel refuelling stations and traditional fuel refuelling stations in each region. It serves as an indicator of the region's capacity to support alternative vehicles through infrastructure.
4) percentage of alternative vehicles over total of new vehicles registered. This condition assesses the relative strength of alternative vehicle sales during the period 2005-2009. We calculated this measure by determining the ratio between the percentage of new alternative fuel vehicles) registered and the total number of new vehicles registered during the 2005-2009 period.

Table 3 shows the raw measures for the causal conditions and the outcome.

Table 3. Raw measures of the policy instruments adopted by the regions (2000-2004) and the outcome (2005-2009)

Region	Incentives	Regulation (hours)	Alternative fuels infrastructure	% of alternative vehicles
Lombardia	51.65%	1495	6.99%	5%
Piemonte	0.13%	3285	6.37%	6%
Veneto	11.83%	1224	13.38%	8%
Emilia-Romagna	32.45%	4649	12.12%	14%
Toscana	20.61%	1090	10.82%	7%

Source: own elaboration.

6. Qualitative comparative analysis

In this research, we formulated the research question of identifying the principles that should be considered when designing a policy to address the issue of fleet inertia. Our hypothesis, developed in Section 3, posits that the give-and-take causal mechanism, through the complementarity between stimulative and repressive measures, can be more effective and precise in promoting alternative vehicle sales compared to single

instruments. Based on this research question and hypothesis, we created a causal model exhaustive of the logical possibilities implied by Van der Doelen typology (Section 3). The method we use to test our causal model is Crisp Sets Qualitative Comparative Analysis (CSQca) (Ragin 1987, 2000). Compared with other semi-experimental methods, CSQca's causal assumptions make it particularly suitable to answer our research question. QCA, in fact, does not seek to isolate the net effects of each variable (as in multivariate analysis) -- such as the net effects of economic incentives on alternative vehicles sales. What QCA does instead is to gauge 'multiple conjuctural causality', i.e., it identifies the causal pathways that can produce the outcome (Ragin 2005). In doing this, QCA accepts the possibility that there can be many effective pathways, so that it can highlight different means to achieve the same result. Moreover, variables (causal conditions in the QCA lexicon) are considered in 'combination' when analysing their causal relation to the outcome.

6.1. Calibration of the conditions

Having identified the scope condition and the causal model which will underlie the analysis, it is necessary to calibrate the raw measures we outlined in Section 6. Compared to FsQCA, CsQCA uses crisp conditions, coded as 0 or 1. The value '1' means that a case (e.g., Emilia-Romagna) fully belongs to a set (e.g., regulation). Hence, if Emilia-Romagna scores '1' on the regulation set, it means that in Emilia-Romagna there was strong regulation during the period under investigation. The value '0' means the absence of a condition for a given case. If Lombardia scores '0' on the alternative fuels infrastructure set, it means that in Lombardia the refuelling infrastructure for alternative vehicles is absent. Given the fact that the empirical support for the analysis is dated, quantitative measures are less interesting than the general validity of the causal model: this should make the loss of quantitative information due to the use of crisp sets acceptable. In turn, the analysis results will be easier to interpret than with FsQCA.

To identify the calibration crossover thresholds (at 0.5 for each causal condition), we resorted to the TOSMANA threshold-setter function. This allowed us to identify the natural gaps in the distribution of each causal condition. The only exception was for the alternative fuel infrastructure condition: we know from the literature that the minimum threshold to have alternative fuel infrastructural capacity is that the ratio of alternative fuel refuelling stations to the traditional fuel refuelling infrastructure is at least 10%. The crossover threshold, the one distinguishing the presence from the absence of a condition, resulted in the following for each condition:

1. *Incentives*: crossover at 25.88%.
2. *Regulations:* crossover at 2874.5 hours.
3. *Infrastructure*: crossover at 10%.
4. *Outcome*: crossover at 9.5%.

Table 3 shows the crisp value for each causal condition and the outcome.

Table 3. Crisp set calibration of the causal conditions

	Incentives	Regulations	Infrastructure	Outcome
Lombardia	1	0	0	0
Piemonte	0	1	0	0
Veneto	0	0	1	0
Emilia-Romagna	1	1	1	1
Toscana	0	0	1	0

Source: own elaboration.

6.2. Analysis of the necessary and sufficient conditions

QCA can tell us the necessary and sufficient conditions for both the positive and the negative outcome. Concerning the necessary conditions, the literature outlined in Section 2 showed that, in the absence of an adequate alternative fuel infrastructure, there can be no market for alternative vehicles. The csQCA table contained in the Appendix confirms this finding. The analysis of the necessary conditions for the outcome shows that three conditions (infrastructure, incentives and regulations) are necessary for the occurrence of the outcome, with a consistency of 1. This result however is hardly surprising, given the fact that there is only one instance of positive outcome (Emilia-Romagna). We found more interesting the analysis of the conditions necessary for the absence of the outcome (which is signified by the tilde '¬'). In this case we have no condition that is necessary for the outcome to be absent. The threshold to consider a condition 'necessary' is, conventionally, 0.95. Hence, the analysis confirms that, in the absence of alternative fuel infrastructural capacity, alternative vehicle sales will be low.

The analysis of sufficient conditions (see Appendix) should show which condition, or combination of conditions, is able to produce the outcome, hence answering the question 'what works?'. The empirical data confirm that the hypothesized combination:

*Incentives * Regulations * Infrastructure*

can be considered jointly sufficient in explaining the positive outcome of Emilia-Romagna. On the other hand, the analysis of the sufficient conditions for the absence of the outcome shows that there are three possible explanations accounting for low alternative vehicle sales:

1) *¬incentives*¬infrastructure*, in the case of Piemonte the policy mix lacked incentives and the AFSR capacity was non-adequate. The strong reliance on regulation, by itself, was not able to produce a positive outcome in terms of alternative vehicle sales.
2) *¬regulations*¬incentives*, both Toscana and Veneto share the absence of strong regulation combined with the absence of stimulative measures. This combination, by itself, is able to explain the absence of a positive outcome for these two regions. It is worth noting that both regions displayed a sufficient infrastructural capacity. Still, without different forms of public intervention, the sale of alternative vehicles was still laggard. This could show that a well-developed alternative fuels infrastructure, i.e., well above the 'necessary' threshold of 10%, is not

sufficient to push alternative vehicle sales, contrary to the expectations developed by Melaina and Bremson (2008).

3) *¬regulative*¬capacity*: in the case of Lombardia, the alternative fuel infrastructure was absent. On top of this, disincentives to resort to traditional vehicles were weak; these two conditions explain why, even with very generous alternative vehicles incentives, the overall alternative vehicle sales were low.

7. Conclusions

In this paper, we investigated how public policy can effectively foster the sale of alternative fuel vehicles. The current literature explains the increase in alternative vehicle adoption by focusing on economic and cultural factors. It is acknowledged that the presence of economic incentives and adequate refuelling infrastructures can boost alternative vehicle sales and change consumer behaviour. However, the current approach tends to focus on the net effect of single instruments, overlooking the potential of combinations of different instruments.

This research aims to advance the current knowledge on the role that policy instruments play in promoting alternative vehicle adoption in two ways. Firstly, we explored the literature on policy design to discuss principles that can assist in designing alternative vehicle incentives more effectively. We discovered that the pitfalls associated with the use of single policy instruments can be overcome by creating mixes of different types of instruments that exploit complementarity to better influence consumers' behaviour. One type of such mixes appears particularly promising for fostering policy effectiveness: the give-and-take approach. This approach is based on the combination of regulations and incentives to achieve more precise behavioural changes by targeting the same policy issue from different angles.

To test the effectiveness of the give-and-take approach, we focused on the sustainable mobility policies of five Italian regions during the 2000-2004 period. During this time, these regions created new policy mixes to foster sustainable mobility in their major cities, including both regulations and incentives to buy alternative fuel vehicles. To analyse the effectiveness of the give-and-take approach, we employed QCA (Qualitative Comparative Analysis).

In comparison with the current literature, we found that while incentives and infrastructural capacity are necessary to foster alternative fuel vehicle sales, they are less effective when not combined. Incentives for alternative vehicle purchases work better at changing consumer behaviour when coupled with restrictive measures (regulations) that target traditional fuel vehicles. In this scenario, the desirability of alternative fuel vehicles increases. However, regulations targeting traditional fuel vehicles alone could be insufficient to foster alternative vehicle sales, as consumers may prefer alternative modes of transport (such as public transport) due to the perceived high cost of alternative vehicles. It is the combination of the two instruments – stringent regulations and adequate incentives – that creates a clear pattern towards the desired behaviour, i.e., purchasing an alternative vehicle. The combination of complementary instruments, by increasing the precision of the single instruments, is crucial in enhancing the effectiveness of the policy.

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Appendix
QCA Tables

```
Analysis of Necessary Conditions

Outcome variable: outcome

Conditions tested:
                     Consistency          Coverage
capacity             1.000000             0.500000
~capacity            0.000000             0.000000
stimulative          1.000000             0.333333
~stimulative         0.000000             0.000000
regulation           1.000000             0.500000
~regulation          0.000000             0.000000


Outcome variable: ~outcome

Conditions tested:
                     Consistency          Coverage
capacity             0.333333             0.500000
~capacity            0.666667             1.000000
stimulative          0.666667             0.666667
~stimulative         0.333333             1.000000
regulation           0.333333             0.500000
~regulation          0.666667             1.000000



--- INTERMEDIATE SOLUTION ---
frequency cutoff: 1.000000
consistency cutoff: 1.000000
Assumptions:
regulation (present)
capacity (present)

                                       raw       unique
                                      coverage    coverage
consistency
                                     ----------
----------  ----------
regulative*stimulative*capacity     1.000000    1.000000
1.000000
solution coverage: 1.000000
```

```
Cases with greater than 0.5 membership in term
regulation*stimulative*capacity: EMILIA-ROMAGNA (1,1)

**********************
*TRUTH TABLE ANALYSIS*
**********************

File:  //psf/SHARING_IS_CARING/crisp_set.csv
Model: ~output = f(regulation, stimulative, capacity)

 Rows:       6



 Algorithm: Quine-McCluskey
      True: 1
  0 Matrix: 0L
Don't Care: -

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 1.000000
consistency cutoff: 1.000000
Assumptions:
~regulation (absent)

                              raw       unique
                            coverage    coverage
consistency
                           ----------  ----------
----------
~stimulative*~capacity      0.333333    0.333333
1.000000
~regulative*stimulative     0.666667    0.666667
1.000000
solution coverage: 1.000000
solution consistency: 1.000000



Cases with greater than 0.5 membership in term
~stimulative*~capacity: PIEMONTE (1,1)
Cases with greater than 0.5 membership in term
```