cepe
Centre for Energy Policy and Economics
Department of Management, Technology and Economics

Economic analysis of policy measures to reduce CO_2 emissions of passenger cars in Switzerland

(Ökonomische Analysen der politischen Massnahmen zur Reduktion der CO_2-Emissionen von Personenwagen in der Schweiz)

Im Auftrag des Bundesamtes für Umwelt (BAFU)
Sur mandat de l'Office fédéral de l'environnement (OFEV)
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The report is written in English and composed of three independent modules that are summarized in German, French and Italian at the beginning.

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Summary: German/Deutsch

In der internationalen Klimapolitik hat man, aufgrund wissenschaftlicher Erkenntnisse, das sogenannte „2 Grad Ziel“ festgelegt. Dabei soll die Erderwärmung auf maximal zwei Grad Celsius gegenüber dem Niveau von 1990 beschränkt werden. Die Schweiz leistet mit einer aktiven Klimapolitik einen Beitrag zum Gelingen dieser Zielerreichung und hat in ihrem CO_2-Gesetz das Ziel festgelegt, gegenüber dem Jahr 1990 den CO_2-Ausstoss bis 2020 um 20 Prozent zu reduzieren. Gemäss der CO_2-Statistik des Bundesamts für Umwelt (BAFU) erfolgt seit ungefähr 2004 eine kontinuierliche Reduktion der absoluten CO_2-Emissionen aus der Verbrennung von Brennstoffen. Die CO_2-Emissionen aus Treibstoffen verharren hingegen auf einem hohen Niveau. [1] Ein Grossteil dieser Emissionen stammt vom motorisierten Personenverkehr, d.h. vor allem von Personenwagen.

Für die Eindämmung der CO_2-Emissionen gibt es verschiedene mögliche staatliche Massnahmen auf Angebots- sowie Nachfrageseite. Die weltweit wohl am häufigsten eingeführten Massnahme sind CO_2-Emissionsvorschriften. Dabei wird die Angebotsseite, d.h. die Hersteller und Importeure von Fahrzeugen, dazu verpflichtet, die durchschnittlichen CO_2-Emissionen oder den durchschnittlichen Treibstoffverbrauch ihrer Flotte auf einen vorgegebenen Wert zu reduzieren. Nachfrageseitig wird versucht, mit Steueranreizsystemen den Fahrzeugkauf und das Fahrverhalten zu beeinflussen. Der Kauf von effizienten Fahrzeugen kann gefördert werden, indem man einerseits Rabatte für effiziente Fahrzeuge bei der einmaligen Verkaufssteuer oder bei der jährlichen Registrationssteuer (Motorfahrzeugsteuer) gewährt, oder anderseits diese Steuern für ineffiziente Fahrzeuge erhöht. Eine weitere Möglichkeit besteht darin, das Steuersystem direkt auf die CO_2-Emissionen des Fahrzeugs abzustützen. Eine CO_2-Abgabe auf Treibstoffe erhöht die Kosten pro gefahrenen Kilometer und gibt Anreize zur Anpassung des Fahrverhaltens und zum Kauf sparsamerer Fahrzeuge. Ökonomisch gesehen gilt eine lenkende CO_2-Abgabe als äusserst effektives Vehikel. Eine CO_2-Abgabe internalisiert (je nach Höhe vollständig oder teilweise) die externen Kosten, welche durch die Emission von CO_2 entstehen. Die Kosten werden somit direkt vom Verursacher und nicht von der Allgemeinheit getragen. Das Schweizer Parlament hat eine solche CO_2-Abgabe im Jahr 2008 auf Brennstoffe eingeführt. Eine CO_2-Abgabe auf fossile

[1] Quelle: http://www.bafu.admin.ch/klima/13879/13880/14486/index.html?lang=de, zuletzt besucht am 22.10.2015.

Treibstoffe fand bisher keine politische Mehrheit in der Schweiz. Im Verkehrsbereich sind jedoch andere Massnahmen in Kraft, die dazu beitragen sollen, die CO_2-Emissionen in der Schweiz zu reduzieren. Seit 2003 gibt es beispielsweise die Energieetikette für Personenwagen, welche Neuwagenkäufer über die CO_2-Emissionen und den Treibstoffverbrauch eines spezifischen Fahrzeugs informiert und diese ins Verhältnis zu den Neuwagen auf dem Schweizer Markt setzt. Des Weiteren sind seit 2012 die CO_2-Emissionsvorschriften für Personenwagen in Kraft, die Importeure verpflichten, die durchschnittlichen CO_2-Emissionen ihrer Neuwagenflotte bis 2015 auf durchschnittlich 130 Gramm pro Kilometer zu reduzieren. Auf kantonaler Ebene haben in den letzten Jahren mehrere Kantone ihre Motorfahrzeugsteuer ökologisiert und gewähren effizienten Fahrzeugen einen Steuerrabatt (Bonus) oder bestrafen Halter von stark emittierenden Fahrzeugen mit einer Steuererhöhung (Malus). Konsumenten haben somit einen Anreiz, effizientere Fahrzeuge zu kaufen, da sich die Kosten effizienter Fahrzeuge im Vergleich zu den Kosten ineffizienter Fahrzeuge reduzieren.

Um Erkenntnisse über die Wirkung solcher Massnahmen zu gewinnen, hat das BAFU mit finanzieller Beteiligung des Bundesamtes für Strassen (ASTRA) Ende 2012 ein dreijähriges Forschungsprojekt beim Center for Energy Policy and Economics (CEPE) der ETH Zürich in Auftrag gegeben. Ziele des Projekts sind einerseits die Darstellung der Zusammensetzung der Schweizer Personenwagenflotte, wobei die Entwicklung über die Zeit und regionale Disparitäten aufgezeigt werden, sowie die Schätzung der Wirkung der Ökologisierung der kantonalen Motorfahrzeugsteuern und der CO_2-Emissionsvorschriften auf die Anzahl Registrationen effizienter Fahrzeuge. Das Projekt ist in die drei folgenden Module aufgeteilt:

1. Datenpräparation und deskriptive Statistiken zur Verteilung der Personenwagenflotte in der Schweiz aufgrund verschiedener Kriterien.
2. Abschätzung der Wirkung der kantonalen Motorfahrzeugsteuer auf den Anteil von in-/effizienten Neuwagen
3. Abschätzung der Wirkung der CO_2-Emissionsvorschriften für Personenwagen auf die durchschnittlichen CO_2-Emissionen der Neuwagenflotte

Die drei Module wurden in einzelnen Artikeln auf Englisch verfasst und befinden sich im Anhang dieser Zusammenfassung. Die gewonnenen Erkenntnisse werden im Folgenden kurz dargestellt.

Modul 1: Überblick über die Fahrzeugflotte in der Schweiz (und der EU)

Das Modul 1 dient einerseits dazu, die Daten für den ganzen Bericht aufzuarbeiten. Anderseits werden ausführliche deskriptive Statistiken über die Zusammensetzung des Schweizer Personenwagenparks erstellt. Im Fokus stehen dabei vor allem die Entwicklungen der durchschnittlichen CO_2-Emissionen und Treibstoffverbräuche. Anschauliche Karten auf Kantons- und Gemeindeebene zeigen regionale Disparitäten auf.

Datenaufbereitung

Das ASTRA und das Bundesamt für Statistik (BFS) stellten Daten sowohl zum jährlichen Bestand aller an einem bestimmten Stichtag registrierten Personenwagen in der Schweiz und den Neuwagenimmatrikulationen von 2005 bis 2012 zur Verfügung. Die Daten stammen aus dem Motorfahrzeuginformationssystem (MOFIS), in welchem die Fahrzeugregistrationen aller kantonalen Strassenverkehrsämter zusammenfliessen. Die Informationen der Registrationsdaten wurden anhand der Typengenehmigungsnummer und des Getriebecodes mit den Homologationsdaten (TARGA) aus der Typenprüfstelle verknüpft. Die TARGA-Daten enthalten detaillierte Informationen zu den technischen Parametern für jedes in der Schweiz typengenehmigte Fahrzeug. Da uns detaillierte TARGA Daten erst ab dem Jahr 1996 zur Verfügung stehen, mussten wir Fahrzeuge, welche bereits früher auf den Markt kamen, aus dem Datensatz entfernen.

Anhand der vorhandenen MOFIS-Angaben und den technischen Parametern aus TARGA konnten wir für jedes Fahrzeug die Energieetikettenkategorie und die kantonsspezifische Motofahrzeugsteuer berechnen und je nach Ausgestaltung der Steuer einen Bonus oder Malus zuweisen. Detaillierte Informationen zum Fahrzeughalter sind aus Datenschutzgründen nicht im Datensatz enthalten. Über die Postleitzahl der Wohngemeinde des Fahrzeughalters war es aber möglich, dem Datensatz sozio-ökonomische und geografische Variablen auf Gemeindeebene hinzuzufügen.

Es waren nicht für alle Fahrzeuge alle Verknüpfungen mit den verschiedenen Datensätzen machbar, wodurch ein paar Observationen verloren gingen. Verschiedene Tests bestätigen aber, dass die Datenverluste nicht systematisch sind und der Datensatz repräsentativ bleibt. Abbildung 1 zeigt auf, wie viele Fahrzeuge der Gesamtflotte pro Jahr zur Verfügung standen.

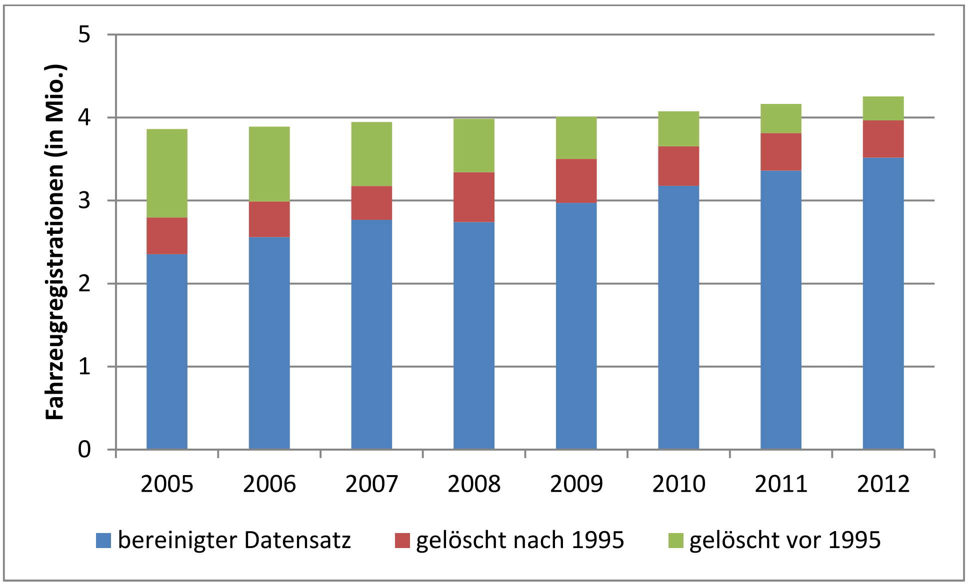

Abbildung 1: Anzahl verfügbare Fahrzeuge von 2005 – 2012

Bei der Bestandsaufnahme im Jahr 2012 waren beispielsweise 4.255 Millionen Personenwagen in der Schweiz registriert. In unserem Datensatz konnten wir für 83% dieser Fahrzeuge alle nötigen Informationen hinzufügen.

Deskriptive Statistiken zur Schweizer Personenwagenflotte

Der zweite Teil von Modul 1 untersucht die Entwicklung des Personenwagenbestands in der Schweiz von 2005 bis 2012 und zeigt anhand des Personenwagenbestands von 2012 die unterschiedliche Verteilung der Flotte innerhalb der Schweiz auf. Wir verknüpfen die Flottenverteilung beispielsweise mit topographischen Gegebenheiten oder dem durchschnittlichen Einkommen einer Gemeinde und veranschaulichen dies auf Schweizer Landkarten, um regionale Disparitäten grafisch aufzuzeigen.

Von 2005 bis 2012 hat der Anteil an Diesel-Fahrzeugen von 13.9 % auf 23.6 % zugenommen, dies auf Kosten des Anteils an Benzinfahrzeugen. Die Anteile an Hybrid- und Elektrofahrzeugen bleiben im Jahr 2012 mit 0.77 %, respektive 0.03 % im Verhältnis zur Gesamtflotte äusserst bescheiden. Das Leergewicht und der Hubraum haben sich im Durchschnitt nicht gross verändert, während die Leistung (Pferdestärken) zugenommen hat und der Treibstoffverbrauch sowie die CO_2-Emissionen abgenommen haben (vgl. Tabelle 1). Die Angaben zum Treibstoffverbrauch und den CO_2-Emissionen entsprechen, anhand des Neuen Europäischen Fahrzyklus (NEFZ), auf dem Rollband gemessenen Werten. Die tatsächlichen Verbrauchs- und Emissionswerte hängen vom Fahrverhalten und den

Fahrzeugeinstellungen ab und können somit von den NEFZ-Verbrauchsmessungen abweichen.[2]

Tabelle 1: Entwicklung verschiedener Fahrzeugcharakteristiken des Personenwagenbestands von 2005 – 2012 (CEPE-Datensatz)

Jahr	Leer-gewicht kg	Hubraum ccm	Leis-tung kW	CO_2 g/km	Verbrauch l/100km Benzin-äquivalent	Verbrauch (Benzin) l/100km Benzin	Verbrauch (Diesel) l/100km Diesel
2005	1'484	1'964	97	204	8.5	8.7	6.9
2006	1'473	1'962	98	202	8.4	8.6	6.9
2007	1'474	1'964	99	200	8.4	8.5	6.9
2008	1'473	1'956	100	196	8.2	8.4	6.8
2009	1'428	1'952	101	194	8.1	8.3	6.8
2010	1'436	1'942	101	191	8.0	8.2	6.7
2011	1'443	1'929	102	189	7.9	8.1	6.7
2012	1'450	1'916	103	185	7.8	8.0	6.6

Abbildung 2 zeigt die kantonale Verteilung der durchschnittlichen CO_2-Emissionen der Fahrzeugflotte in Gramm pro Kilometer, wobei ersichtlich wird, dass in der deutschsprachigen Schweiz stärker emittierende Fahrzeuge gefahren werden als in der französisch- und italienischsprachigen Schweiz.

2 http://www.transportenvironment.org/sites/te/files/publications/TE_Mind_the_Gap_2015_FINAL.pdf

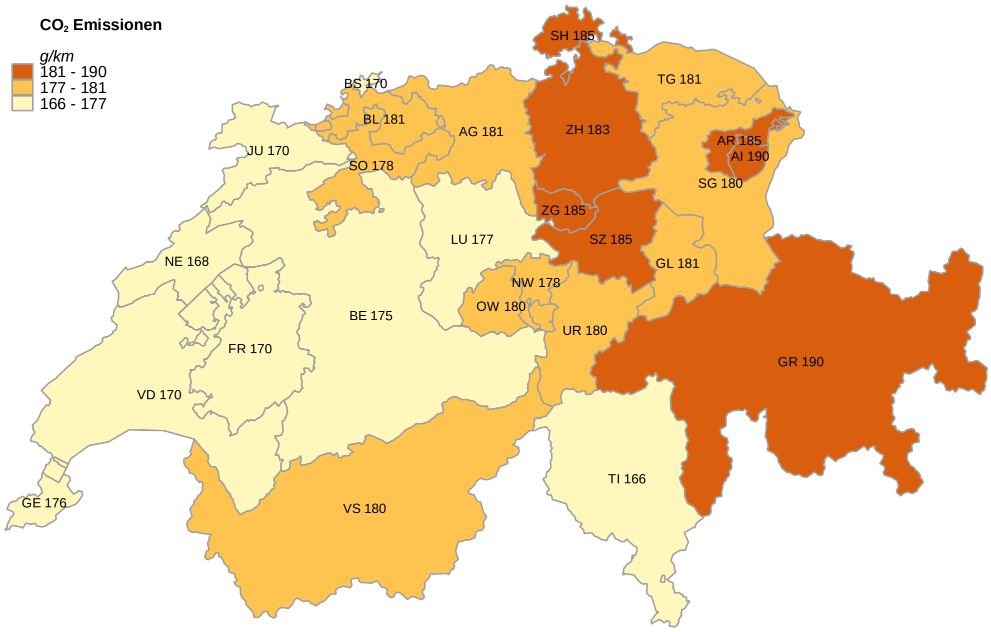

Abbildung 2: CO_2-Emissionen des Fahrzeugbestands auf kantonaler Ebene im Jahr 2012

Vergleicht man die durchschnittlichen Treibstoffverbrauchswerte aufgrund der Topographie, ist in Abbildung 3 klar ersichtlich, dass registrierte Fahrzeuge in höhergelegenen Gemeinden (über 706 Meter über Meer) grösstenteils höhere Treibstoffverbrauchswerte aufzeigen als jene im Flachland.[3]

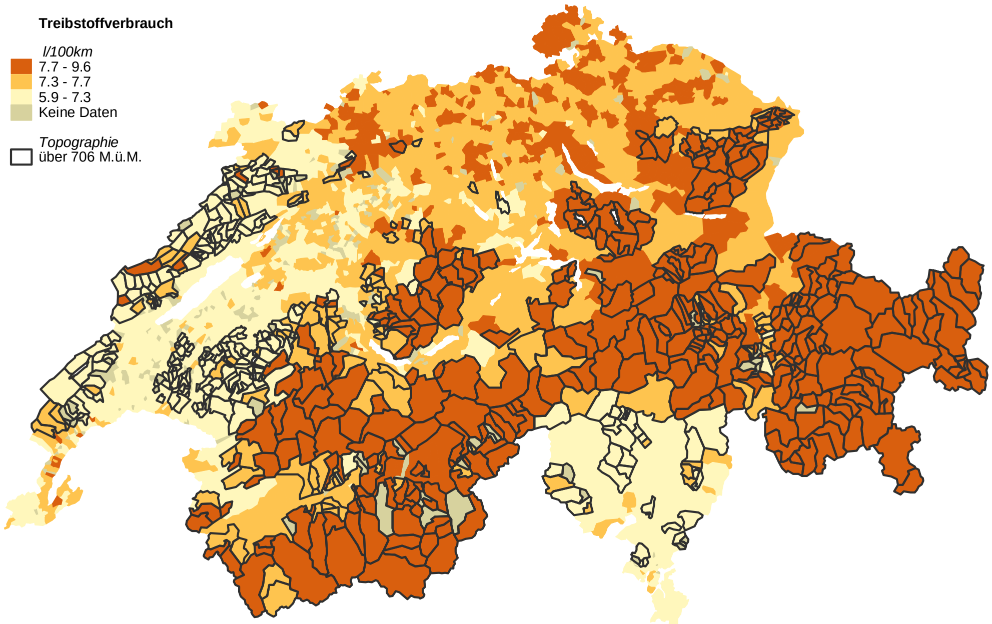

Abbildung 3: Illustrierter Treibstoffverbrauch des Fahrzeugbestands von 2012 (Berggebiete hervorgehoben).

[3] Abbildung 3 bildet die durchschnittlich gemessenen Verbrauchswerte der Fahrzeuge in Liter pro 100 Kilometer ab. Der absolute Treibstoffverbrauch ist mit den verfügbaren Daten nicht messbar, da er abhängig vom Fahrverhalten und den gefahrenen Kilometern ist.

Die Untersuchung der Verteilung der Fahrzeugsegmente ergibt in Abbildung 4a, dass der Anteil Geländewagen (SUV) in den Bergregionen am höchsten ist. Schaut man aber den Treibstoffverbrauch der SUV an, so wird aus Abbildung 4b ersichtlich, dass die SUV v.a. im flachen Norden der Schweiz durchschnittlich am meisten Treibstoff verbrauchen, während in Berggebieten meist sparsamere SUV gefahren werden.

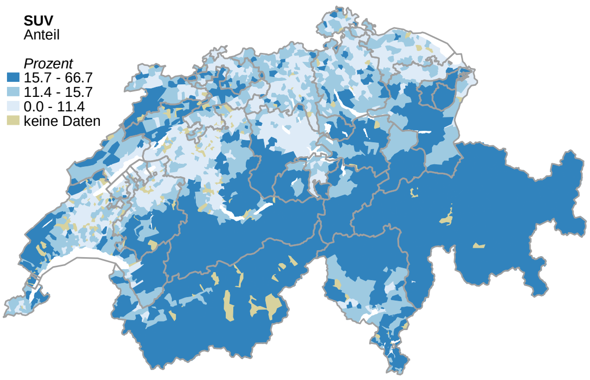

Abbildung 4a: Verteilung der SUV 2012

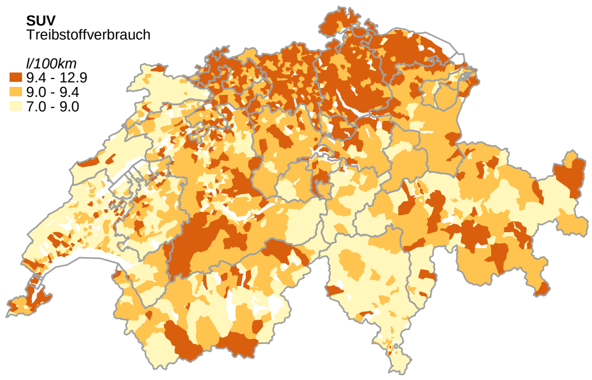

Abbildung 4b: Treibstoffverbrauch der SUV 2012

Für weitere Auswertungen und Abbildungen verweisen wir gerne auf den Bericht zu Modul 1.

Modul 2: Einfluss der Ökologisierung der Motorfahrzeugsteuer

Die für Motorfahrzeugbesitzer jährlich anfallende Motorfahrzeugsteuer ist in der Schweiz kantonal geregelt und basiert je nach Kanton auf einem spezifischen Parameter des Fahrzeugs, wie zum Beispiel dem Gewicht, dem Hubraum oder der Leistung. In den letzten zehn Jahren haben verschiedene Kantone ihre Motorfahrzeugsteuer ökologisiert, in dem sie für besonders energieeffiziente oder CO_2-arme Personenwagen die Steuer reduziert (Bonus) und/oder für Personenwagen mit hohem Treibstoffverbrauch bzw. hohen CO_2-Emissionen die Steuer erhöht (Malus) haben. Ein Bonus bzw. Malus führt zu einer Veränderung des relativen Preises eines Fahrzeugs und macht dadurch effiziente Fahrzeuge gegenüber ineffizienten attraktiver. Ökonomisch gesehen ist die gleichzeitige Einführung eines Bonus für CO_2-arme Erstimmatrikulationen sowie eines Malus für stark emittierende Gebraucht- und Neuwagen sinnvoll. Ein solches System fördert den Kauf von sparsamen Neuwagen und schmälert gleichzeitig die Attraktivität ineffizienter Fahrzeuge. Zudem führt es finanzpolitisch zu einem besser ausgeglichenen Staatshaushalt, als wenn nur ein Bonus eingeführt würde. Tabelle 2 zeigt die Massnahmen auf, welche jeder Kanton in unserem Untersuchungszeitraum von 2005 bis 2011 eingeführt hat. Nach 2011 haben noch weitere Kantone ihre Motorfahrzeugsteuersystem ökologisiert.[4] Dabei wurde auch damit begonnen, die Berechnungsgrundlage für die Motorfahrzeugsteuer auf die CO_2-Emissionen des Fahrzeugs zu basieren anstatt ein Bonus/Malus System einzuführen.[5] Ein solches System wird als interessant erachtet, ist jedoch nicht Gegenstand dieser Untersuchung.

Wie in Tabelle 2 ersichtlich, gibt es Steuerrabatte, welche auf der Kategorie der Energieetikette (grün markiert), einem CO_2-Grenzwert (orange markiert) oder einer Kombination von beiden (blau markiert) basieren. Um Mitnahmeeffekte[6] zu reduzieren, gelten die Steuerrabatte nur für Erstimmatrikulationen und in den meisten Kantonen nur für zwei bis drei Jahre. Der Malus basiert entweder auf der Energieetikette oder einem CO_2-Grenzwert, wobei der Malus im Kanton Obwalden für alle Personenwagen gilt, welche das Kriterium erfüllen, also auch die Gebrauchtwagen, und in den anderen Kantonen nur für die betroffenen Personenwagen mit Erstimmatrikulation nach Einführung der Massnahme. Aus der Tabelle wird ersichtlich, dass bis 2011 noch nicht alle Kantone ihre Motorfahrzeugsteuer ökologisiert haben und dass oft nur ein Bonus ohne einen zusätzlichen Malus eingeführt wurde.

Im Folgenden untersuchen wir, wie sich die Ökologisierung der Motorfahrzeugsteuer auf die Neuwagenregistrationen. Untersuchungsgegenstand sind jeweils mit Benzin oder Diesel betriebene Fahrzeuge ohne Hybridantrieb. Neben den hier aufgeführten Anreizsystemen gewähren gewisse Kantone noch spezielle Steuerrabatte für Personenwagen mit alternativen Treibstoffen oder Antriebssystemen, wie Hybrid, Gas-, oder Elektrofahrzeuge. Diese sind jedoch nicht Gegenstand unserer Untersuchungen.

4 Es sind dies die Kantone Basel-Landschaft (BL), Basel-Stadt (BS), Bern (BE), Glarus (GL) und Zürich (ZH).
5 Ein solches System hat der Kanton Neuenburg (NE) im Jahr 2014 eingeführt.
6 Ein Mitnahmeeffekt liegt dann vor, wenn ein Käufer von einem Rabatt profitiert, obwohl er dieses Fahrzeug auch ohne das Anreizsystem gekauft hätte.

Tabelle 2: Kantonale Anreizsysteme für alle Treibstoffarten von 2005 bis 2011

Kanton		Jahr der Einführung	Anreizsystem
Aargau	AG	keine	
Appenzell A. Rh.	AI	keine	
Appenzell I. Rh.	AR	2011	50% Bonus wenn CO_2 ≤130g/km
Bern	BE	keine	
Basel-Landschaft	BL	keine	
Basel-Stadt	BS	keine	
Freiburg	FR	2011	100% Bonus wenn Etikette A; 2.2% zusätzliche Steuer wenn D, E, F, G oder keine Etikette
Genf	GE	2010	50% Bonus wenn CO_2 ≤120g; 50% Malus wenn CO_2 >200g
Glarus	GL	keine	
Graubünden	GR	2009	2009: 80% Bonus wenn CO_2 ≤140g & PM10≤0.01g; 60% Bonus wenn CO_2 ≤160g & PM10≤0.01g; 2011: 80% Bonus wenn CO_2 ≤120g & PM10≤0.01g; 60% Bonus wenn CO_2 ≤140g & PM10≤0.01g
Jura	JU	keine	
Luzern	LU	keine	
Neuenburg	NE	keine	
Nidwalden	NW	2009	100% Bonus (für die ersten 3 Jahre) wenn Etikette A
Obwalden	OW	2009	100% Bonus (für die ersten 3 Jahre) wenn Etikette A; 50% Bonus (für die ersten 2 Jahre) wenn Etikette B; 60.- Malus, wenn Etikette G oder keine Etikette
St. Gallen	SG	2009	100% Bonus wenn Etikette A & CO_2 ≤130g (für die ersten 3 Jahre)
Schaffhausen	SH	keine	
Solothurn	SO	keine	
Schwyz	SZ	keine	
Thurgau	TG	2011	50% Bonus wenn Etikette A (max. 5 Jahre); 25% Bonus wenn Etikette B (max. 5 Jahre) ; 50% Malus, wenn Etikette F oder G
Tessin	TI	2009	50% Bonus wenn Etikette A & CO_2 ≤140g (+Filter); 20% Malus wenn Etikette F; 50% Malus wenn Etikette G
Waadt	VD	2005	50% Bonus wenn CO_2 ≤120g
Wallis	VS	2010	50% Bonus wenn Etikette A & CO_2 ≤130g
Uri	UR	keine	
Zug	ZG	keine	
Zürich	ZH	keine	

Für die Untersuchung verwenden wir Neuwagenregistrationen in der Schweiz von 2005 bis 2011. Die kantonale sowie die zeitliche Differenzierung der Einführung dieser Massnahme eignet sich sehr gut, um die Anteile der Neuwagen, welche die Kriterien für einen Bonus oder Malus erfüllen, in Gemeinden von Kantonen mit und ohne Massnahme über die Zeit zu vergleichen. Die Kantone mit einer Massnahme betrachtet man dabei als Behandlungsgruppe, die Kantone ohne Massnahme definieren die Kontrollgruppe. In der Ökonometrie (einer Kombination von mathematischen und statistischen Methoden, um ökonomische Fragestellung zu analysieren) nennt man einen solchen Ansatz „Differenz von Differenzen" (englisch: difference-in-differences, DiD).

Der DiD-Ansatz ist eine weitverbreitete empirische Methode für die Wirkungsabschätzung politischer Massnahmen. Indem man die Entwicklung der Untersuchungsvariable zum einen über die Zeit und zum anderen zwischen Gruppen vergleicht, kann man eine abweichende Entwicklung der Untersuchungsvariable in der Behandlungsgruppe genau der Massnahme zuweisen. Für die Bestimmung dieser Kausalität müssen aber zwei Hauptkriterien geben sein: Wir stellen zuerst sicher, dass die Einführung der Massnahme in einem Kanton exogen ist, d.h. nicht von Effekten beeinflusst wurde, welche wir in unserem Modell nicht kontrollieren können. Zudem testen wir, ob die Entwicklung der Untersuchungsvariable (abhängige Variable) vor Einführung der Massnahme in der Behandlungsgruppe gleich verlaufen ist wie in der Kontrollgruppe. Andernfalls ist es nicht möglich eine klare Aussage zu treffen, ob der geschätzte Effekt tatsächlich von der Einführung der Massnahme stammt. Die Untersuchungsvariable ist in unserem Modell der Anteil der von der Massnahme betroffenen Fahrzeuge auf Gemeindeebene.

Anhand ökonometrischer Verfahren vergleichen wir somit beispielsweise den Anteil Fahrzeuge der Kategorie A von Gemeinden in Kantonen mit Massnahmen mit dem Anteil Fahrzeuge der Kategorie A von Gemeinden in den Kontrollkantonen über die Zeit, d.h. sowohl vor als auch nach Einführung der Massnahme. Die ökonometrischen Schätzungen verfeinern wir zusätzlich, indem wir nur die Entwicklung des Anteils von einer Massnahme betroffenen Fahrzeugen in ähnlichen Gemeinden miteinander vergleichen.

Zur Überprüfung der Robustheit der erhaltenen Resultate wenden wir ein zusätzliches Modell an, in welchem wir den Anteil jedes einzelnen Fahrzeugtyps in einem Bezirk (Region) als Untersuchungsvariable verwenden.[7] In diesem alternativen Modell können wir jedem einzelnen Fahrzeug die spezifische Motorfahrzeugsteuer und den allfälligen Bonus oder Malus zuweisen und somit schätzen, wie sich ein Bonus oder Malus auf die Fahrzeugregistrationen auswirkt.

Bevor wir die Schätzresultate analysieren, zeigen wir rein rechnerisch und deskriptiv auf, wie sich der Anteil der Fahrzeuge, welche die Massnahmenkriterien erfüllen, im Jahr vor und nach der Einführung der Massnahme in einem Kanton der Behandlungsgruppe im Vergleich zur Kontrollgruppe entwickelt hat. Als Beispiel werden in Tabelle 3 die Berechnungen für die Einführung eines Steuerrabatts basierend auf der Energieetikette im Kanton Obwalden aufgeführt.[8] Es ist ersichtlich, dass der Anteil Fahrzeuge der Kategorie A im Kanton Obwalden vor der Einführung der Massnahme 17.19 % betrug und somit 1.66 Prozentpunkte weniger als in der Kontrollgruppe (KG). Im Jahr nach der Einführung der Massnahme war der Anteil Neuregistrationen der Kategorie A in Obwalden zwei Prozentpunkte höher als in der Kontrollgruppe. Die Zunahme der Registrationen der A-Fahrzeuge in Obwalden gegenüber der Kontrollgruppe betrug somit über den Zeitraum 3.66 Prozentpunkte.

In einem weiteren Schritt stellen wir die Entwicklung der Anteile von Fahrzeugen, welche von der Massnahme betroffen sind, graphisch dar. Abbildung 5 zeigt als Beispiel die Entwicklung der Anteile A-Fahrzeuge im Kanton Freiburg und in den Kontrollkantonen in der Zeit vor sowie nach Einführung der Massnahme im Kanton Freiburg. Dabei ist ersichtlich, dass nach der Einführung der Massnahme der Anteil A-Fahrzeuge im Kanton Freiburg im Vergleich zur Kontrollgruppe stärker zugenommen hat.

Tabelle 3: DiD Berechnung– Bonus für Kategorie A Fahrzeuge in Obwalden

	Kanton Obwalden (OW)		
	2008	2009	Differenz
KG*	18.85%	24.54%	5.70%
OW	17.19%	26.54%	9.35%
Differenz	-1.66%	2.00%	**3.66%**

* KG = Kontrollgruppe

[7] Wir führen diese Analyse auf Bezirksebene durch, weil die Anzahl Registrationen eines einzelnen Fahrzeugmodells auf der Gemeindeebene meist äusserst gering sind.

[8] Für die weiteren Abbildungen und Statistiken verweisen wir auf den Bericht von Modul 2.

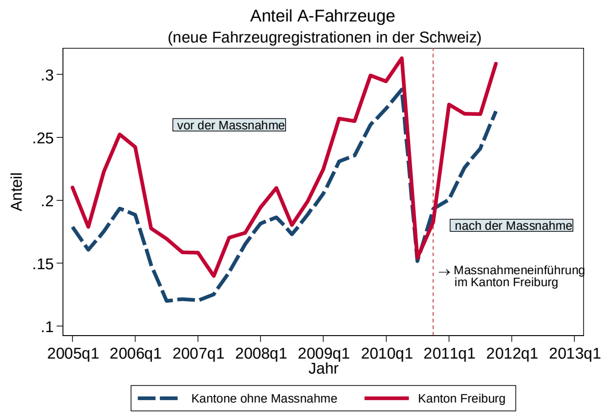

Abbildung 5: Entwicklung des Anteils Kategorie A Fahrzeuge im Kanton Freiburg im Vergleich zur Kontrollgruppe

Anhand der Resultate in Tabelle 3 und den Graphen in Abbildung 5 ist eine unterschiedliche Entwicklung nach Einführung der Massnahme auszumachen. Zu bemerken ist aber, dass ohne eine ökonometrische Schätzung, in welcher wir auch für weitere Variablen kontrollieren, der Effekt nicht eindeutig der Erhöhung bzw. Vergünstigung der Motorfahrzeugsteuer zugewiesen werden kann. Aufgrund der Resultate ökonometrischer Tests können wir die DiD-Schätzungen lediglich für die Kantone mit einem Bonus basierend auf der Energieetikette oder einem Bonus basierend auf den CO_2-Emissionen durchführen. Für die Kantone mit einem Malus und die Kantone mit einem Bonus basierend auf einer Kombination von Energieetikette und CO_2-Emissionen war der parallele Trend vor Einführung der Massnahmen nicht gegeben und wir können somit den Effekt der Massnahmen nicht genügend genau eruieren. Die Hauptresultate unserer ökonometrischen Schätzungen, bei welchem wir auch die Matching-Methode anwenden, um nur die Entwicklungen in ähnlichen Gemeinden miteinander zu vergleichen, ergeben, dass die Einführung eines Steuerrabatts für energieeffiziente Fahrzeuge zu einer statistisch signifikanten Erhöhung des Anteils von Fahrzeugen der Energieetikettenkategorie A von rund 2.1 Prozentpunkten führt. Für Steuerrabatte auf emissionsarme Fahrzeuge ergeben die Schätzungen statistisch leicht weniger signifikante Resultate in einer Höhe von rund 1.7 Prozentpunkten. Fahrzeuge mit Energieetikettenkategorie A sowie Fahrzeuge mit einem CO_2-Ausstoss von maximal 130 g/km machen ungefähr je 20 % der Gesamtflotte aus, womit eine Steigerung von knapp zwei Prozentpunkten zu einer relativen Erhöhung der Anteile von ca. 10 % führt. Der Panel-Ansatz kommt zu ähnlichen Resultaten, welche die Robustheit der Resultate des DiD-Ansatzes zusätzlich untermauern.

Dieser Effekt auf die Registration von effizienter Fahrzeuge scheint relativ klein zu sein. Betrachtet man jedoch den Motorfahrzeugsteuerrabatt im Verhältnis zu den Gesamtkosten eines Fahrzeugs, so ist dieser eher bescheiden. Der durchschnittliche Rabatt beträgt ungefähr CHF 240 pro Jahr und wird in den meisten Kantonen für maximal drei Jahre gewährt. Ein weiterer Grund für die eher geringe Wirkung könnte sein, dass wahrscheinlich viele Fahrzeugkäufer die Höhe der Motorfahrzeugsteuer nicht kennen und ihnen auch nicht bewusst ist, dass sie bei der Zulassung eines sparsamen Fahrzeugs von einem Bonus profitieren können.

Da uns die Informationen zur individuellen Fahrleistung nicht bekannt sind, können wir nicht abschätzen, wie sich die Steigerung des Anteils effizienter Fahrzeuge auf die tatsächlichen CO_2-Einsparungen ausgewirkt hat. Ein Wechsel zu einem effizienteren Fahrzeug kann möglicherweise einen sogenannten Rebound-Effekt auslösen. Dies ist der Fall, wenn das effizientere Fahrzeug zwar weniger CO_2 pro Kilometer emittiert, damit aber mehr Kilometer gefahren und somit die CO_2-Einsparungen reduziert oder gar rückgängig gemacht werden.

Die Einführung eines Bonus oder Bonus und Malus Systems hat auch Auswirkungen auf die kantonalen Einnahmen aus der Motorfahrzeugsteuer. In Kantonen, die nur einen Bonus eingeführt haben, werden sich die Steuereinnahmen reduzieren. Diese Steuerverluste können mit einem wirksam ausgestalteten Malus kompensiert werden. Der Effekt der Ökologisierung der Motorfahrzeugsteuer auf die kantonalen Steuereinnahmen kann mit den vorhandenen Daten nur ansatzweise ermittelt werden. Als Beispiel nehmen wir an, dass ein durchschnittlicher Schweizer Kanton ein Bonus-System (ohne Malus) einführt, durch welches die Besitzer erstimmatrikulierter Fahrzeuge mit einem CO_2-Ausstoss von maximal 130 g/km für die drei Jahre in den Genuss einer 50 prozentigen Steuerreduktion kommen. Bei einer angenommenen durchschnittlichen Fahrleistung von 13‘800 km pro Jahr und einer durchschnittlichen Lebensdauer von zwölf Jahren, kommt man auf Kosten von ca. 248 Franken pro Tonne CO_2.[9] Dieser hohe Wert ist darauf zurückzuführen, dass der Steuerrabatt natürlich für alle Neuregistrationen, welche maximal 130 g CO_2/km ausstossen, gewährt wird und somit auch die oben erwähnten 20 % der Gesamtflotte profitieren, welche auch ohne die Massnahme ein solches Fahrzeug gekauft haben. Bei der Analyse wird klar ersichtlich, dass sich ein reiner Bonus ohne zusätzlichen Malus negativ auf den Staatshaushalt auswirkt und zu

[9] Es gilt darauf hinzuweisen, dass die Berechnungen anhand der offiziellen NEFZ-Verbrauchswerten durchgeführt wurden, welche von den realen Verbrauchswerten abweichen können.

sehr hohen Kosten pro eingesparter Tonne CO_2 führt. Finanzpolitisch ist deshalb zwingend zu empfehlen, dass neben einem Bonus auch ein Malus eingeführt wird. So findet eine Steuerumverteilung von effizienten zu ineffizienten Fahrzeugen statt und die Steuereinnahmen bleiben relativ ausgeglichen.

Modul 3: Effekt der CO_2-Emissionsvorschriften für Personenwagen

Der Bundesrat und das Parlament haben im Jahr 2011 entschieden, CO_2-Emissionsvorschriften für Schweizer Automobilimporteure einzuführen, analog zu den Vorschriften, wie sie die EU auf Herstellerebene eingeführt hat. Diese Vorschriften sind im CO_2-Gesetz verankert und wurden in der Schweiz am 1. Juli 2012 in Kraft gesetzt. Die Vorschriften geben vor, dass Importeure von neuen Personenwagen bis 2015 ein spezifisches CO_2-Ziel erreichen müssen, welches vom Durchschnittsgewicht ihrer Flotte abhängt. Über alle Importeure wird so ein Ziel von durchschnittlich 130 g CO_2/km angestrebt.[10] Die Importeure haben die Möglichkeit, sich zu Emissionsgemeinschaften zusammenschliessen, um das Ziel gemeinsam zu erreichen. Pro Gramm Zielverfehlung wird eine Sanktion fällig. Während den Jahren 2012 bis 2014 gab es eine Übergangsphase (englisch: phase-in period) in welcher nur ein bestimmter Anteil der Flotte pro Importeur (bzw. pro Emissionsgemeinschaft) den vorgegebenen Zielwert erreichen musste (2012: 65%, 2013: 75%, 2014: 80%). Ab dem Jahr 2015 gilt das Ziel für die Gesamtflotte.

In einer ersten explorativen Analysen untersuchen wir in Modul 3 dieses Berichts, was für einen Einfluss die CO_2-Emissionvorschriften auf die CO_2-Reduktion von Neuwagen in der Schweiz haben. Es gilt zu betonen, dass es sich dabei um eine explorative Analyse handelt, da für eine robuste empirische Analyse folgende Punkte nicht gegeben sind:

- Für Modul 3 haben wir Daten von Neuwagenregistrationen bis 2014 zur Verfügung. Die Zeitperiode seit der Einführung der Massnahme ist somit ziemlich kurz und wir können noch nicht den Gesamteffekt der Massnahme abschätzen, da diese bis 2015 läuft.

[10] Relevant sind dabei die CO_2 Emissionen jedes einzelnen Fahrzeugs, welche anhand des Neuen Europäischen Fahrzyklus (NEFZ) gemessenen werden. Dass die realen Verbrauchswerte von diesen gemessenen Werten abweichen können, wird dabei nicht berücksichtigt (http://www.transportenvironment.org/sites/te/files/publications/TE_Mind_the_Gap_2015_FINAL.pdf).

- Im verfügbaren Datensatz fehlt die Information über die Importeure der Fahrzeuge oder die gebildeten Emissionsgemeinschaften, welche für die spezifische Zielerreichung verantwortlich sind. Unsere Schätzungen haben wir deshalb auf Markenebene durchgeführt.
- Da in der EU zeitgleich eine analoge Vorschrift eingeführt wurde, können wir nicht, wie in Modul 2, einen DiD-Ansatz oder andere geeignete empirische Politikevaluierungsmethoden anwenden, da keine Kontrollgruppe vorhanden ist. Wir müssen deshalb auf eine klassische Regressionsgleichung zurückgreifen, mit welcher wir die CO_2-Absenkung vor und nach der Massnahmeneinführung vergleichen. So können wir eine mögliche Korrelation zwischen der CO_2-Absenkung und der Massnahme eruieren, jedoch nicht die Kausalität bestimmen, da eine Veränderung der Absenkung auch aufgrund anderer, zeitgleich auftretender Effekte erfolgen kann.

Wie in Abbildung 6 ersichtlich ist, haben die durchschnittlichen CO_2-Emissionen von Neuwagen in der Schweiz kontinuierlich abgenommen. Während die EU das durchschnittliche Ziel von 130 g/km bereits im Jahr 2013 unterschritten hatte, braucht es in der Schweiz noch grosse Anstrengungen, um das Ziel bis Ende 2015 zu erreichen.

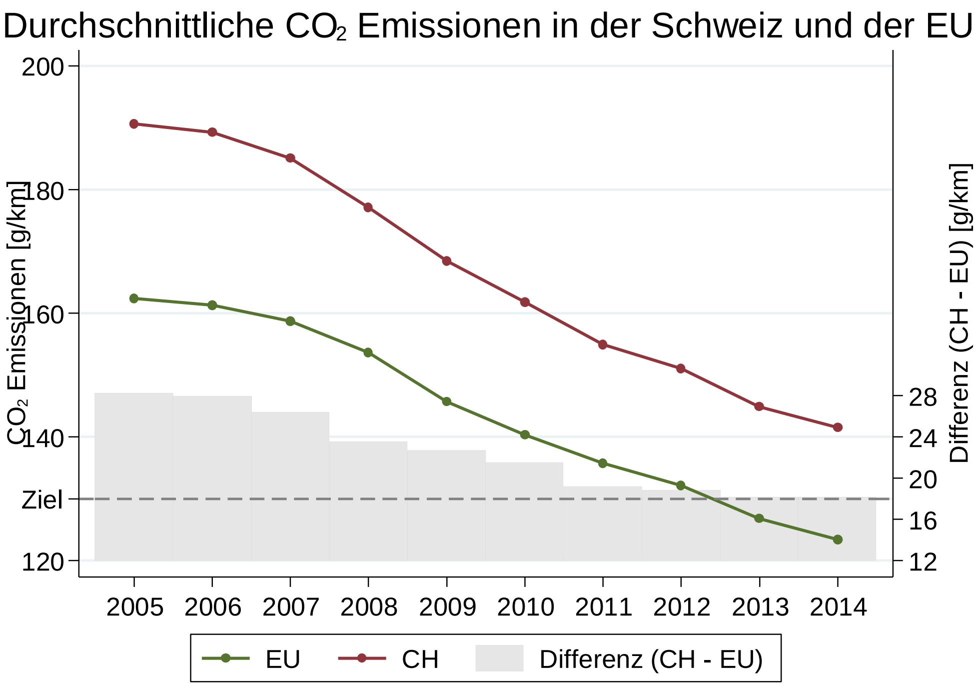

Abbildung 6: Durchschnittliche CO_2-Emissionen von Neuwagen in der Schweiz und der EU (Quelle: eigene Berechnungen, ASTRA, European Environment Agency)

Wir schätzen mit Neuwagenregistrationsdaten von 2005 bis 2014 ein klassisches Regressionsmodel und eruieren einerseits, ob die Massnahme zu einem Sprung in der CO_2-Absenkung führte und anderseits, ob sich die Steigung der CO_2-Absenkung änderte. Um die Robustheit unserer Schätzresultate zu testen, modifizieren wir unser Modell auf unterschiedliche Arten. Einmal betrachten wir nur die Jahre 2010 bis 2014, um allfällige Schwankungen von nicht beobachteten Einflüssen zu reduzieren. In einem anderen Ansatz vergleichen wir die geschätzten Koeffizienten der Periode vor der Massnahmeneinführung von 2005 – 2011 mit den geschätzten Koeffizienten der Periode nach der Massnahmeneinführung von 2013 – 2014.

Mit allen Modellen erhalten wir das Resultat, dass sich die durchschnittlichen CO_2-Emissionen nach Einführung der CO_2-Emissionsvorschriften zwar sprunghaft reduzieren, sich danach aber weniger stark absenken als noch vor der Einführung der Vorschriften. Dieses Resultat wird in Abbildung 7 veranschaulicht und ist auf den ersten Blick äusserst erstaunlich.

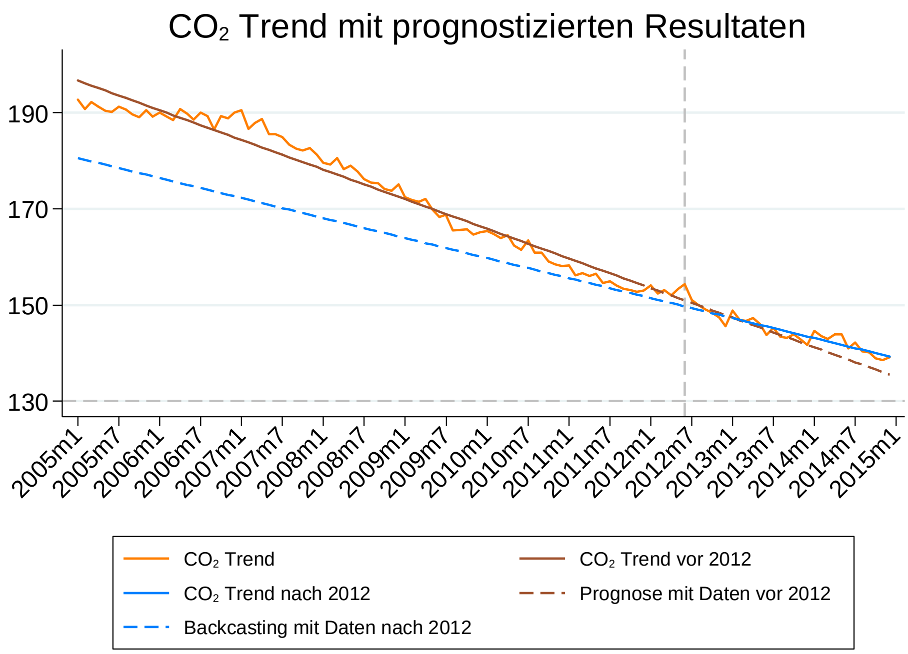

Abbildung 7: Veränderung der Regressionsgerade seit Einführung der CO_2-Emissionsvorschriften

Der erwartete Effekt der Regulierung ist, dass sich die durchschnittlichen CO_2-Emissionen nach Einführung der Vorschriften stärker absenken. Die Schätzergebnisse können so interpretiert werden, dass die Importeure zu Beginn der Einführung der Massnahme mit grosser Anstrengung die CO_2-Emissionen ihrer Flotte sprunghaft senkten und danach die Absenkung versuchten so zu steuern, dass das Ziel gerade erreicht, aber nicht übererfüllt wurde. Ein anderer Grund kann aber auch die Einführungsphase sein, während der nur ein bestimmter Prozentsatz der Flotte das Ziel erreichen musste. Im Jahr 2014 mussten zum Beispiel erst 80 % der Flotte jedes Importeurs das Emissionsziel erreichen.

Die Abschwächung des Absenkpfads darf aber nicht dazu verleiten, anzunehmen, dass die CO_2-Emissionen ohne die Vorschriften stärker gesunken wären. Ohne eine vergleichbare Kontrollgruppe und den genauen Daten zum Verhalten der Importeure kann nicht genau abgeschätzt werden, wie sich die CO_2-Emissionen ohne Vorschriften entwickelt hätten. Zudem kann der geschätzte Effekt auch nicht vollständig den CO_2-Emissionsvorschriften zugewiesen werden, da noch weitere, nicht beobachtbare Variablen einen Einfluss gehabt haben könnten. Wie bereits oben erwähnt, kann die tatsächliche Emissionsreduktion sowieso erst bestimmt werden, wenn die Daten für das Jahr 2015 vorliegen. Erst im Jahr 2015 muss die gesamte Flotte den Zielwert durchschnittlich erreichen. Deshalb handelt es sich hierbei erst um eine explorative Analyse, welche zu einem späteren Zeitpunkt mit dem vollständigen Datensatz weitergeführt werden sollte.

Summary: French/Français

En matière de politique climatique internationale, on s'est fixé – sur la base des connaissances scientifiques existantes – l'objectif dit des deux degrés : il s'agit de limiter le réchauffement de la Terre à un maximum de 2° C par rapport au niveau des températures de 1990. La Suisse contribue à la réalisation de cet objectif en menant une politique climatique active. Dans sa loi sur le CO_2, elle s'est fixé pour but de réduire d'ici 2020 ses émissions de CO_2 de 20 % par rapport à leur niveau de 1990. Selon la statistique sur le CO_2 établie par l'Office fédéral de l'environnement (OFEV), les émissions de CO_2 dues aux combustibles diminuent de façon constante en valeur absolue depuis 2004 environ, tandis que celles dues aux carburants se maintiennent à un niveau élevé[11]. Cette dernière catégorie d'émissions provient en grande partie du trafic individuel motorisé, c'est-à-dire avant tout des voitures.

Pour endiguer les émissions de CO_2, différentes mesures étatiques sont possibles. Elles peuvent porter aussi bien sur l'offre que sur la demande. Au plan mondial, les mesures les plus fréquemment introduites sont les prescriptions relatives aux émissions de CO_2. Elles agissent sur l'offre en obligeant les constructeurs et les importateurs de voitures à ramener à une valeur cible prescrite les émissions moyennes de CO_2 ou la consommation moyenne de carburant de leur parc automobile. En ce qui concerne la demande, on essaie d'agir sur l'achat de véhicules ou sur le comportement au volant au moyen de systèmes d'incitations fiscales. Il est possible de promouvoir l'achat de véhicules efficaces, d'une part, en octroyant des rabais sur l'impôt unique perçu à l'achat ou sur l'impôt annuel perçu une fois les véhicules immatriculés (taxe automobile) et, d'autre part, en augmentant ces impôts pour les véhicules inefficaces. Une autre possibilité consiste à faire reposer le système d'imposition directement sur les émissions de CO_2 du véhicule. Une taxe sur le CO_2 prélevée sur les carburants augmente le coût du kilomètre parcouru et incite les automobilistes à adapter leur comportement au volant et à acquérir des véhicules plus économiques. Du point de vue économique, les taxes d'incitation sur le CO_2 sont considérées comme des instruments extrêmement efficaces. Elles ont pour effet d'internaliser (partiellement ou entièrement, selon leur montant) les coûts externes occasionnés par les émissions de CO_2. Ces coûts sont ainsi supportés directement par ceux qui les occasionnent et non plus par la collectivité. Le

[11] Source : http://bafuidkprd01.hse.begasoft.ch/Public/IndicatorData?indiRef=KL001&language=0, consulté pour la dernière fois le 10.09.2015.

parlement suisse a introduit une taxe sur le CO_2 prélevée sur les combustibles en 2008. L'introduction d'une taxe sur le CO_2 prélevée sur les carburants fossiles n'a pour l'heure pas réuni de majorité dans le pays. D'autres mesures sont néanmoins en vigueur dans le domaine des transports. Elles visent à réduire les émissions de CO_2 de la Suisse. Par exemple, il existe depuis 2003 une étiquette-énergie qui renseigne les acquéreurs de voitures neuves sur les émissions de CO_2 et sur la consommation de carburant spécifiques à chaque véhicule, tout en comparant ces paramètres avec la moyenne des voitures neuves sur le marché suisse. En outre, les prescriptions relatives aux émissions de CO_2 des voitures, en vigueur depuis 2012, obligent les importateurs à réduire les émissions moyennes de CO_2 de leur parc de voitures neuves à une moyenne de 130 grammes par kilomètre d'ici fin 2015. À l'échelon cantonal, plusieurs cantons ont introduit ces dernières années une différenciation de l'impôt sur les véhicules à moteur (ci-après « taxe automobile ») fondée sur des critères écologiques et ils accordent un rabais fiscal (bonus) pour les véhicules efficaces ou sanctionnent par une augmentation d'impôt (malus) les détenteurs de véhicules à émissions élevées. En réduisant le relatif coût des voitures efficaces, ils incitent donc les consommateurs à opter pour celles-ci.

Pour acquérir des connaissances sur l'effet de pareilles mesures, à la fin de 2012 l'Office fédéral de l'environnement (OFEV), avec le soutien financier de l'Office fédéral des routes (OFROU), a chargé le Center for Energy Policy and Economics (CEPE) de l'École polytechnique fédérale de Zurich (EPFZ) de mener un projet de recherche sur trois ans en vue, d'une part, d'établir une représentation de la composition du parc automobile suisse en mettant en évidence son évolution au fil du temps ainsi que les disparités régionales, et, d'autre part, d'évaluer les effets de l'écologisation de la taxe automobile et des prescriptions en matière d'émissions de CO_2 sur les immatriculations de véhicules efficaces. Le projet en question est subdivisé en trois modules :

1. préparation des données et établissement de statistiques descriptives concernant la répartition du parc automobile suisse selon différents critères ;
2. évaluation de l'effet de la taxe automobile sur les parts relatives des voitures efficaces et inefficaces ;
3. évaluation de l'effet des prescriptions concernant les émissions de CO_2 sur les émissions moyennes de CO_2 du parc de voitures neuves.

Chacun de ces modules a fait l'objet d'un article rédigé en anglais qui figure en annexe du présent document. Les connaissances acquises sont brièvement présentées ci-dessous.

Module 1: vue d'ensemble du parc automobile suisse (et de celui de l'UE)

Le module 1 sert, d'une part, à préparer les données pour l'ensemble du rapport et, d'autre part, à établir des statistiques descriptives détaillées sur la composition du parc automobile suisse. Dans ce contexte, l'accent est mis sur l'évolution des émissions moyennes de CO_2 et de la consommation moyenne de carburant. Les disparités régionales sont mises en évidence au moyen de cartes établies à l'échelle cantonale et communale.

Préparation des données

L'OFROU et l'Office fédéral de la statistique (OFS) ont fourni des données, d'une part, sur le nombre annuel de voitures en circulation à une date de référence déterminée et, d'autre part, sur les immatriculations de voitures neuves pendant la période allant de 2005 à 2012. Ces données proviennent du système d'information sur les véhicules à moteur (MOFIS), qui regroupe les immatriculations de véhicules effectuées par tous les services cantonaux des automobiles. Ces données d'immatriculation ont été rattachées aux données d'homologation (TARGA) fournies par le service d'homologation au moyen du numéro de réception par type et du code de boîte de vitesses. Les données TARGA contiennent des informations détaillées sur les paramètres techniques de tous les véhicules dont le type a été réceptionné en Suisse. Étant donné que nous ne disposons de données TARGA détaillées qu'à partir de 1996, il nous a fallu éliminer du jeu de données les véhicules mis sur le marché auparavant.

Les données du MOFIS et les paramètres techniques tirés de la base de données TARGA ont permis de calculer la classe d'efficacité énergétique de chaque véhicule et la taxe automobile s'y appliquant dans le canton considéré, puis d'attribuer à celle-ci un bonus ou un malus sur la base de ses modalités. Pour des raisons de protection des données, le jeu de données utilisé ne contient pas d'informations détaillées sur les détenteurs des véhicules. Les codes postaux des communes de domicile ont toutefois permis d'ajouter au jeu de données des variables socio-économiques et géographiques à l'échelon communal.

L'établissement de tous les liens possibles entre les différents jeux de données n'a pas été réalisable pour tous les véhicules, si bien qu'un certain nombre d'observations ont été perdues. Différents tests confirment toutefois que les pertes de données ne sont pas systématiques et que le jeu de données reste représentatif. La figure 1 indique pour chaque année le nombre de voitures que comptait le parc automobile suisse.

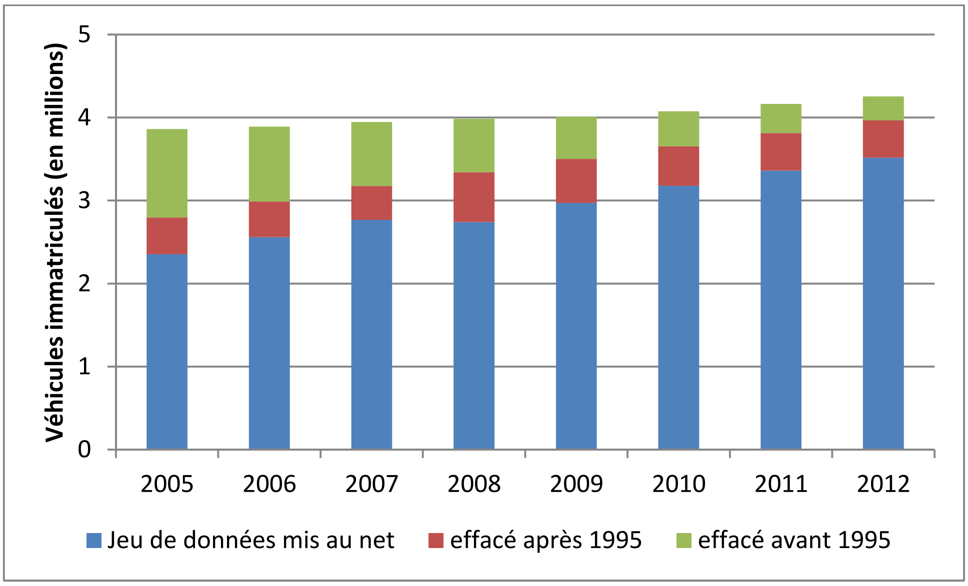

Figure 8 : Nombre de véhicules disponibles pendant la période 2005 – 2012

Lors du recensement de 2012, le nombre de voitures immatriculées en Suisse s'élevait par exemple à 4,255 millions. Dans le jeu de données, il a été possible d'adjoindre toutes les informations nécessaires à 83 % de ces véhicules.

Statistiques descriptives sur le parc automobile suisse

Le second volet du module 1 a consisté à analyser l'évolution du parc automobile suisse pendant la période allant de 2005 à 2012 et à mettre en évidence, sur la base des données de 2012, les différences dans la répartition nationale de ce parc. Cette dernière a été mise en relation avec par exemple des données topographiques ou le revenu moyen des communes, et les résultats obtenus sont présentés sur des cartes afin de mettre en évidence les disparités régionales.

Pendant la période allant de 2005 à 2012, la part des véhicules diesel a augmenté, passant de 13,9 % à 23,6 % au détriment des véhicules à essence. Les parts des voitures hybrides et des voitures électriques étaient encore extrêmement modestes en 2012 et ne représentaient respectivement que 0,77 % et 0,03 % du parc automobile. Le poids à vide et la cylindrée n'ont en moyenne pas beaucoup changé, tandis que la puissance (chevaux-vapeur) a augmenté et que la consommation de carburant ainsi que les émissions de CO_2 ont diminué (cf. tableau 1). Les données sur la consommation d'essence et les émissions de CO_2 correspondent aux valeurs mesurées sur bancs à rouleaux dans le cadre du nouveau cycle européen de conduite

(NEDC). La consommation et les émissions effectives dépendent du comportement au volant et des réglages du véhicule, si bien qu'elles peuvent différer des mesures NEDC[12].

Tableau 4: Évolution de différentes caractéristiques des véhicules du parc automobile pendant la période allant de 2005 à 2012 (jeu de données du CEPE)

Année	Poids à vide	Cylindrée	Puissance	CO_2	Consommation (éq.-essence)	Consommation (essence)	Consommation (diesel)
	kg	ccm	kW	g/km	l/100 km	l/100 km	l/100 km
2005	1484	1964	97	204	8,5	8,7	6,9
2006	1473	1962	98	202	8,4	8,6	6,9
2007	1474	1964	99	200	8,4	8,5	6,9
2008	1473	1956	100	196	8,2	8,4	6,8
2009	1428	1952	101	194	8,1	8,3	6,8
2010	1436	1942	101	191	8,0	8,2	6,7
2011	1443	1929	102	189	7,9	8,1	6,7
2012	1450	1916	103	185	7,8	8,0	6,6

La figure 2 présente la répartition par canton des émissions moyennes de CO_2 du parc automobile, en grammes par kilomètre. Il apparaît que dans la partie germanophone de la Suisse, les véhicules en circulation émettent plus de CO_2 que dans les parties francophone et italophone du pays.

[12] http://www.transportenvironment.org/sites/te/files/publications/TE_Mind_the_Gap_2015_FINAL.pdf

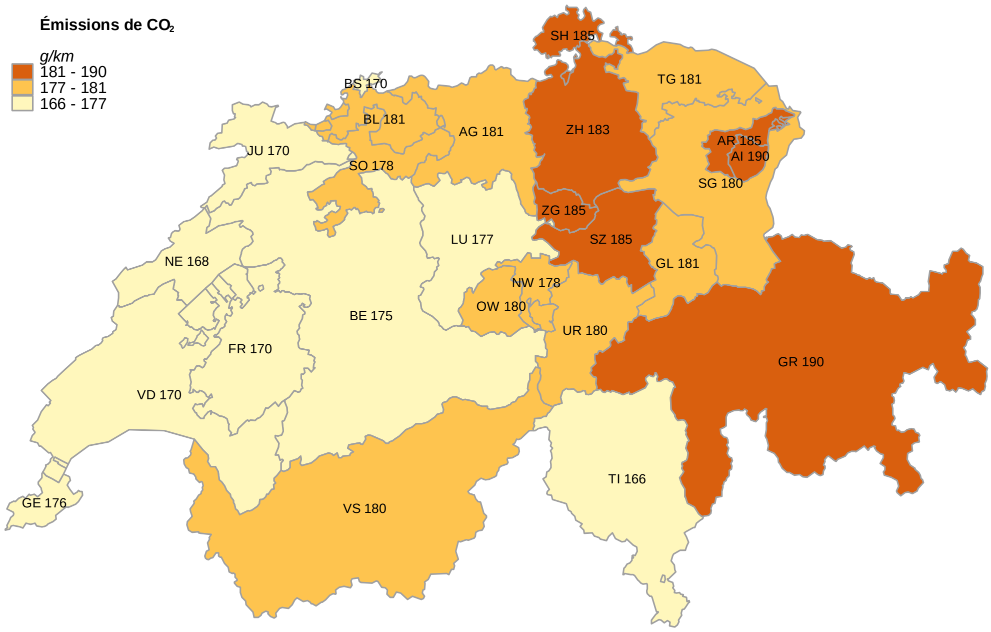

Figure 9: Émissions de CO_2 du parc automobile en 2012, par canton

S'agissant de la relation entre consommation moyenne de carburant et topographie, la figure 3 montre clairement que les voitures immatriculées dans des communes d'altitude (à partir de 706 mètres) ont pour la plupart une consommation plus élevée que celles dont les détenteurs vivent en plaine.[13]

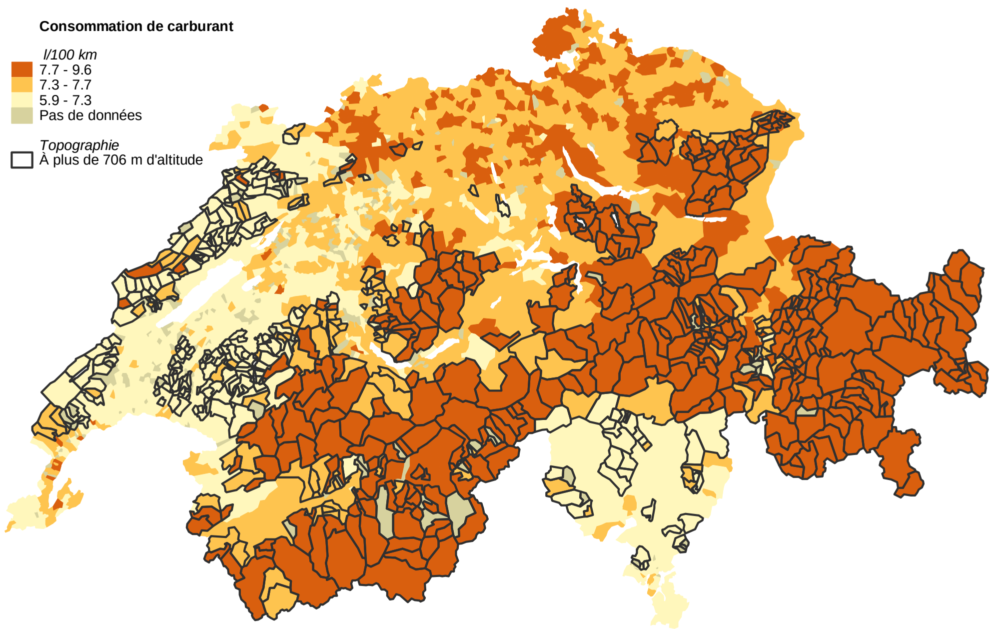

Figure 10: Consommation de carburant du parc automobile en 2012 (Les régions de montagne sont mises en évidence par un trait noir.)

[13] La figure 3 représente la consommation moyenne mesurée des voitures, exprimée en litres aux 100 km. Les données disponibles ne permettent pas de déterminer la consommation en valeur absolue, car cette dernière dépend du comportement au volant et du nombre de kilomètres parcourus.

L'analyse de la répartition des différentes catégories de voitures montre, à la figure 4a, que c'est dans les régions de montagne que la proportion de voitures tout-terrain (SUV) est la plus élevée. Si l'on examine la consommation des SUV, on constate néanmoins (cf. figure 4b) que les SUV les plus gourmands en carburant sont avant tout concentrés dans les régions de plaine du nord de la Suisse, tandis que ceux des régions de montagne sont généralement plus économiques.

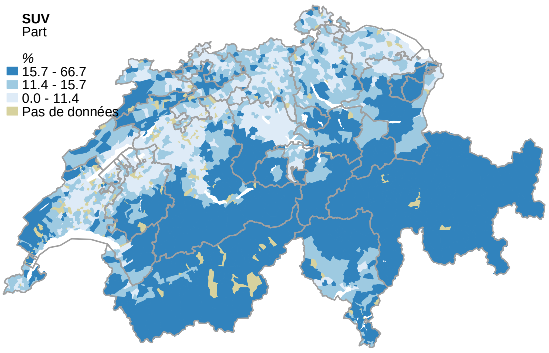

Figure 11a : Répartition des SUV en 2012

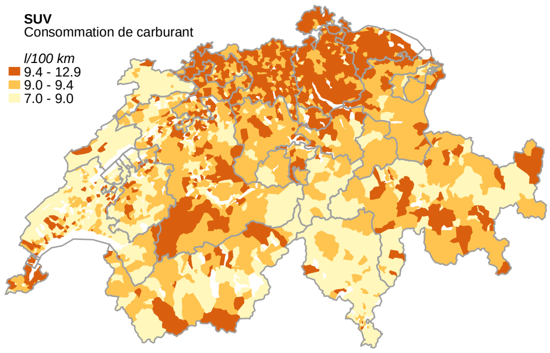

Figure 4b : Consommation de carburant des SUV en 2012

D'autres analyses et figures sont disponibles dans le rapport sur le module 1.

Module 2: impact de l'écologisation de la taxe automobile

Perçue chaque année auprès des propriétaires de voiture, la taxe automobile est réglementée en Suisse à l'échelon cantonal. Elle repose sur un paramètre spécifique qui varie d'un canton à l'autre. Il peut s'agir par exemple du poids, de la cylindrée ou de la puissance du véhicule. Au cours de la dernière décennie, plusieurs cantons ont procédé à une écologisation de cette taxe en accordant des réductions (bonus) pour les voitures particulièrement efficaces ou pauvres en CO_2, et/ou en infligeant des hausses (malus) aux propriétaires des voitures à forte consommation de carburant ou à émissions de CO_2 élevées, l'objectif étant de modifier le prix relatif du véhicule et de renforcer l'attractivité des voitures efficaces par rapport aux modèles inefficaces. Du point de vue économique, une solution judicieuse consiste à introduire simultanément un bonus pour la première immatriculation des véhicules à faibles taux d'émissions de CO_2 et un malus pour les voitures, neuves ou d'occasion, à émissions élevées. Un tel système encourage l'achat de voitures neuves économiques tout en réduisant l'attrait des véhicules inefficaces. Il permet en outre de mieux équilibrer les finances publiques que ne le ferait la seule introduction d'un bonus. Le tableau 2 indique les cantons qui ont introduit une mesure, et laquelle, pendant la période sous revue, à savoir celle de 2005 à 2011. Après 2011, d'autres cantons[14] ont écologisé leur taxe automobile, et l'on a commencé à axer la base de calcul de cette taxe sur les émissions de CO_2 du véhicule plutôt que d'opter pour un système de bonus/malus[15]. Si une telle approche est considérée intéressante, elle ne fait toutefois pas l'objet de notre étude.

Comme le montre le tableau 2, il existe des rabais fiscaux fondés sur la classe d'efficacité énergétique (lignes surlignées en vert), sur une valeur limite des émissions de CO_2 (lignes surlignées en orange) ou sur une combinaison de ces deux éléments (lignes surlignées en bleu). Pour réduire l'effet d'aubaine[16], ces rabais fiscaux ne s'appliquent qu'aux premières immatriculations et, dans la plupart des cantons, que pendant deux ou trois ans. Quant au malus, il se fonde ou sur l'étiquette-énergie ou sur une valeur limite des émissions de CO_2, sauf dans le canton de Nidwald, qui l'applique à toutes les voitures remplissant le critère fixé, qu'elles soient neuves ou non. Les autres cantons ne l'appliquent qu'aux voitures qui ont été immatriculées pour la première fois après l'introduction de la mesure. Le tableau ci-dessus montre clairement qu'en 2011 tous les cantons n'avaient pas écologisé leur taxe automobile et que dans bien des cas, ils avaient introduit un bonus sans l'accompagner d'un malus.

Dans les paragraphes ci-dessous, nous examinons la façon dont l'écologisation de la taxe automobile se répercute sur les immatriculations des voitures neuves. Cette analyse porte sur les voitures fonctionnant à l'essence ou au diesel, sans propulsion hybride. En plus des systèmes d'incitation mentionnés ici, certains cantons accordent des rabais fiscaux spécifiques aux détenteurs de voitures à carburant ou propulsion alternatifs (voitures hybrides, voitures fonctionnant au gaz et voitures électriques). Ces véhicules-là ne font toutefois par l'objet de notre étude.

[14] Il s'agit des cantons de Bâle-Campagne (BL), Bâle-Ville (BS), Berne (BE), Glaris (GL) et Zurich (ZH).
[15] Le canton de Neuchâtel a introduit ce système en 2014.
[16] Il y a effet d'aubaine lorsqu'un acheteur bénéficie d'un rabais alors qu'il aurait acheté le véhicule même en l'absence de système d'incitations.

Tableau 5: Systèmes d'incitation cantonaux en vigueur pendant la période 2005-2011 pour tous les types de carburants

Canton		Année d'intro-duction	Système d'incitation
Argovie	AG	-	
Appenzell Rh. Ext.	AI	-	
Appenzell Rh. Int.	AR	2011	Bonus de 50 % si $CO_2 \leq 130$ g/km
Berne	BE	-	
Bâle-Campagne	BL	-	
Bâle-Ville	BS	-	
Fribourg	FR	2011	Bonus de 100 % si étiquette A ; 2,2 % d'impôt en plus si étiquette D, E, F, G ou si aucune étiquette
Genève	GE	2010	Bonus de 50 % si $CO_2 \leq 120$ g ; malus de 50 % si $CO_2 > 200$ g
Glaris	GL	-	
Grison	GR	2009	2009 : bonus de 80 % si $CO_2 \leq 140$ g & PM10≤0,01 g ; bonus de 60 % si $CO_2 \leq 160$ g & PM10≤0,01 g ; 2011 : bonus de 80 % si $CO_2 \leq 120$ g & PM10≤0,01 g ; bonus de 60 % si $CO_2 \leq 140$ g & PM10≤0,01 g
Jura	JU	-	
Lucerne	LU	-	
Neuchâtel	NE	-	
Nidwald	NW	2009	Bonus de 100 % (pendant les 3 premières années) si étiquette A
Obwald	OW	2009	Bonus de 100 % (pendant les 3 premières années) si étiquette A ; bonus de 50 % (pendant les 2 premières années) si étiquette B ; malus de 60 francs si étiquette G ou en l'absence d'étiquette
Saint-Gall	SG	2009	Bonus de 100 % (pendant les 3 premières années) si étiquette A & $CO_2 \leq 130$ g
Schaffhouse	SH	-	
Soleure	SO	-	
Schwyz	SZ	-	
Thurgovie	TG	2011	Bonus de 50 % (pendant 5 ans au plus) si étiquette A ; bonus de 25 % (pendant 5 ans au plus) si étiquette B ; malus de 50 % si étiquette F ou G
Tessin	TI	2009	Bonus de 50 % si étiquette A & $CO_2 \leq 140$ g (+filtre); Malus de 20 % si étiquette F ; malus de 50 % si étiquette G
Vaud	VD	2005	Bonus de 50 % si $CO_2 \leq 120$ g
Valais	VS	2010	Bonus de 50 % si étiquette A & $CO_2 \leq 130$ g
Uri	UR	-	
Zoug	ZG	-	
Zurich	ZH	-	

Pour examiner la question de savoir si l'écologisation de la taxe automobile a des effets sur la part des voitures neuves concernées par cette mesure, nous nous sommes fondés sur les immatriculations de voitures neuves en Suisse pendant la période allant de 2005 à 2011. Les différences existant entre les cantons et entre les dates d'introduction de ce type de mesures permettent de comparer dans le temps la part des voitures neuves qui remplissent les critères d'un bonus ou d'un malus selon leur appartenance à des communes situées dans des cantons ayant introduit des mesures ou non. Dans ce contexte, on considère les cantons ayant pris des mesures comme le groupe expérimental et les autres cantons comme le groupe témoin. En économétrie, on appelle cette approche « différences de différences » (en anglais : *difference-in-differences*, DiD).

L'approche DiD est une méthode répandue pour évaluer l'efficacité d'une mesure. On compare l'évolution de la variable d'étude au fil du temps et entre différents groupes, ce qui permet, si l'on constate que la variable en question n'évolue pas de la même façon dans le groupe expérimental et dans le groupe témoin, d'attribuer précisément cette divergence à la mesure mise en œuvre. Pour la détermination d'une telle causalité, deux grands critères doivent toutefois être remplis. Il faut tout d'abord s'assurer que l'introduction de la mesure dans un canton est exogène, c'est-à-dire qu'elle n'a pas été soumise à des effets ne pouvant pas être contrôlés dans le modèle. Il faut aussi vérifier que l'évolution de la variable étudiée (variable dépendante) était la même dans les deux groupes avant l'introduction de la mesure. À défaut, on ne peut pas dire clairement si l'effet estimé provient ou non de la mesure introduite. Dans notre modèle, la variable d'étude est la part des voitures concernées par la mesure à l'échelon communal.

Ainsi, nous utilisons des méthodes économétriques pour comparer par exemple l'évolution au fil du temps (c'est-à-dire avant et après l'introduction de la mesure) de la part des voitures de classe A dans les communes de cantons ayant introduit la mesure avec la part des voitures de même classe énergétique dans les communes des cantons témoins. Nous affinons ensuite ces évaluations économétriques en comparant uniquement la façon dont la part des voitures concernées par une mesure évolue dans des communes similaires.

Pour vérifier la robustesse des résultats obtenus, nous appliquons un modèle supplémentaire dans lequel la part de chaque type de véhicule d'un district (d'une région) est utilisée comme variable d'étude[17]. Dans le cadre de ce modèle alternatif, nous établissons un lien entre chaque véhicule et la taxe automobile, ainsi que l'éventuel bonus ou malus qui s'y applique, ce qui nous permet d'évaluer l'effet d'un bonus et d'un malus sur les immatriculations de véhicules.

Avant d'analyser les résultats obtenus, nous présentons de façon purement mathématique et descriptive l'évolution – durant l'année précédant et celle suivant l'introduction de la mesure – de la part des véhicules qui remplit les critères d'application de la mesure, dans un canton du groupe expérimental par rapport au groupe témoin. Le calcul relatif à l'introduction d'un rabais fiscal fondé sur l'étiquette-énergie dans le canton d'Obwald est présenté à titre d'exemple au tableau 3[18]. On constate que dans ce canton, la part des voitures de classe A s'élevait à 17,19 % avant l'introduction de la mesure. Elle était donc de 1,66 point inférieure à celle du groupe témoin (GT). L'année suivant l'introduction de la mesure, la part des nouvelles immatriculations de voitures de classe A était deux points plus élevée à Obwald que dans le groupe témoin. L'augmentation des immatriculations de voitures de classe A a donc dépassé de 3,66 points celle du groupe témoin pendant la période considérée.

L'étape suivante a consisté à établir des graphiques représentant l'évolution de la part des véhicules concernés par la mesure. La figure 5 présente par exemple l'évolution de la part des voitures de classe A dans le canton de Fribourg et dans les cantons témoins avant et après que la mesure a été introduite dans le canton de Fribourg. On constate qu'après l'introduction de la mesure, la part des voitures de classe A a augmenté plus fortement dans le canton de Fribourg que dans le groupe témoin.

Tableau 6 : Calcul DiD – bonus pour les voitures de classe A dans le canton d'Obwald

	Canton d'Obwald (OW)		
	2008	2009	Différence
GT*	18,85 %	24,54 %	5,70 %
OW	17,19 %	26,54 %	9,35 %
Différence	-1,66 %	2,00 %	**3,66 %**

* GT = groupe témoin

17 Si nous effectuons cette analyse à l'échelon du district, c'est parce que le nombre d'immatriculations d'un modèle donné de véhicule est souvent extrêmement bas à l'échelon communal.

18 Pour les autres illustrations et statistiques, veuillez vous reporter à l'article sur le module 2.

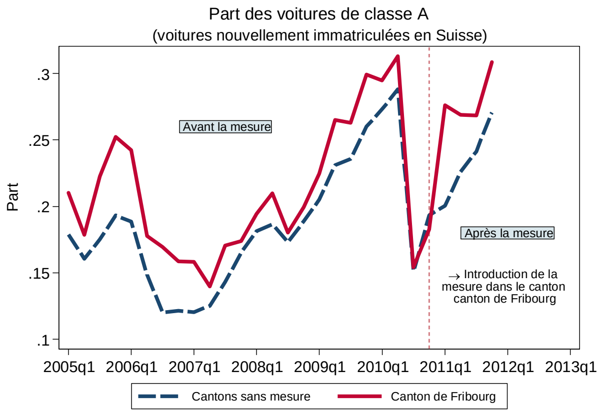

Figure 12: Évolution de la part des voitures de classe A dans le canton de Fribourg par rapport au groupe témoin

Les résultats du tableau 3 et les courbes de la figure 5 montrent que l'évolution du groupe expérimental s'écarte de celle du groupe témoin après l'introduction de la mesure. Il convient ici de relever que sans l'évaluation économétrique par laquelle nous avons également contrôlé d'autres variables, l'effet constaté ne pourrait pas être attribué clairement à l'augmentation ou à la diminution de la taxe automobile. En raison des résultats des tests économétriques réalisés, nous n'avons pu procéder à des estimations DiD que pour les cantons offrant un bonus fondé sur l'étiquette-énergie ou sur les émissions de CO_2. Pour les autres groupes, il n'y avait pas d'évolution parallèle avant l'introduction des mesures, si bien qu'il ne nous était pas possible de déterminer l'effet de ces dernières avec une précision suffisante. Selon les principaux résultats de nos estimations économétriques, lors desquelles nous avons notamment appliqué la méthode du *matching* pour ne comparer entre elles que les évolutions observées dans des communes similaires, l'introduction d'un rabais fiscal pour les véhicules énergétiquement efficaces entraîne une augmentation statistiquement significative (env. 2,1 points) de la part des véhicules de classe A. S'agissant des rabais fiscaux pour les voitures à faible taux d'émission, les estimations donnent des résultats légèrement moins significatifs, à savoir une hausse de 1,7 point environ. Les véhicules de classe A et les véhicules émettant 130 g CO_2/km au plus représentent environ 20 % du parc automobile, de sorte qu'une hausse d'à peine deux points entraîne une augmentation relative de la part de ces véhicules de 10 % environ. L'approche du panel débouche sur des résultats similaires, ce qui confirme la robustesse des résultats de l'approche DiD.

Cet effet sur les immatriculations de véhicules efficaces semble relativement faible. Néanmoins, si l'on met en relation le rabais fiscal accordé sur la taxe automobile et le coût global d'un véhicule, il apparaît que le rabais en question est plutôt modeste. Le rabais moyen s'élève à quelque 240 francs par an et n'est octroyé dans la plupart des cantons que pour trois ans. La faiblesse de l'effet obtenu pourrait aussi s'expliquer par le fait qu'un grand nombre d'acquéreurs de véhicules ne connaissent probablement pas le montant de la taxe automobile et ne savent pas non plus qu'ils peuvent bénéficier d'un bonus lors de la mise en circulation d'un véhicule économique.

Comme nous ne disposons pas d'informations sur le kilométrage individuel, il nous est impossible d'estimer l'impact qu'a l'augmentation de la part des véhicules efficaces sur les économies effectives de CO_2. Il se peut que le fait de passer à un véhicule plus efficace provoque ce qu'il est convenu d'appeler un effet rebond. C'est le cas lorsque le véhicule plus efficace a certes un taux d'émission moins élevé, mais parcourt plus de kilomètres, si bien que l'économie de CO_2 diminue et peut même être annulée.

L'introduction d'un bonus ou d'un système de bonus ou de malus a aussi des répercussions sur le produit de la taxe automobile engrangé par le canton. Les cantons qui introduisent uniquement un bonus verront leurs recettes fiscales diminuer. Ces pertes fiscales peuvent être compensées par un malus conçu de façon ingénieuse. Les données disponibles ne permettent de calculer que très approximativement l'effet de l'écologisation de la taxe automobile sur les recettes fiscales cantonales. Imaginons par exemple qu'un canton moyen introduise un système de bonus (sans malus) permettant aux propriétaires des voitures immatriculées pour la première fois qui émettent au plus 130 g CO_2/km de bénéficier d'une réduction fiscale de 50 % pendant trois ans. Admettons que le nombre moyen de kilomètres parcourus par année soit de 13 800 et la durée de vie moyenne du véhicule de douze ans, on arrive à un rapport coûts/efficacité d'environ 248 francs par tonne de CO_2[19]. Ce chiffre élevé s'explique par le fait que le rabais fiscal est octroyé à toutes les voitures nouvellement immatriculées qui rejettent un maximum de 130 g CO_2/km, y compris aux 20 % du parc automobile qui seraient acquis même en l'absence de mesures en faveur de l'achat de véhicules efficaces (cf. plus haut). Cette analyse montre que l'introduction d'un bonus non assorti d'un malus a des répercussions négatives sur le budget de l'État et entraîne des coûts très élevés par tonne de CO_2 économisée. Du point de vue de la politique des finances, il faut donc impérativement recommander de toujours accompagner l'introduction d'un bonus de celle d'un malus. La répartition de l'impôt est ainsi modifiée en ce sens que l'impôt perçu sur

[19] Il convient d'attirer l'attention sur le fait que les calculs ont été effectués sur la base des valeurs de consommation NEDC officielles, qui peuvent différer des valeurs réelles.

les véhicules inefficaces augmente tandis que celui frappant les véhicules efficaces diminue, si bien que les recettes fiscales restent sensiblement les mêmes.

Module 3: effet des prescriptions concernant les émissions de CO_2 des voitures

Le Conseil fédéral et le Parlement ont décidé en 2011 d'introduire des prescriptions sur les émissions de CO_2 pour les importateurs suisses d'automobiles, comme l'UE l'a fait à l'échelon des fabricants. Ces prescriptions sont inscrites dans la loi sur le CO_2 et ont été mises en vigueur le 1er juillet 2012. Elles prévoient que les importateurs de voitures neuves doivent atteindre un objectif spécifique en matière de CO_2 d'ici 2015, objectif qui dépend du poids moyen des véhicules de leur parc. On entend ainsi atteindre l'objectif de 130 g CO_2/km sur la moyenne de tous les importateurs[20]. Ces derniers peuvent former des groupements d'émission afin d'atteindre l'objectif ensemble. Une sanction est appliquée pour chaque gramme de CO_2 en trop. Les années 2012 à 2014 ont constitué une période transitoire lors de laquelle seule une partie du parc automobile de chaque importateur (ou de chaque groupement d'émission) était soumise à la valeur cible (2012: 65 %, 2013: 75 %, 2014: 80 %). En 2015, l'objectif s'applique à l'ensemble de leurs parcs.

Dans le troisième module du rapport, nous procédons à une première analyse exploratoire visant à déterminer l'effet des prescriptions en matière d'émissions de CO_2 sur la réduction des émissions de CO_2 des voitures neuves en Suisse. Il convient de souligner le caractère exploratoire de ce travail car les éléments suivants, indispensables à une analyse empirique robuste, font défaut :

- Pour le module 3, nous disposons des données relatives aux immatriculations de voitures neuves jusqu'à fin 2014. La période écoulée depuis l'introduction de la mesure est donc relativement courte et il ne nous est pas possible d'évaluer l'effet total de cette dernière car elle court jusqu'à fin 2015.
- Le jeu de données disponible n'indique pas l'importateur du véhicule, ni les groupements d'émission responsables de la réalisation de l'objectif visé. Nous avons donc effectué nos estimations au niveau du marché.

[20] Sont déterminantes les émissions de CO_2 de chacun des véhicules du parc, mesurées au moyen du nouveau cycle européen de conduite (NEDC). Il n'est pas tenu compte du fait que les valeurs réelles de consommation peuvent différer des valeurs mesurées (http://www.transportenvironment.org/sites/te/files/publications/TE_Mind_the_Gap_2015_FINAL.pdf).

- Comme une prescription analogue a été introduite en même temps au sein de l'UE, nous ne pouvons pas appliquer, comme au module 2, une approche DiD ou des méthodes empiriques d'évaluation des mesures prises par les pouvoirs publics, car il n'existe pas de groupe témoin. Il nous faut donc recourir à une équation de régression classique, avec laquelle nous comparons la réduction des émissions de CO_2 avant et après l'introduction de la mesure. Cette procédure nous permet certes de mettre en évidence une éventuelle corrélation entre la réduction des émissions de CO_2 et la mesure, mais non la cause de cette dernière car une éventuelle modification de rythme de diminution pourrait aussi s'expliquer par d'autres effets concomitants.

Comme le montre la figure 6, les émissions moyennes de CO_2 des voitures neuves diminuent de façon continue en Suisse. Néanmoins, si l'UE a atteint l'objectif des 130 g CO_2/km en 2013 déjà, la Suisse doit encore fournir des efforts importants si elle veut atteindre ce même objectif d'ici fin 2015.

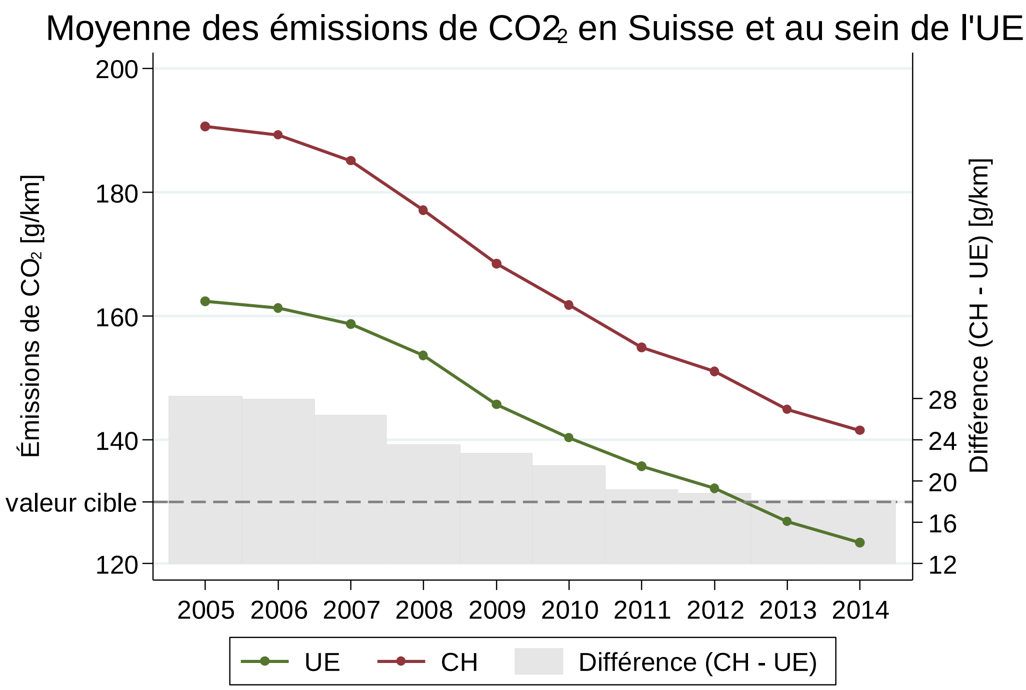

Figure 13: Émissions moyennes de CO_2 des voitures neuves en Suisse et au sein de l'UE (source : nos propres calculs, OFROU, Agence européenne pour l'environnement)

Avec les données relatives aux immatriculations de voitures neuves intervenues pendant la période allant de 2005 à 2014, nous évaluons un modèle de régression classique et déterminons, d'une part, si la mesure a entraîné un saut dans la réduction des émissions de

CO_2 et, d'autre part, si la pente de la trajectoire de réduction de ces mêmes émissions s'est modifiée. Pour tester la robustesse des résultats de nos estimations, nous modifions notre modèle de diverses manières. L'une d'elles consiste à ne prendre en compte que les années de 2010 à 2014 pour réduire les éventuelles variations dues à des effets sortant du cadre de nos observations. Une autre approche consiste à comparer les coefficients estimés de la période précédant l'introduction de la mesure (2005-2011) avec ceux de la période suivant l'introduction de la mesure (2013-2014).

Tous les modèles débouchent sur le résultat suivant : les émissions moyennes de CO_2 diminuent certes brusquement après l'introduction de la mesure, mais la réduction est ensuite moins forte qu'avant l'introduction des prescriptions. Ce résultat est illustré à la figure 7.

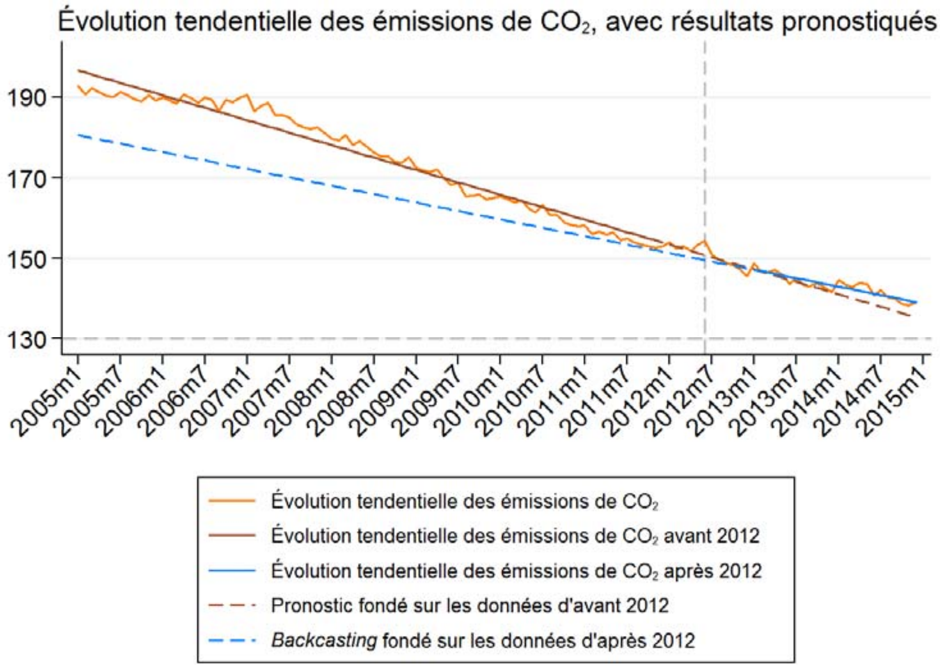

Figure 14: Modification de la pente de régression linéaire depuis l'introduction des prescriptions sur les émissions de CO_2

À première vue, ce résultat est extrêmement surprenant. On s'attend en effet à ce que les émissions moyennes de CO_2 diminuent plus fortement après l'introduction de la règlementation. Une possible interprétation de ce résultat est qu'au début de l'introduction de la mesure, les importateurs réduisent brusquement, moyennant un effort important, les émissions de CO_2 de leur parc automobile, et qu'ils essaient ensuite de gérer la réduction des émissions de manière à ce que l'objectif soit atteint, mais non dépassé. Ce résultat peut aussi s'expliquer par l'existence d'une phase d'introduction pendant laquelle seul un pourcentage déterminé du parc automobile doit atteindre l'objectif. Pour exemple seuls les 80 % du parc de chaque importateur devaient atteindre l'objectif en 2014.

Cette atténuation de la pente de la trajectoire de réduction ne doit toutefois pas nous amener à conclure que les émissions de CO_2 auraient diminué plus fortement si les prescriptions en question n'avaient pas été adoptées. En l'absence de groupe témoin comparable et de données exactes sur le comportement des importateurs, on ne peut pas estimer ce qu'aurait été l'évolution en pareil cas. De plus, l'effet estimé ne peut pas être attribué entièrement aux prescriptions car des variables non observables peuvent aussi avoir eu une influence. Comme indiqué plus haut, la réduction effective des émissions ne pourra de toute manière être déterminée qu'une fois les données 2015 disponibles. Le parc automobile dans son ensemble ne doit atteindre, en moyenne, la valeur cible que fin 2015. C'est pourquoi il ne s'agit ici que d'une analyse exploratoire qu'il serait souhaitable de poursuive ultérieurement sur la base de toutes les données nécessaires.

Summary: Italian/Italiano

Nell'ambito delle discussioni di politica climatica a livello internazionale e sulla base di conoscenze scientifiche, è stato stabilito il cosiddetto «obiettivo dei 2 gradi» con il quale si vuole limitare l'aumento della temperatura globale a un massimo di due gradi rispetto al 1990. La Svizzera contribuisce al raggiungimento di tale obiettivo mediante una politica climatica attiva grazie alla legge sul CO_2, nella quale si vuole raggiungere l'obiettivo di ridurre entro il 2020 le emissioni del 20 per cento rispetto al 1990. Secondo le statistiche sulle emissioni di CO_2 dell'Ufficio federale dell'ambiente (UFAM), in Svizzera dal 2004 si assiste a una riduzione costante delle emissioni assolute di CO_2 derivanti dall'utilizzo di combustibili. Le emissioni di CO_2 dovute ai carburanti rimangono per contro a livelli elevati[21]. La maggior parte di tali emissioni è causata dal trasporto privato di persone e quindi in gran parte dall'utilizzo di automobili.

Per limitare le emissioni di CO_2 nel settore dei trasporti i governi possono adottare numerose misure di politica energetica e climatica. In generale, le misure più diffuse a livello globale sono le prescrizioni riguardo ai consumi e alle emissioni di CO_2. Tali misure obbligano l'offerta, ossia i produttori e gli importatori di veicoli, a ridurre a un valore prestabilito le emissioni medie di CO_2 o il consumo medio di carburante delle automobili e rispettivamente della propria flotta. Per quanto riguarda la domanda, si cerca di influenzare l'acquisto di veicoli e il comportamento di guida mediante un sistema di incentivi fiscali. L'acquisto di automobili a basso consumo può essere promosso riducendo per questi veicoli la tassa una tantum sulla vendita o l'imposta annuale di immatricolazione. In questo contesto, è inoltre ipotizzabile anche l'introduzione di un aumento dell'imposta di immatricolazione per le automobili inefficienti da un punto di vista energetico. Un'ulteriore possibilità consiste nell'introdurre un sistema d'imposta annuale di immatricolazione direttamente basato sulle emissioni di CO_2 dei veicoli. Da ultimo, si può pensare all'introduzione di una tassa sul CO_2 sui carburanti. Questa tassa fa aumentare i costi per chilometro percorso e funge da incentivo per modificare il comportamento di guida e acquistare veicoli più efficienti. Dal punto di vista economico, una tassa sul CO_2 è vista come lo strumento più efficace. Una tassa sul CO_2 permette di internalizzare (totalmente o parzialmente, a seconda dell'ammontare) i costi

[21] Fonte: http://www.bafu.admin.ch/klima/13879/13880/14486/index.html?lang=it, ultima consultazione: 22.10.2015.

esterni generati dalle emissioni di CO_2. Questi costi sono quindi sopportati direttamente da chi li causa e non dalla comunità. Il Parlamento svizzero ha introdotto nel 2008 una tassa sulle emissioni di CO_2 generate dai combustibili. Una tassa sulle emissioni generate dai carburanti fossili non ha ancora trovato una maggioranza politica favorevole. Nel settore dei trasporti su strada sono tuttavia in vigore altre misure che mirano a ridurre le emissioni di CO_2 in Svizzera. Ad esempio, nel 2003 è stata introdotta l'etichetta energia per le automobili. Questa etichetta informa gli acquirenti di nuove automobili sulle emissioni di CO_2 e sul consumo di carburante del veicolo, fornendo un confronto con le altre nuove automobili presenti sul mercato svizzero. Inoltre, dal 2012 sono in vigore le prescrizioni sulle emissioni di CO_2 delle automobili che obbligano gli importatori entro il 2015 a ridurre in media a 130 grammi/km le emissioni di CO_2 delle nuove flotte di veicoli. A livello cantonale, negli ultimi anni molti Cantoni hanno reso più ecologica l'imposta di circolazione annuale per autoveicoli, introducendo una riduzione dell'imposta (bonus) per le automobili particolarmente efficienti da un punto di vista energetico e un aumento (malus) per i veicoli inefficienti e molto inquinanti. Questa differenziazione delle imposte di circolazione annuali dovrebbe incentivare l'acquisto di automobili efficienti.

Per conoscere gli effetti delle misure sopraelencate, a fine 2012 l'Ufficio federale dell'ambiente (UFAM), con il sostegno finanziario dell'Ufficio federale delle strade (USTRA) , ha commissionato al Center for Energy Policy and Economics (CEPE) del PF di Zurigo un progetto di ricerca di tre anni. Gli obiettivi del progetto sono:

1. illustrare per la Svizzera la composizione, lo sviluppo nel tempo e le disparità regionali nella composizione della flotta di automobili;
2. stimare gli effetti della riforma ecologica dell'imposta cantonale di circolazione dei veicoli e delle prescrizioni sulle emissioni di CO_2 sul numero di immatricolazioni di automobili efficienti.

Il progetto è suddiviso in tre moduli che contemplano i seguenti ambiti:

1. elaborazione dei dati e delle statistiche descrittive riguardanti la dimensione e la composizione della flotta di automobili in Svizzera;
2. stima degli effetti della riforma ecologica dell'imposta di circolazione cantonale sulla quota di nuovi veicoli efficienti e non efficienti;
3. stima degli effetti delle prescrizioni sulle emissioni di CO_2 sul valore delle emissioni medie di CO_2 della nuova flotta di automobili.

I tre moduli sono stati redatti in inglese in articoli distinti e sono allegati al presente documento. La sintesi dei risultati ottenuti è illustrata nel presente rapporto.

Modulo 1: panoramica della flotta di automobili in Svizzera (e nell'UE)

Nel modulo 1 vengono presentati i dati utilizzati nell'intero rapporto e vengono elaborate statistiche descrittive dettagliate riguardo all'evoluzione e composizione della flotta di automobili in Svizzera. Vengono trattati con particolare attenzione l'evoluzione delle emissioni medie di CO_2 e i consumi di carburante. Le carte cantonali e comunali mostrano le disparità a livello regionale.

Elaborazione dei dati

L'USTRA e l'Ufficio federale di statistica (UST) mettono a disposizione i dati annuali relativi a tutte le automobili registrate in Svizzera in un particolare giorno di riferimento e i dati sulle immatricolazioni di nuovi veicoli dal 2005 al 2012. I dati derivano dal sistema automatizzato d'informazione sui veicoli a motore (MOFIS) nel quale confluiscono tutte le immatricolazioni di veicoli effettuate dagli uffici cantonali del traffico. Le informazioni relative ai dati di immatricolazione vengono collegate, mediante il numero di approvazione del tipo e il codice del cambio, ai dati di omologazione (TARGA) del Servizio di omologazione. I dati TARGA contengono informazioni dettagliate sui parametri tecnici per ogni tipo di veicolo approvato in Svizzera. Poiché i dati TARGA dettagliati sono a nostra disposizione solo a partire dal 1996, abbiamo dovuto eliminare i dati sui veicoli immessi sul mercato prima di tale data.

Le informazioni MOFIS disponibili e i parametri tecnici TARGA consentono di calcolare per ogni veicolo la categoria di etichetta energia e le imposte cantonali annuali di circolazione. Inoltre, per i veicoli immatricolati in un cantone che ha adottato una riforma ecologica dell'imposta di circolazione è possibile assegnare ad ogni autoveicolo un bonus o un malus. Per motivi di protezione dei dati la banca dati a nostra disposizione non contiene informazioni dettagliate sui proprietari dei veicoli. Sulla base dei codici postali dei comuni di residenza dei proprietari dei veicoli è stato comunque possibile inserire nella banca dati variabili socio-economiche e geografiche a livello comunale.

Da notare, che durante la preparazione della banca dati finale che si basa sulla combinazione di diverse banche dati, non è sempre stato possibile collegare i dati per tutti i veicoli. Qualche osservazione è quindi andata persa. Diversi test statistici confermano comunque che le perdite di dati non sono sistematiche e che i dati rimangono rappresentativi. La figura 1 mostra il numero di veicoli della flotta complessiva disponibile per anno.

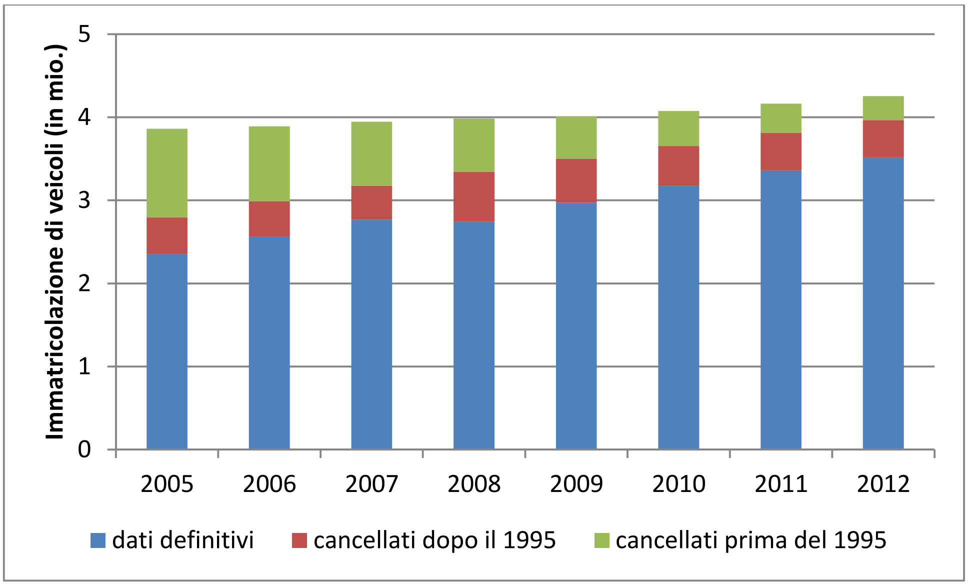

Figura 15: quota di veicoli disponibili dal 2005 al 2012

Ad esempio, in Svizzera secondo la rilevazione del 2012 erano registrati 4,255 milioni di automobili. Per l'83 per cento di esse è stato possibile ottenere tutte le informazioni necessarie per la nostra analisi.

Statistiche descrittive della flotta di automobili in Svizzera

La seconda parte del modulo 1 analizza lo sviluppo del parco veicoli della Svizzera tra il 2005 e il 2012 e per il 2012 vengono illustrate le differenze cantonali nella composizione della flotta. In questa analisi sono state preparate delle carte della Svizzera con le quali è possibile osservare le differenze regionali della composizione della flotta di automobili a seconda di alcune caratteristiche topografiche o di reddito medio.

Dal 2005 al 2012, la quota di veicoli diesel è salita dal 13,9 al 23,6 per cento a scapito della quota di veicoli a benzina. La percentuale di veicoli ibridi ed elettrici è rimasta molto bassa. Nel 2012 i veicoli ibridi rappresentavano lo 0,77 per cento del totale delle automobili mentre le auto elettriche erano 0,03 per cento. Nel periodo di analisi, il peso a vuoto e la cilindrata delle automobili non hanno subito particolari variazioni nel tempo, mentre la potenza (cavalli vapore) è aumentata ed il consumo di carburante e le emissioni di CO_2 sono diminuiti (cfr. tabella 1). Le indicazioni sul consumo di carburante e sulle emissioni di CO_2

corrispondono, secondo il nuovo ciclo di guida europeo per automobili (New European Driving Cycle, NEDC), ai valori misurati sui rulli. I valori effettivi relativi al consumo e alle emissioni dipendono dal comportamento di guida e dalle impostazioni del veicolo e possono quindi differire dalle misurazioni di consumo NEDC[22].

Tabella 7: sviluppo delle differenti caratteristiche della flotta di automobili dal 2005 al 2012 (set di dati CEPE)

Anno	Peso a vuoto kg	Cilindrata ccm	Potenza kW	CO_2 g/km	Consumo l/100km benzina equivalenti	Consumo (benzina) l/100km benzina	Consumo (diesel) l/100km diesel
2005	1'484	1'964	97	204	8.5	8.7	6.9
2006	1'473	1'962	98	202	8.4	8.6	6.9
2007	1'474	1'964	99	200	8.4	8.5	6.9
2008	1'473	1'956	100	196	8.2	8.4	6.8
2009	1'428	1'952	101	194	8.1	8.3	6.8
2010	1'436	1'942	101	191	8.0	8.2	6.7
2011	1'443	1'929	102	189	7.9	8.1	6.7
2012	1'450	1'916	103	185	7.8	8.0	6.6

La figura 2 mostra la ripartizione a livello cantonale delle emissioni medie di CO_2 della flotta di veicoli in grammi per chilometro. La carta mostra come nei cantoni della Svizzera tedesca vengano utilizzati veicoli con emissioni più elevate rispetto alla Svizzera francese e italiana.

[22] http://www.transportenvironment.org/sites/te/files/publications/TE_Mind_the_Gap_2015_FINAL.pdf

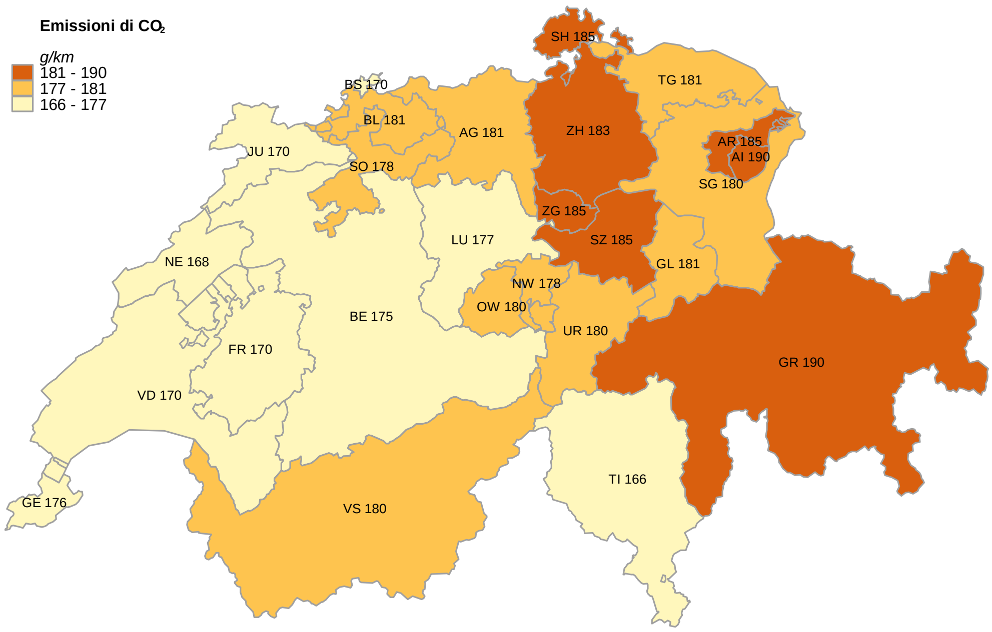

Figura 16: emissioni di CO_2 del parco veicoli a livello cantonale nel 2012

Se si osservano i valori medi di consumo di carburante a livello topografico (cfr. fig. 3) si vede come i veicoli registrati in comuni di montagna (sopra i 706 m.s. l. m.) siano generalmente caratterizzati da un consumo più elevato di carburante rispetto ai veicoli registrati in pianura[23].

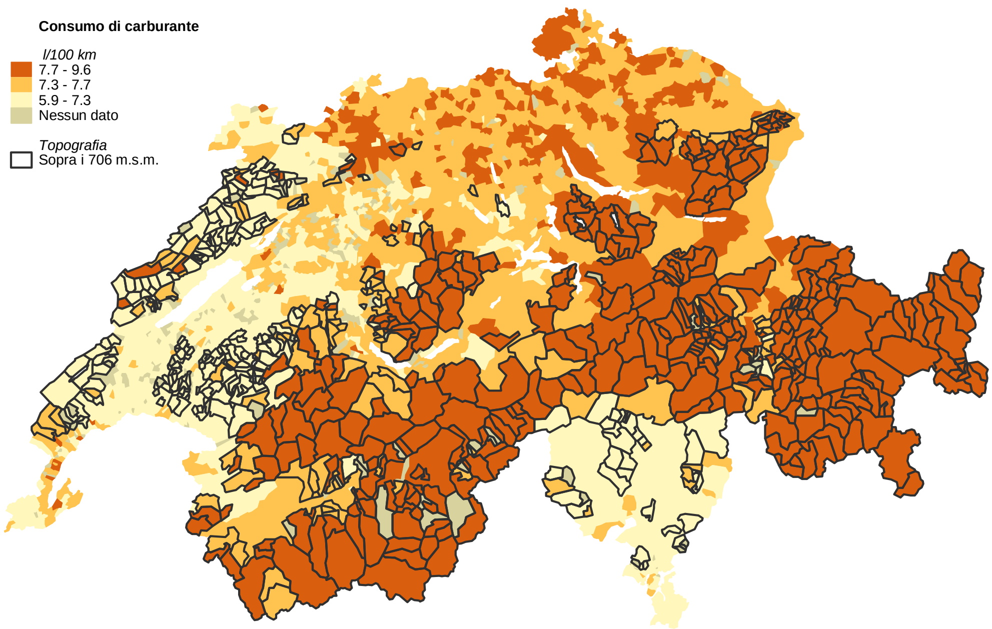

Figura 17: raffigurazione del consumo di carburante della flotta di veicoli 2012 (zone di montagna in evidenza).

[23] La figura 3 rappresenta i valori di consumo medi dei veicoli in litri per 100 chilometri. Il consumo assoluto di carburante non è misurabile con i dati disponibili poiché dipende dal comportamento di guida e dai chilometri percorsi.

L'analisi della suddivisione regionale dei tipi di veicoli mostra (figura 4a) come la quota di fuoristrada (SUV) sia più elevata nelle regioni di montagna. Se invece si analizza il consumo di carburante dei SUV (cfr. fig. 4b) si vede che i fuoristrada utilizzati in particolare nel nord della Svizzera consumano in media più carburante. Da ultimo, si può notare come nelle regioni di montagna si tenda a utilizzare SUV con consumi più ridotti.

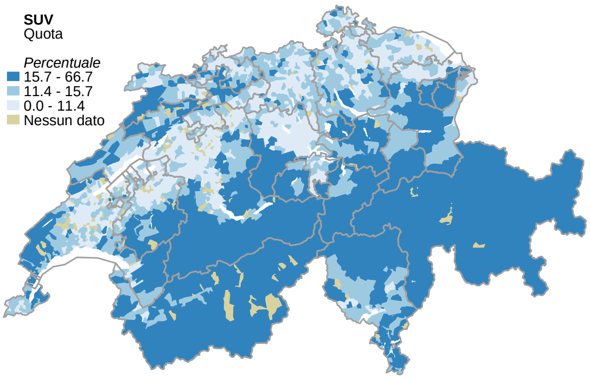

Figura 18a: suddivisione dei SUV 2012

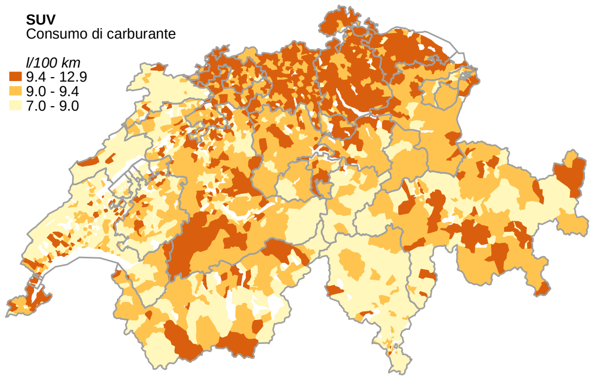

Figura 4b: consumo di carburante dei SUV 2012

Ulteriori analisi e rappresentazioni grafiche sono disponibili nel rapporto relativo al modulo 1.

Modulo 2: Effetti della riforma ecologica dell'imposta sui veicoli

In generale, in Svizzera l'imposta annuale di circolazione dei veicoli è disciplinata a livello cantonale e si basa, a seconda del cantone, su un parametro specifico del veicolo come ad esempio il peso, la cilindrata o la potenza. Negli ultimi dieci anni, molti cantoni hanno attuato una riforma ecologica di questa imposta. In questi cantoni, l'imposta annuale di circolazione è stata ridotta (bonus) per le automobili molto efficienti e/o contraddistinte da un basso livello di emissioni di CO_2 e/o aumentata (malus) per le automobili inefficienti e caratterizzate da elevate emissioni di CO_2. Un bonus, o rispettivamente un malus, porta ad una modifica del prezzo relativo di un veicolo e rende più attrattive le automobili efficienti rispetto a quelle inefficienti. Da un punto di vista economico, l'introduzione di un sistema di tassazione caratterizzato da bonus e malus rappresenta una soluzione interessante. Infatti, questo sistema incentiva l'acquisto di veicoli nuovi ed ecologici e diminuisce l'attrattiva dei veicoli inefficienti. Inoltre, da un di vista della politica finanziaria, tale sistema porta ad un bilancio statale più equilibrato rispetto a una soluzione che prevede solo l'introduzione di un bonus. La tabella 2 mostra quali cantoni hanno introdotto nell'ambito dell'imposta di circolazione un bonus e/o un malus nel periodo considerato in questo progetto che va dal 2005 al 2011. Dopo il 2011 anche altri cantoni hanno attuato una riforma ecologica dell'imposta di circolazione [24]. Inoltre, in alcuni cantoni si è iniziato a pensare all'introduzione di un'imposta annuale di registrazione dei veicoli basata esclusivamente sulle emissioni di CO_2 e non più sul peso del veicolo[25]. Da un punto di vista economico, un'imposta basata sulle emissioni di CO_2 è interessante poiché considera, almeno in parte , i costi ambientali determinati dall'utilizzo di un veicolo.

Come mostra la tabella 2, le riduzioni dell'imposta di circolazione si basano sulla categoria dell'etichetta energia (in verde), su un valore limite per le emissioni di CO_2 (in arancione) o su una combinazione dei due elementi (in blu). Per ridurre gli effetti di trascinamento[26], le riduzioni dell'imposta si applicano solo alle prime immatricolazioni e, nella maggior parte dei Cantoni, solo per due o tre anni. I rincari dell'imposta (malus) si basano invece sull'etichetta energia o su un valore limite di emissioni CO_2. Nel Canton Obvaldo, il malus si applica sia alle automobili nuove che a quelle già immatricolate. Negli altri cantoni, il malus si applica solo alle automobili immatricolate per la prima volta. La tabella mostra inoltre come nel 2011 non tutti i Cantoni abbiano attuato una riforma ecologica della propria imposta sui veicoli. Inoltre, spesso è stato introdotto solo un bonus senza un corrispondente malus.

Qui di seguito analizzeremo in che modo la riforma ecologica dell'imposta di circolazione dei veicoli ha avuto un effetto sull'immatricolazione di automobili nuove. Oggetto dell'analisi sono le automobili a benzina o diesel senza motore ibrido. Oltre al sistema di incentivazione presentato sopra, alcuni cantoni applicano riduzioni speciali dell'imposta di circolazione per automobili che utilizzano carburanti o motori alternativi (veicoli ibridi, a gas o elettrici). Questi ultimi non sono tuttavia oggetto del presente studio.

[24] I Cantoni di Basilea Campagna (BL), Basilea Città (BS), Berna (BE), Glarona (GL) e Zurigo (ZH).
[25] Un sistema simile è stato introdotto nel Canton Neuchâtel (NE) nel 2014.
[26] L'effetto di trascinamento si verifica allorquando un acquirente avrebbe comunque acquistato un veicolo efficiente anche senza un bonus.

Tabella 8: sistema di incentivazione cantonale per tutti i tipi di carburante dal 2005 al 2011

Cantone		Anno di adozione	Sistema di incentivazione
Argovia	AG	nessuno	
Appenzello Interno	AI	nessuno	
Appenzello Esterno	AR	2011	Bonus del 50% se CO_2 ≤130g/km
Berna	BE	nessuno	
Basilea Campagna	BL	nessuno	
Basilea Città	BS	nessuno	
Friburgo	FR	2011	Bonus del 100% se etichetta A; aumento dell'imposta del 2,2% se D, E, F, G o nessuna etichetta
Ginevra	GE	2010	Bonus del 50% Bonus se CO_2 ≤120g; malus del 50% Malus se CO_2 >200g
Glarona	GL	nessuno	
Grigioni	GR	2009	2009: bonus dell'80% se CO_2 ≤140g e PM10≤0,01g; bonus del 60% se CO_2 ≤160g e PM10≤0,01g; 2011: bonus dell'80% se CO_2 ≤120g e PM10≤0,01g; bonus del 60% se CO_2 ≤140g e PM10≤0,01g
Giura	JU	nessuno	
Lucerna	LU	nessuno	
Neuchâtel	NE	nessuno	
Nidvaldo	NW	2009	Bonus del 100% (per i primi 3 anni) se etichetta A
Obvaldo	OW	2009	Bonus del 100% (per i primi tre anni) se etichetta A; bonus del 50% (per i primi due anni) se etichetta B; malus di 60.- se etichetta G o nessuna etichetta
San Gallo	SG	2009	Bonus del 100% se etichetta A e CO_2 ≤130g (per i primi 3 anni)
Sciaffusa	SH	nessuno	
Soletta	SO	nessuno	
Svitto	SZ	nessuno	
Turgovia	TG	2011	Bonus del 50% se etichetta A (max. 5 anni); bonus del 25% se etichetta B (max. 5 anni); malus del 50% se etichetta F o G
Ticino	TI	2009	Bonus del 50% se etichetta A e CO_2 ≤140g (+filtro); malus del 20% se etichetta F; malus del 50% se etichetta G
Vaud	VD	2005	Bonus del 50% se CO_2 ≤120g
Vallese	VS	2010	Bonus del 50% se etichetta A e CO_2 ≤130g
Uri	UR	nessuno	
Zugo	ZG	nessuno	
Zurigo	ZH	nessuno	

Per l'analisi vengono utilizzate le informazioni riguardanti le nuove immatricolazioni di veicoli in Svizzera per il periodo che va dal 2005 al 2011. Sfruttando le differenze cantonali e temporali nell'introduzione dell'imposta annuale di circolazione con bonus e/o malus è possibile realizzare uno studio sugli effetti di tale riforma sulla quota di nuove automobili efficienti. Da un punto di vista metodologico, i cantoni che applicano delle misure a sostegno dei veicoli efficienti e poco inquinanti sono considerati il gruppo sottoposto a trattamento e i cantoni che non applicano queste misure costituiscono il gruppo di controllo. In econometria, un simile approccio è detto «differenza nella differenza» (in inglese: difference-in-differences, DiD). L'approccio DiD è un metodo ampiamente utilizzato per la valutazione degli effetti di politiche pubbliche. Questo metodo permette di misurare gli effetti di un "trattamento", nel nostro caso l'introduzione di un incentivo finanziario per promuovere l'adozione di veicoli efficienti, confrontando le variazioni intervenute nel tempo della variabile di riferimento, in questo caso la quota di veicoli efficienti, di due gruppi, quello sottoposto al trattamento e quello di controllo. Da un punto di vista metodologico, per poter identificare un rapporto di causalità tra l'introduzione di una misura politica e la variabile di riferimento, è necessario che due condizioni siano soddisfatte. Innanzitutto va verificato che l'introduzione della misura in un cantone sia esogena, ossia non sia influenzata da effetti che il nostro modello non può controllare. Inoltre, prima dell'introduzione del sistema bonus/malus l'evoluzione temporale della variabile di riferimento, in questo caso la quota di veicoli efficienti, deve essere simile nei due gruppi (gruppo sottoposto a trattamento e gruppo di controllo). In caso contrario non è possibile stabilire in modo chiaro se gli effetti rilevati derivano effettivamente dall'introduzione del sistema bonus/malus oppure da altri fattori. Nell'analisi econometrica svolta nell'ambito di questo progetto abbiamo considerato come variabile di riferimento la quota di automobili efficienti e poco inquinanti a livello comunale.

Mediante procedure econometriche viene confrontata l'evoluzione temporale, sia prima che dopo l'introduzione delle misure di politica, della quota di veicoli di categoria energetica A nei comuni di cantoni che hanno introdotto un bonus e/o un malus, con l'evoluzione della quota di questi veicoli nei comuni di cantoni di controllo. I calcoli econometrici vengono poi ulteriormente raffinati in modo da identificare solo l'impatto dell'introduzione di un sistema bonus/malus sullo sviluppo della quota di veicoli efficienti e poco inquinanti.

Per verificare la solidità dei risultati ottenuti è stato utilizzato un secondo approccio. Quest'ultimo si basa sulla stima di un modello aggiuntivo nel quale come variabile dipendente del modello econometrico viene utilizzata la quota di ogni tipo di veicolo immatricolato in una zona (regione)[27]. Mediante tale modello alternativo è stato possibile calcolare per ogni tipo di veicolo l'imposta di circolazione specifica e gli eventuali bonus o malus e quindi stimare l'effetto della riforma dell'imposta sul numero di ogni tipo di veicoli immatricolati. Come si spiegherà più avanti, per alcuni problemi econometrici non abbiamo potuto svolgere l'analisi per tutti i cantoni che hanno introdotto un sistema bonus/malus.

Prima di analizzare i risultati delle analisi econometriche si è deciso di confrontare l'andamento nel tempo della quota di veicoli che soddisfano i criteri per l' ottenimento di un bonus in un cantone sottoposto a trattamento rispetto all'andamento della stessa variabile in un cantone del gruppo di controllo. Nella tabella 3 sono state calcolate due differenze. La prima si riferisce alla differenza della quota di veicoli efficienti di categoria A prima e dopo l'introduzione del bonus nel canton Obvaldo. La seconda differenza si riferisce alla differenza della quota di veicoli efficienti prima e dopo la riforma del canton Obvaldo per i cantoni di controllo.[28] La quota di veicoli di categoria A nel Canton Obvaldo prima dell'introduzione delle misure corrispondeva al 17,19 per cento ed era quindi inferiore di 1,66 punti percentuali a quella del gruppo di controllo. Nell'anno successivo all'introduzione delle misure, la quota di nuove immatricolazioni per la categoria A nel Canton Obvaldo era superiore di due punti percentuali rispetto al gruppo di controllo. L'aumento delle immatricolazioni di veicoli di categoria A per questo periodo corrisponde quindi a 3,66 punti percentuali.

Il passo successivo è stato quello di rappresentare in modo chiaro lo sviluppo della quota di veicoli interessati dalle misure mediante grafici. Nella figura 5 viene utilizzato come esempio lo sviluppo della quota di veicoli di categoria A nel Canton Friburgo e nei Cantoni di controllo per il periodo prima e dopo l'introduzione delle misure nel Canton Friburgo. I dati rappresentati nella figura mostrano come a seguito dell'introduzione del bonus per i veicoli di categoria A la quota di questi veicoli nel Canton Friburgo sia aumentata in maniera più significativa rispetto alla quota nei cantoni che fanno parte del gruppo di controllo.

[27] L'analisi è stata effettuata a livello regionale poiché la quota di immatricolazioni di un singolo modello di veicolo a livello comunale era generalmente molto ridotta.

[28] Per ulteriori rappresentazioni e statistiche, si veda il modulo 2 del rapporto.

Tabella 9: calcolo DiD, bonus per i veicoli di categoria A nel Canton Obvaldo

	Canton Obvaldo (OW)		
	2008	2009	Differenza
Gruppo di controllo	18.85%	24.54%	5.69%
OW	17.19%	26.54%	9.35%
Differenza	-1.66%	2.00%	**3.66%**

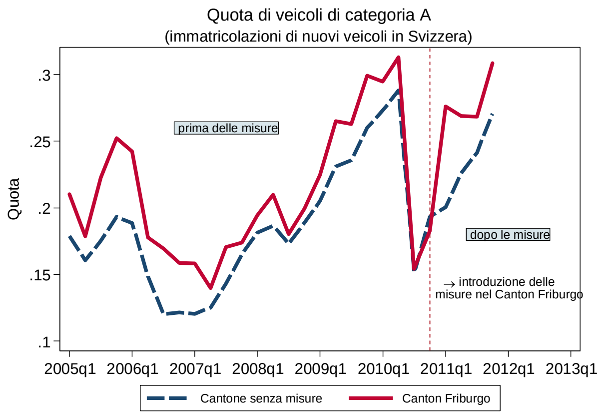

Figura 19: sviluppo della quota di veicoli di categoria A nel Canton Friburgo rispetto al gruppo di controllo

I risultati della tabella 3 e la figura 5 mostrano come lo sviluppo della quota dei veicoli di categoria A dopo l'introduzione delle misure a sostegno dell'acquisto di questi veicoli sia differente tra cantoni sottoposti a trattamento e i cantoni di controllo. Tuttavia, senza un'analisi econometrica che permette di controllare anche l'influsso di altre variabili non è possibile identificare in modo chiaro gli effetti dell'aumento o della riduzione dell'imposta di circolazione sulla quota di veicoli efficienti. Da notare, che i risultati dei test econometrici hanno consentito di effettuare le stime con il metodo DiD solo per i cantoni che applicano bonus basati sull'etichetta energia o sulle emissioni di CO_2. Per gli altri gruppi di cantoni sottoposti a trattamento, il risultati del test statistico riferito alla presenza di un trend parallelo prima dell'introduzione delle misure non hanno permesso l'utilizzo del metodo DiD.

I risultati principali delle stime econometriche, fra i quali anche i risultati ottenuti con la tecnica «matching» per paragonare solo comuni simili, mostrano come l'introduzione di una riduzione dell'imposta di circolazione per i veicoli con etichetta energia A porti ad un aumento statisticamente significativo di circa 2,1 punti percentuali della quota di questo tipo di veicoli. Per i cantoni che concedono una riduzione dell'imposta annuale di circolazione in base al livello di emissioni di CO2 e non in base all'etichetta energia, i risultati sono leggermente meno significativi. L'impatto è di circa 1,7 punti percentuali. Considerando che i veicoli con etichetta energia A e i veicoli con emissioni di CO_2 inferiori o uguali a 130 g/km costituiscono circa il 20 per cento della flotta complessiva, un aumento di quasi due punti percentuali porta a un aumento relativo della quota dei veicoli efficienti di circa il 10 per cento. Questi risultati sono confermati dai risultati ottenuti con la stima econometrica del modello relativo all'impatto delle misure politiche sul singolo tipo di veicolo.

Da notare, come gli effetti stimati dell'introduzione di una riduzione dell'imposta per veicoli efficienti siano relativamente bassi. Bisogna comunque considerare come in relazione al costo complessivo di un'automobile, la riduzione dell'imposta sui veicoli sia piuttosto ridotta. La riduzione media dell'imposta ammonta a circa 240 franchi all'anno. Inoltre, nella maggior parte dei cantoni, questa riduzione è accordata per un massimo di tre anni. Un ulteriore motivo che potrebbe spiegare la presenza di deboli effetti è la possibile mancanza d'informazione sulla presenza di bonus e malus al momento dell'acquisto di un veicolo.

Dato che non sono disponibili informazioni sui chilometri percorsi dai singoli veicoli, non è stato possibile stimare l'effetto dell'aumento della quota di veicoli efficienti sull'effettiva riduzione di emissioni di CO_2. Da notare, che cambiare veicolo scegliendo un veicolo più efficiente potrebbe generare il cosiddetto «effetto rebound», vale a dire una situazione dove il veicolo più efficiente che emette meno CO_2 per chilometro viene utilizzato per percorrere più chilometri. In questo caso, l'adozione di un veicolo efficiente non porta alla riduzione del CO_2 e si potrebbe addirittura verificare un aumento delle emissioni.

L'introduzione di un sistema di bonus o di bonus/malus ha effetti anche sulle entrate cantonali derivanti dall'imposta sui veicoli. Nei Cantoni che hanno introdotto solo un bonus le entrate diminuiscono. Tale perdita può essere compensata mediante l'introduzione di un malus. I dati disponibili permettono di calcolare solo in modo approssimativo l'effetto dell'introduzione di bonus e bonus/malus sulle entrate cantonali. Può essere interessante a questo punto stimare in modo approssimativo il costo per la riduzione di emissioni di CO2 ottenuta tramite l'introduzione di un bonus. Supponiamo ad esempio che un cantone svizzero rappresentativo introduca un sistema di bonus (senza malus) che permette al proprietario di un veicolo immatricolato per la prima volta con emissioni di CO_2 inferiori o uguali a 130 g/km di ottenere una riduzione dell'imposta del 50 per cento per tre anni. Ipotizzando una percorrenza media annuale del veicolo di 13 800 km e una durata di vita media del veicolo di dodici anni si ottiene un costo di riduzione delle emissioni di circa 248 CHF/t CO_2[29]. Questo valore è molto elevato e può essere spiegato dal fatto che la riduzione dell'imposta viene applicata a tutte le immatricolazioni di nuovi veicoli che emettono al massimo 130g CO_2/km, anche ai veicoli che anche senza l'introduzione di un bonus sarebbe stati acquistati ed immatricolati. Questa analisi mostra chiaramente come l'introduzione di un bonus e non di un bonus combinato con un malus determini effetti negativi sul bilancio dello Stato e produca costi molti elevati per la riduzione di una tonnellata di CO_2. Dal punto di vista della politica finanziaria e climatica è quindi importante raccomandare l'introduzione di un sistema che comprenda sia un malus che un bonus. Cosi facendo la riduzione delle imposte provenienti dai veicoli efficienti verrebbe compensata dalle maggiori entrate dovute all'aumento delle imposte per i veicoli inefficienti e le entrate derivanti dalle imposte rimarrebbero equilibrate.

Modulo 3: effetti delle prescrizione sulle emissioni di CO_2 per le automobili

Nel 2011, il Consiglio federale e il Parlamento hanno deciso l'introduzione di prescrizioni relative alle emissioni di CO_2 per gli importatori svizzeri di automobili, analoghe alle prescrizioni introdotte nell'UE per i produttori. Tali prescrizioni si basano sulla legge sul CO_2 e sono entrate in vigore in Svizzera il 1° luglio 2012. Le prescrizioni stabiliscono che gli importatori di nuove automobili devono raggiungere, entro il 2015, un determinato obiettivo relativo alle emissioni di CO_2 che dipende dal peso medio della flotta. Gli importatori sono tenuti a ridurre in media a 130 gr/km le emissioni di CO2 delle automobili immatricolate per la prima volta in Svizzera. [30] Hanno inoltre la possibilità di formare raggruppamenti per collaborare al raggiungimento dell'obiettivo. Il mancato raggiungimento comporta una sanzione per ogni grammo di CO_2 in eccesso. Il periodo 2012-2014 rappresentava una fase transitoria durante la quale solo una determinata parte della flotta di un importatore (o di un raggruppamento) ha dovuto sottostare agli obiettivi stabiliti (2012: 65%, 2013: 75%, 2014: 80%). Dal 2015 l'obiettivo vale per l'intera flotta.

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[29] Occorre sottolineare che i calcoli sono stati effettuati utilizzando i valori di consumo ufficiali NECD che possono differire dai reali valori di consumo.

[30] Vengono considerate le emissioni di CO_2 di ogni singolo veicolo misurate mediante il Nuovo ciclo di guida europeo per automobili (NEDC). Non è stato tenuto in considerazione il fatto che i valori di consumo reali potrebbero differire dai valori misurati (http://www.transportenvironment.org/sites/te/files/publications/TE_Mind_the_Gap_2015_FINAL.pdf).

Nel modulo 3 del presente rapporto è stato esaminato in modo preliminare l'impatto delle prescrizioni sulla riduzione delle emissioni di CO_2 delle nuove automobili in Svizzera. Va sottolineato che si tratta di un analisi preliminare ed esplorativa poiché non sono disponibili i dati necessari per poter effettuare una solida analisi empirica ed econometrica:

- per il modulo 3 sono disponibili i dati delle immatricolazioni di nuovi veicoli fino al 2014. Il periodo trascorso dall'introduzione delle misure è quindi piuttosto ridotto e non si possono valutare gli effetti complessivi poiché le misure hanno un impatto che si protrae nel tempo.
- Nelle banche dati disponibili mancano le informazioni relative agli importatori di veicoli e ai raggruppamenti costituiti. Non sono quindi a disposizione informazioni precise sui responsabili del raggiungimento degli obiettivi specifici. La presente analisi empirica è stata quindi svolta a livello di marche di auto. Si tratta di un'ipotesi coraggiosa e motivata dal carattere esplorativo dell'analisi.
- Nello stesso periodo dell'analisi nell'UE sono state introdotte prescrizioni analoghe. Poiché non è disponibile un gruppo di controllo, non è quindi stato possibile, come nel modulo 2, utilizzare un approccio DiD o utilizzare altri metodi adatti alla valutazione empirica di politiche pubbliche. È stato quindi utilizzato in modo esplorativo un modello di regressione classico con il quale è stata paragonata a livello svizzero la riduzione delle emissioni di CO_2 prima e dopo l'introduzione delle prescrizioni per gli importatori. In tal modo è stato possibile verificare la presenza di una correlazione tra la riduzione del CO_2 e l'introduzione delle prescrizioni. Purtroppo con questo metodo non si è potuto stabilire la presenza di un rapporto di causalità. Infatti, un impatto sulla riduzione di emissioni CO_2 può derivare anche da altri fattori che non sono considerati nel modello econometrico.

Come mostra la figura 6, dal 2005 le emissioni medie di CO_2 delle nuove automobili in Svizzera è diminuito in maniera costante. Mentre nell'UE l'obiettivo di 130 g/km è stato superato già nel 2013, in Svizzera sarà necessario un impegno ancora maggiore per raggiungerlo entro la fine del 2015.

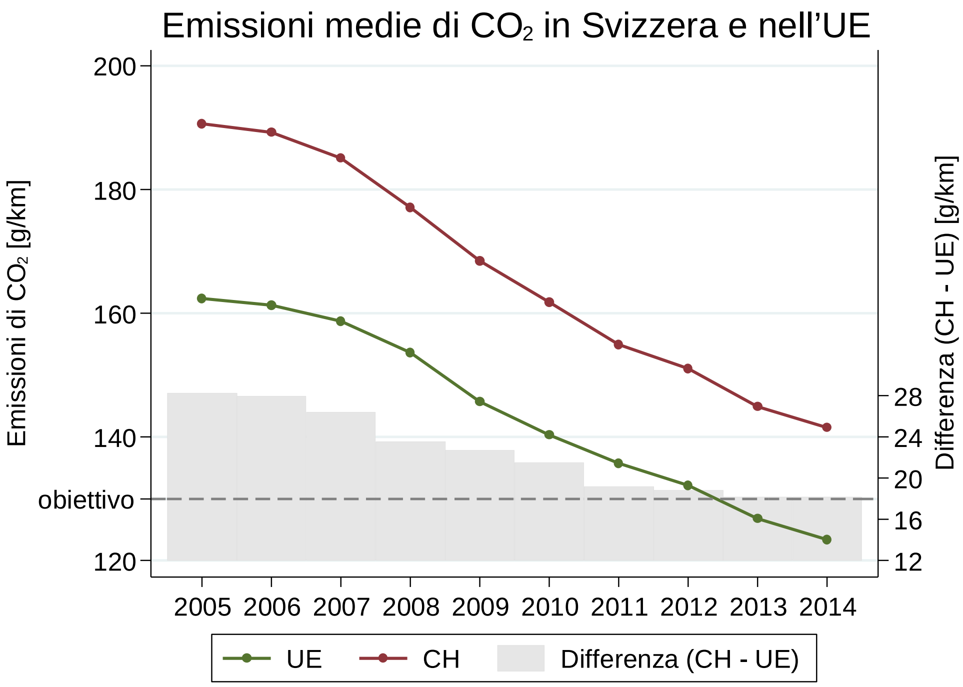

Figura 20: emissioni medie di CO_2 delle nuove automobili in Svizzera e nell'UE (fonte: calcoli propri, USTRA, European Environment Agency)

Come già anticipato, utilizzando i dati relativi alle nuove immatricolazioni per il periodo cha va dal 2005 al 2014, è stato possibile stimare un modello di regressione classica. Con la stima di questo modello si è cercato di stabilire se le prescrizioni per gli importatori introdotte nel 2012 hanno avuto un impatto sul tasso di riduzione delle emissioni CO_2 . Questo tasso di riduzione può essere osservato nella figura 6. Per verificare i risultati empirici, il modello è stato stimato in diversi modi. Un primo approccio è stato quello di considerare nell'analisi empirica solo il periodo 2010-2014. In questo modo si sono volute considerare eventuali fluttuazioni dovute a fattori non considerati nel modello. Nel secondo approccio sono stati paragonati i coefficienti stimati per il periodo precedente all'introduzione delle prescrizioni per gli importatori (2005 – 2011) con i coefficienti stimati per il periodo successivo all'introduzione delle prescrizioni (2013 – 2014).

Tutti i risultati dei modelli econometrici indicano come dopo l'introduzione delle prescrizioni vi sia stato un aumento del tasso di riduzione delle emissioni medie di CO_2 . Questo aumento si è poi ridotto raggiungendo dei livelli inferiori rispetto al periodo antecedente l'introduzione delle prescrizioni. I risultati vengono presentati nella figura 7.

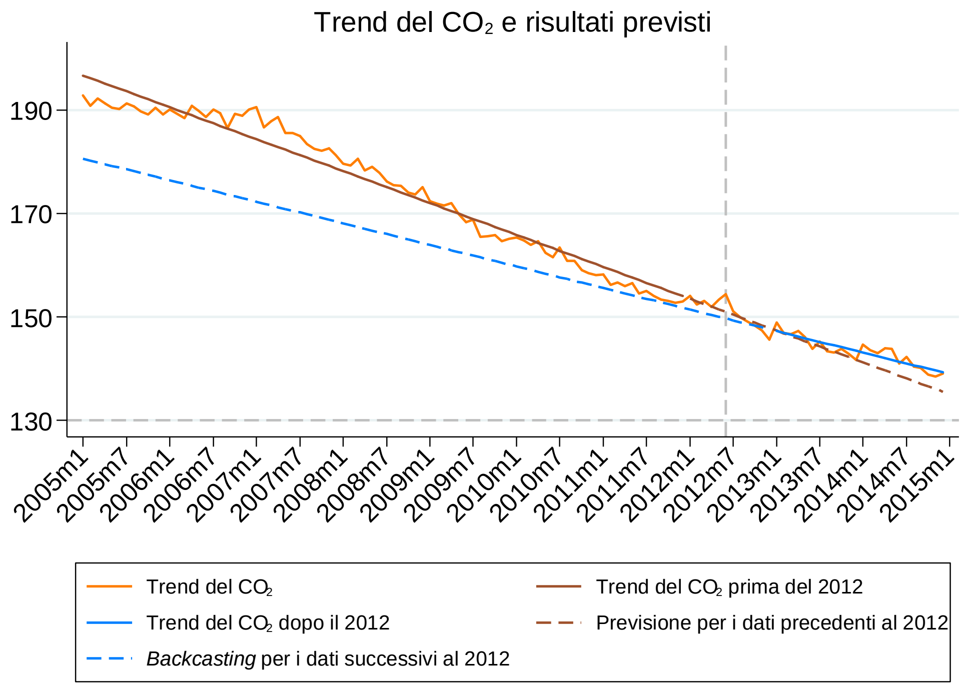

Figura 21: andamento della linea di regressione dall'introduzione delle prescrizioni sulle emissioni di CO_2

Questi risultati sono a prima vista sorprendenti. L'effetto atteso dell'introduzione delle prescrizioni era un aumento del tasso di riduzione delle emissioni medie di CO_2. Una possibile interpretazione dei risultati è che subito dopo l'introduzione delle prescrizioni sulle emissioni, gli importatori si siano impegnati a fondo per ridurre le emissioni di CO_2 della propria flotta. In seguito, hanno adottato una strategia per raggiungere gli obiettivi minimi di riduzione imposti dallo stato. Un altro motivo può essere che nella fase transitoria solo una determinata parte della flotta doveva raggiungere l'obiettivo definito dalle prescrizioni. Ad esempio, nel 2014 solo l'80 per cento della flotta di ogni importatore doveva rispettare l'obiettivo di emissioni.

La diminuzione del tasso di riduzione delle emissioni CO_2 osservata dopo l'introduzione delle prescrizioni per gli importatori non deve indurre a concludere che senza prescrizioni le emissioni di CO_2 sarebbero diminuite maggiormente. Senza un gruppo di controllo comparabile e senza i dati sulle automobili importate dai singoli importatori non è possibile stimare con precisione l'impatto dell'introduzione delle prescrizioni. Come già menzionato in precedenza, l'impatto dell'introduzione delle prescrizioni sul tasso di riduzione delle emissioni CO_2 potrà essere valutato in maniera un po' più precisa quando saranno disponibili i dati per il 2015. In tale anno tutta la flotta dovrà raggiungere in media i valori limite imposti dalle prescrizioni. La presente analisi è quindi esplorativa e dovrà essere approfondita dopo la pubblicazione dei nuovi dati.

Module 1:

Descriptive Statistics

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List of Abbreviations

Abbreviation	Description
ACEA	European Automobile Manufacturers' Association
CC	Compact
CR	Convertible or Roadster
CS	Sports Coupé
DETEC	Department of the Environment, Transport, Energy and Communications
EEA	European Energy Agency
EEL	Energy Efficiency Label
FE	Fuel Economy
FEDRO	Swiss Federal Roads Office
FOEN	Swiss Federal Office for the Environment
FSO	Federal Statistical Office
FS	Full-size
FR	Canton Fribourg
FTA	Swiss Federal Tax Administration (FTA)
GE	Canton Genève
GL	Canton Glarus
GR	Canton Graubünden
JU	Canton Jura
LC	Luxury
LU	Canton Luzern
MC	Micro Car
MOFIS	Motorfahzeuginformationssystem - national vehicle information system
MS	Mid-size
MV	Multi-purpose Van
NE	Canton Neuchâtel
NW	Canton Nidwalden
OW	Canton Obwalden
SC	Subcompact
SG	Canton St. Gallen
SH	Canton Schaffhausen
SO	Canton Solothurn
SUV	Sport Utility Vehicle
SZ	Canton Schwyz
TARGA	Technische Angaben, Rauch, Geräusch und Abgas
TG	Canton Thurgau

TGN	Type approval number
TI	Canton Ticino
UR	Canton Uri
VD	Canton Vaud
VS	Canton Valais
ZG	Canton Zug
ZH	Canton Zürich

1. Introduction and Project Description

In 2012, 45 percent of the CO_2 emissions in Switzerland were emitted by the transport sector.[1] In the previous CO_2 Act (in place until December 31st 2012), Switzerland committed to reduce the CO_2 emission of fossil fuels in the transport sector by 8 percent until 2010, relative to 1990 levels.[2] [3] This target was missed by 22.6 percent (17.4 million compared to 14.2 million tons of CO_2; BAFU, 2013). The new CO_2 Act has been in place since January 1st 2013. It sets targets to reduce total CO_2 emissions in Switzerland by 20% by 2020, relative to 1990, while the CO_2 emissions of the transport sector shall not exceed 100% of the emission level in 1990 by 2015 and shall be reduced by 10% by 2020 (BAFU 2012).[4] [5]

In order to reduce the CO_2 emissions in the passenger car sector, energy policy instruments have been implemented at the federal and cantonal level. In 2011, the Federal Government decided to introduce a mandatory average CO_2 emissions standard for new passenger cars similar to the one adopted by the EU. Therefore Swiss car importers have to reduce the average CO_2 emissions of new cars registered to 130 g/km by 2015. This standard went into effect in July 2012 (BFE, 2011).[6]

Prior to this policy, which is based on regulation, the federal Swiss government has relied on enhanced fuel economy and CO_2 emissions information for new cars conveyed by a system of labels (in place since 2003), and on voluntary schemes.

At the cantonal level, some cantons have introduced a differentiated vehicle registration tax system to promote the purchase of fuel efficient cars. In Switzerland, car owners must pay an annual registration tax for their vehicle to be driven legally on Swiss roads. Some cantons give tax discounts for electric or hybrid vehicles, or have linked the tax with the vehicle's fuel efficiency and/or CO_2 emissions rate. For example, some cantons may offer a 100 % tax reduction for cars that emit less than 130 g CO_2/km and have energy efficiency label A.

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1 These are CO_2 emissions which originate from the thermal use of fossil fuels.
2 In order to reach this target, the average of the years 2008 – 2012 is decisive.
3 SR 641.71: Bundesgesetz über die Reduktion der CO_2-Emissionen (CO_2-Gesetz) vom 8. Oktober 1999 (Stand 1. Mai 2012)
4 SR 641.71: Bundesgesetz über die Reduktion der CO_2-Emissionen (CO_2-Gesetz) vom 23. Dezember 2011 (Stand 1. Januar 2013), Art. 3 Abs. 1
5 SR 641.711: Verordnung über die Reduktion der CO_2-Emissionen vom 30. November 2012 (Stand 1. Januar 2014), Art. 3 Abs. 1 Bst. b
6 SR 641.71: Bundesgesetz über die Reduktion der CO_2-Emissionen (CO_2-Gesetz) vom 23. Dezember 2011 (Stand 1. Januar 2013), Art. 10 Abs. 1

In order to design and implement an effective energy policy, it is necessary to know if these policy measures and incentive schemes help to reduce CO_2 emissions. It is also important to determine if some of these policies are more effective than others.

The Swiss Federal Office for the Environment (FOEN) and the Swiss Federal Roads Office (FEDRO) commissioned the Center for Energy Policy and Economics (CEPE) at ETH Zürich to answer these questions in a research project with the ultimate goal of evaluating the effect of the different policy measures.

The research project is divided into three modules. In the first module – which will be presented in this report – we examine the characteristics of the fleet, present descriptive statistics, and look for possible associations between the characteristics of the cars on Swiss roads and topography and socioeconomic variables, including income. This module relies on univariate and bivariate descriptive statistics, and on maps. In module 2, we will assess the effect of differentiated cantonal vehicle registration taxes on purchasing behavior. Module 2 will rely on econometric models. In the module 3, we will assess the effect of the new CO_2 emission prescription introduced in July 2012.

Our first order of business is to acquire and prepare the data required for all three modules. We describe the data preparation procedures in this report. In this report we also study the characteristics of the Swiss vehicle passenger fleet, including its age distribution, weight, engine size, CO_2 emissions and fuel economy, and examine the relationship between some of these characteristics (for example, weight or engine size and fuel economy). We first look for trends over the 2005-2012 period, and then focus on the state of the Swiss car fleet in 2012. Maps are provided to study the geographical distribution of the fleet and its characteristics, and associations between such characteristics and the population socioeconomics. We use these maps to answer questions such as “Are heavier and less fuel efficient vehicles (such as SUVs) driven at higher altitudes?” and “Is the fleet’s fuel economy and the associated CO_2 emissions better or worse in wealthier communities?”

The remainder of this report on module 1 is organized as follows. Section 2 provides the policy background. Section 3 describes the construction of the dataset used for this report. Section 4 is the main part of this report, and contains descriptive statistics of the Swiss passenger car fleet. First we will provide a quick overview of trends at the national level, and then we will focus on the cantonal and regional level. In section 5 CO_2 emissions of new passenger car registrations in Switzerland - an excellent proxy for new car sales - will be compared with those in neighboring countries and in the European Union. Section 6 concludes.

2. Background

As of August 2012, about 4.3 million passenger vehicles are available to the population of Switzerland, which totals about 8 million (BFS, 2013b). The density of passenger vehicles, which in this report are defined as vehicles registered for personal use, with at most 9 passenger seats and weight not exceeding 3’500 kg, is, therefore, high in Switzerland, with variation across locales depending on the availability of public transportation, urban density, income, etc.

According the Swiss Micro Census of Mobility and Transport (BFS, 2013a), the average passenger vehicle is driven for about 12’000 km a year. Since the average CO_2 emissions rate is about 184 grams per km in 2012, this means that the average car emits 2.2 metric tons of CO_2 every year. Even when attention is restricted to new vehicles, as opposed to the entire fleet, the average CO_2 emissions of new passenger cars in Switzerland were 19 grams per kilometer higher than in the European Union – 151 g/km compared to 132 g/km in 2012 (EEA, 2013).

In 2011, the Swiss Government and Parliament decided to introduce mandatory CO_2 emission targets along the lines of the European Union. This measure requires car importers to reduce the CO_2 emissions of the Swiss new passenger car fleet to an average of 130 grams per kilometer by 2015. This policy was put in place in July 2012.

In addition to the federal policy, some cantons have attempted to influence the composition of the car fleet by implementing vehicle registration tax systems that reward cleaner and more fuel efficient vehicle. We summarize these policies below.

2.1. Policy measures

In order to reduce CO_2 emissions from passenger cars, different policy measures were introduced in Switzerland at the federal and cantonal level.

2.1.1. Measures at the federal level

The Federal Government has resorted to a variety of approaches in its policies aimed at influencing CO_2 emissions from passenger vehicles. Some of these policies rely on informational approaches, others on regulation, and others yet on voluntary initiatives.

Energy label for new passenger cars: In 2003, the Swiss government implemented an energy label which has to be displayed on every new passenger car for sale in Switzerland (BFE, 2003).[7] The energy label is an indirect measure and informs potential customers about different car characteristics and most important the fuel consumption and CO_2 emissions of the car. The cars are ranked in an energy efficiency rating from A (most efficient) to G (most inefficient). The rating is based on a combination of absolute fuel consumption (l/100km) and the fuel consumption per unit of curb weight. This measure allows larger but comparatively energy efficient vehicles (like e.g. family vans) to attain the best category.

Because of the energy efficiency improvements of new cars over the years the rating is adjusted periodically so that in the new due date only one seventh of the car models on the Swiss market reach category A.

Voluntary target agreement between DETEC and auto-schweiz: The association of Swiss car importers (auto-schweiz) and the Federal Department of the Environment, Transport, Energy and Communications (DETEC) agreed upon a reduction of fossil fuel consumption of new passenger cars in February 2002 (BFE, 2002). The goal was to reduce average fuel consumption from 8.4 liters per 100 kilometers (l/100 km) in 2000 to 6.4 l/100 km by 2008 – a 24% reduction. At an average of 7.14 l/100 km in 2008, this goal was missed by 12% (BFE, 2009).

CO_2 emission targets for new car importers: In order to reduce CO_2 emissions and fuel consumptions a mandatory CO_2 emissions target for new passenger cars was introduced in 2011. The average CO_2 emissions from new cars must be 130 grams per kilometer or less by 2015.[8] Every importer gets a specific fleet target which is based on the average curb weight of its new car sales. If the target is missed a sanction has to be paid (BFE, 2011). More about the emission target will be explained in module 3 of this project.

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7 SR 730.01: Energieverordnung vom 7. Dezember 1998 (Stand am 1. Januar 2014), Art. 11

8 see Footnote 6

SwissEnergy: Further indirect measures are supported by the governmental program SwissEnergy. These include, for example, promotions for energy efficient cars, technical car checks to improve energy efficiency or eco-driving.[9]

2.1.2. Measures at the cantonal level

Vehicle registration tax and feebate schemes: In Switzerland, every vehicle must be registered with the canton and an annual registration fee must be paid for it to be driven legally on Swiss roads. All of the 26 cantons in Switzerland are free to choose their registration tax system. This leads to a variety of tax bases and levels. Several cantons crafted their tax system to provide incentives for fuel efficient cars. For example, several cantons offer tax waivers for alternative fuels (e.g., electric or hybrid cars), or reduced registration fees for cars with a certain energy label or below a specified CO_2 emission threshold. The effect of these tax differentiations will be analyzed in module 2 of this project.

2.2. Existing Studies and Statistics

There are several official studies and statistics at the federal level which describe the Swiss car market and its characteristics. These studies describe trends in the car fleet and/or consumer behavior. We briefly describe some of these studies below.

2.2.1. Berichterstattung im Rahmen der Energieverordnung über die Absenkung des spezifischen Treibstoff-Normverbrauchs von Personenwagen

(Report in the framework of the Energy Ordinance about the reduction of the specific fuel consumption of passenger cars)

Annex 3.6 of the Energy Ordinance requires annual reports about the fuel economy of new cars sold in Switzerland. The association of Swiss car importers - auto-schweiz - is assigned to write these reports.[10] The most recent report was issued in August 2013 (BFE, 2013). Auto-schweiz uses actual new car sales data from importers and combines them with MOFIS data. Because some makes (e.g., Ferrari) are not covered by auto-schweiz members, and because some people simply go abroad to buy their cars, the new car sales figures in the auto-schweiz

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[9] For more Information: http://www.energieschweiz.ch/de-ch/mobilitaet.aspx
[10] SR 730.01: Energieverordnung vom 7. Dezember 1998 (Stand am 1. Oktober 2012)

reports slightly underestimated total sales and new car registrations. In the latest issue of the report, the 2013 one, auto-schweiz used also MOFIS data of non auto-schweiz members. With this method around 6 % of car registration could be added. However the results did not vary significantly.

The report gives information about the average fuel consumption, CO_2 emissions, curb weight and engine displacement and provide information about the seven fuel economy categories established by the Swiss energy label system. The statistics are also broken down by weight categories, engine displacement class and energy efficiency categories.[11]

2.2.2. Synthesebericht „Mobilität und Verkehr“

(Report „Mobility and Transport“)

The „Synthesebericht Mobilität und Verkehr“ gives a broad overview on the Swiss transport system. It is issued every third year as a report and every year as a pocket booklet by the Swiss Federal Statistical Office (FSO). It gives a good statistical overview about the transportation network, its usage, the social framework and the influence on the population and the environment. It covers passenger and freight transport on roads, railroad, waterways and aviation. The last publication was in August 2013 (BFS 2013b).

2.2.3. Statistics provided by the Swiss Federal Office of Statistics

The FSO in cooperation with the FEDRO publishes on its website information about new car registrations in Switzerland at the cantonal level on an annual and monthly basis. It also provides information on the existing stock of cars by canton, classifying them by engine size, propulsion, transmission and number of seats.

Furthermore the FOEN, the FEDRO and the Federal Office of Energy (SFOE) finance research projects which go into more detail of certain topics of interest such as electric cars, tank tourism or rebound effects.[12]

[11] The reports can be found on http://www.bfe.admin.ch/energieetikette/00886/index.html?lang=de&dossier_id=00959.

[12] For more information about these research projects please visit the websites of the Federal Offices.

2.3. Contribution of this report (module 1)

The abovementioned studies provide statistics at the aggregate federal level, or simply report the number of vehicles at the cantonal level. To study the fleet, its current and future emissions, and trends in the characteristics of cars, we must therefore draw on the original, disaggregate registration data.

Using the original, disaggregate registration data we

- examine trends in weight, emissions, engine size and shares of cars in the various energy efficiency classes;
- look at the geographic distribution of specific car characteristics;
- look for possible association between car characteristics and topography and income.

3. Methodology

This section explains how we compiled the data used in the remainder of the report, and how we checked their reliability and quality.

3.1. The Data

We use several datasets, which are explained in detail below.

3.1.1. Vehicle data

MOFIS Data

In Switzerland cars have to be registered with the cantonal road traffic licensing department and an annual vehicle registration tax must be paid to obtain a number plate and legally drive the vehicle on Swiss roads. All of the data in the different cantonal road traffic licensing departments are collected into a national vehicle information system (Motorfahzeug-informationssystem, MOFIS) which is operated by the FEDRO. The MOFIS dataset contains detailed information about the owner of the car and car itself. For our analysis, we received all car registrations documented in MOFIS from 2005 to 2012. These data were transmitted to us by FSO, stripped of all confidential information such as the name and full address of the owner. Only the zip code at the residence of the vehicle owner was retained to allow us to examine geographical patterns. All variables in the MOFIS data which are available for the project are listed in Appendix 1, Table 22.

TARGA Data

Besides the vehicle registration data, FEDRO provided CEPE with the TARGA dataset, the dataset with the type approval information. These data are collected by FEDRO from the general car importers. A car must receive approval by the FEDRO before it can be sold in Switzerland, and this approval, along with assorted information of the car, is documented in the TARGA dataset. TARGA data is more detailed than MOFIS, and so, when the registration data from MOFIS are merged with the TARGA information, we accord the information from the TARGA dataset priority over that from MOFIS. To illustrate, if, for example, MOFIS states that a specific engine size 3000 ccm, but TARGA reports the engine size of that make-model-year to be 2940 ccm, we trust the correct engine size to be that coming from the TARGA dataset.

The TARGA data were merged with the MOFIS data, as we explain below. The TARGA variables available for this project are listed in the appendix 1, Table 23.

3.1.2. Vehicle tax and Bonus schemes

In order to estimate the effect of the different vehicle registration taxes and their differentiation for fuel efficient and inefficient cars, CEPE collected data on all cantonal registration taxes for passenger cars from 2005 to 2012. Most cantons base their tax on either the engine-size or the total weight of the car, while only few cantons base it on horsepower (or their Kilowatt equivalent). Table 24 in appendix 1 gives an overview of the actual basis for tax calculations.

The differentiation of the vehicle registration tax started around 2004 when cantons began to give rebates for electric vehicles, hybrids or cars using alternative fuels such as natural gas. In 2005, Vaud was the first canton to link the registration fee to the CO_2 emissions of the car. Table 25 in appendix 1 gives an overview about the different tax differentiations based on the energy efficiency label, the CO_2 emissions or if the car is a hybrid.

3.1.3. Data at the municipal level

We collected data on socio-demographics at the municipality and canton level.[13] We began with the population structure for each municipality, which we obtained from the FSO online data library.[14] We obtained age, gender, nationality and household size. It should be noted that only gender and nationality (Swiss or foreigner) are available over the entire period 2005-2011. Information on the age of the municipal population can be found for 2010 and 2011. In addition, for these two years information about the nationality of the municipal population is provided in detail, listing all citizenships individually. Household size and composition data are only available for the year 2000.

Data about the political orientation of municipalities are gathered from the parliament elections that take place every four years, the last one being held in 2011. We use these data to construct a measure of the strength of the political parties at the municipal level.

An important economic variable is income. The Swiss Federal Tax Administration (FTA) pro-vides annual statistics on various income measures,[15] net income and taxable income of individuals by employment status and municipality. The dataset includes the number of taxpayers, net income, taxable income, tax revenue and various sorts of tax deductions summarized at the municipal level. Note that net income is defined as gross earnings less reduction costs and general deductions whereas taxable income is defined as gross earning less reduction costs, general deductions and social service taxes.[16] The most recent published set of income statistics is from 2009. In addition to the income variables, we have a dataset containing a census of enterprises at the municipal level with information on the size of enterprise, number of workplaces and full time equivalent employees. This census was done in 1995, 2001, 2005 and 2008 and is available online in the data library of FSO.

The stock of cars in any one place is likely related to the availability of transport networks.[17] For this purpose two datasets are helpful, both created by the Federal Office for Spatial Development (ARE) for their report "Erschliessung und Erreichbarkeit in der Schweiz mit dem öffentlichen Verkehr und dem motorisierten Individualverkehr." One dataset contains

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[13] We like to mention, that not all of the collected data will be used for the descriptive statistics in this report, but will be useful for the further analysis in the following modules.
[14] http://www.pxweb.bfs.admin.ch/dialog/statfile.asp?lang=1
[15] http://www.estv.admin.ch/dokumentation/00075/00076/index.html?lang=de
[16] http://www.steueramt.zh.ch/internet/finanzdirektion/ksta/de/steuererklaerung/glossar.html
[17] These data are collected for the 2nd module and are not used in this report.

information on the quality of public transport access in municipalities, whereas the other dataset stems from a sophisticated traffic model reporting average travel times from municipality centers to the nearest metropolitan area by public transport or motorized individual transport.[18]

Topography plays a key role in this report, and FSO and GEOSTAT offer detailed topography information at the national, cantonal and municipal level – the elevation above sea level being of special interest. Minimum, maximum, median and mean elevation values are provided by municipality, along with the elevation of the municipal center. The dataset is published annually. The most recent issue is the 2009 one.

In addition to the topographic variables, planning data can be used to group municipalities together when they have similar characteristics. The spatial planning datasets are published annually and are available online until 2013. From year to year minor changes in the variable compilation occur, which means that not all variables are observed for the entire period from 2005 to 2012. An overview of all collected socio-economic and topographic variables at the municipal level is found in appendix 1, Table 26 - Table 29.

3.2. Data merge, construction and reliability check

3.2.1. Data merge

Our starting point and main data source is the MOFIS dataset, which contains the vehicle registrations for all of Switzerland. This dataset is merged with the other datasets mentioned above. This is implemented through the following steps:

1. First, we merge MOFIS with the TARGA dataset, which contains detailed information about the vehicle. The merge is by type approval number (TGN) and transmissions (automatic or manual, number of gears) of the vehicle.
2. One problem with this merge is that it does not give 100% matches. TARGA data of sufficiently good quality and with complete TGN and transmissions information are available only for most of the cars of vintage 1995 and younger. Even cars that were registered after 1995 sometimes do not have a TGN because they were imported directly without specific approval.

[18] Source: Verkehrsmodellierung VM-UVEK (ARE), INFOPLAN-ARE, swisstopo

3. In some cases, several variants of the same make and model have the same TGN. They can be distinguished by the four-digit transmissions code. Unfortunately our MOFIS dataset only has a one-digit transmission code. We describe in the next subsection how we dealt with this particular problem.

4. To add the correct vehicle registration tax and/or rebate or fee linked with emissions or fuel economy, we wrote STATA code based on the information gathered from the cantons for each year.[19]

5. All the collected socio-economic data on municipality level have a so-called BFS-ID (Identification number created by FSO). Any given municipality has a single BFS-ID, but potentially multiple zip codes. Since the MOFIS records have the zip code at the residence of the car owner, we first linked the zip code to the appropriate BFS-ID, and then merged with the socio-economic information at the municipality level by BFS-ID.

3.2.2. Reliability check (Quality control)

MOFIS compiles the registration records from the cantons, and since these are entered by hand, typos and other mistakes can occur. We must therefore check the data to find and correct these mistakes. In checking the data, our goal is to make sure that the information about the date and place of registration of the vehicle, weight, engine size, fuel consumption and CO_2 emissions are correct.

Our data quality checks were done in the following steps:

1. Detect observations with "correct" TGN. Here, "correct" means "non-missing" and with a string of letters and number in the proper format (in terms of number of characters and their composition).

2. Detect observations with non-missing transmissions information.

3. Detect observations in the TARGA dataset where TGN and one-digit transmission information is able to accurately define a car.

4. Merge MOFIS with TARGA dataset by TGN and transmissions code.

5. Check if variables that appear in the MOFIS and TARGA dataset are equal or at least in the same range. If not, we assumed that the TARGA data are better, checked if the

[19] STATA is the statistic software which is used for the analysis.

TARGA data value is reasonable, and applied the value from the TARGA data. For example, suppose that MOFIS lists the engine size of the vehicle as 3100 ccm and TARGA as 2900 ccm. We deem the TARGA data of better quality, and so in the merged dataset the engine size of the car is 2900 ccm.

6. Check if CO_2 emissions and fuel consumption are available in the merged dataset.
7. Check if the registration year is plausible in the merged dataset.
8. Exclude observations for descriptive statistics which were not merged or had no CO_2 and fuel consumption information or the registration year was not correct.
9. Compare average values of engine size, engine power, weight with other statistics to see if the values are plausible
10. Check if the distribution of the dropped observation is similar in all cantons.

Figure 1 displays the number of observations with correct merges between MOFIS and TARGA, cars whose first registration occurred before 1995, and observations that were not merged because of missing TGN and/or transmissions information.

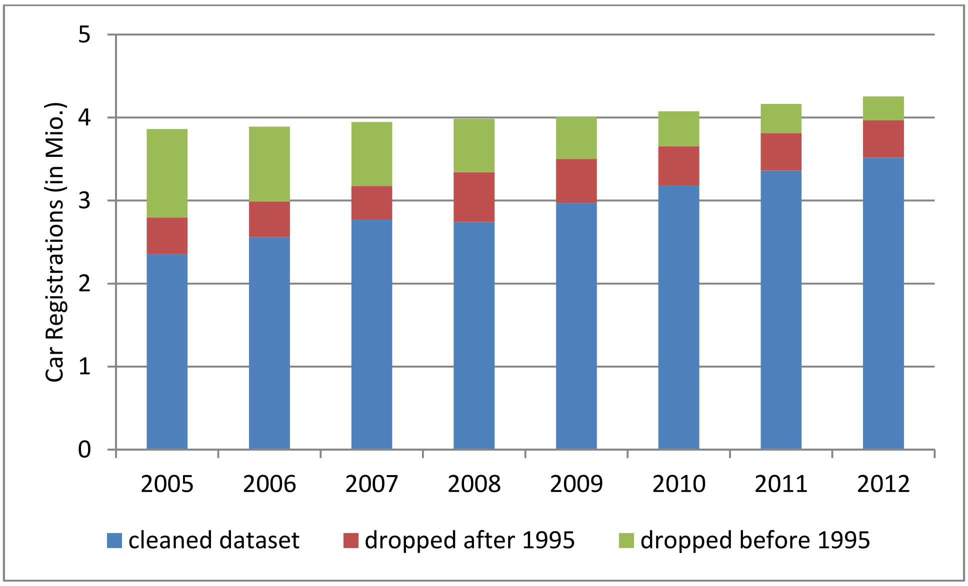

Figure 1: Amount of registered cars before and after 1995 with and without TGN merge

Table 1 summarizes observations and different steps of the merge.

Table 1: Total number of observations and number of observations which can be used for descriptive statistics[20]

	2005	2006	2007	2008	2009	2010	2011	2012
a. Total Observations	3'861'389	3'890'258	3'946'758	3'984'403	4'009'367	4'075'558	4'164'721	4'255'452
b. Cars registered before 1995	1'051'881	873'065	690'239	714'819	434'898	500'100	379'469	279'860
c. Missing or wrong TGN	1'493'820	1'316'818	1'166'017	1'047'454	871'118	762'971	692'757	645'041
d. Correct TGN but no gear information[21]	1	132	193	196'355	165'300	133'847	102'408	87'176
e. Data merged with TARGA[22 23]	2'367'568	2'573'408	2'780'548	2'740'594	2'972'949	3'178'740	3'369'556	3'523'235
f. Data after 1995 not merged[24]	441'940	443'785	475'971	528'990	601'520	396'718	415'696	452'357
g. CO_2 not available after merge	13'249	12'809	12'242	9'950	9'262	8'397	7'523	6'405
h. Merged but wrong registration date	350	251	238	190	162	133	105	80
i. Merged but missing registration date	22'739	0	38	0	0	20	11	0
j. dropped after 1995[25]	455'529	456'839	488'448	539'130	610'943	405'246	423'322	458'840
k. Final dataset	**2'353'979**	**2'560'354**	**2'768'071**	**2'730'454**	**2'963'526**	**3'170'212**	**3'361'930**	**3'516'752**
Percentage of usable data	60.96%	65.82%	70.14%	68.53%	73.92%	77.79%	80.72%	82.64%

[20] The colored rows represent the blocks in Figure 1.
[21] It is assumed that the heavy increase between 2007 and 2008 is due to the fact that the 4-digit transmission variable was introduced into MOFIS and therefore the 1-digit transmission code was not always filled -in anymore. For our analysis, we only have the 1-digit transmission variable available.
[22] Observations where the type approval number and information about transmission are sufficient (e=a-c-d).
[23] The large difference between 2007 and 2008 is likely due to the change in the transmissions coding.
[24] These are observation where either the transmission information is missing or insufficient or the type approval number is not correct.
[25] The dropped observations after 1995 cannot directly be calculated by the figures in the rows above because multiple problems can occur.

The dataset we finally use in our analyses,[26] therefore, does not contain vehicles that were first registered before 1995. The share of pre-1995 vehicles, however, is smaller in more recent years. Cars with incorrect TGN and/or missing transmission information were dropped.

3.2.3. Representativeness of CEPE dataset

The statistics in this report should be interpreted with caution. As is implicit in our explanation of the data merge and construction, the CEPE dataset is not (always) representative of the stock of cars for age. In 2005, we over represent newer vehicles. The quality of the data, however, is better in subsequent years, and so by 2012 our representation of the fleet is very good.

One key question is whether by over representing new vehicles we introduce biases in other important characteristics of a vehicle. We check if this is the case by using information on weight and engine size, which is present for all cars in the registration dataset, whether or not they made it into the final CEPE dataset. We look at mean and median engine size and weight for the original registration dataset and for the CEPE dataset (i.e., the clean merge dataset). Table 2 shows quite clearly that for engine size and weight the original and final dataset were always extremely close (always within 5% or less than one another). Based on this, we are reasonably confident that the CEPE dataset is an acceptable approximation of the stock, at least for main car attributes other than age.

[26] In what follows, the final and cleaned dataset will be referred to as the CEPE dataset.

Table 2: Comparison of mean and median of engine size and curb weight of cars in original and final dataset

Year		Engine Size (original) ccm	Engine Size (CEPE) ccm	Curb Weight (original) kg	Curb Weight (CEPE) kg
2005	Mean	1'974	1'964	1'443	1'484
	Median	1'896	1'896	1'413	1'450
2006	Mean	1'979	1'962	1'410	1'473
	Median	1'896	1'896	1'382	1'440
2007	Mean	1'981	1'964	1'419	1'474
	Median	1'896	1'896	1'390	1'445
2008	Mean	1'976	1'956	1'419	1'473
	Median	1'896	1'896	1'395	1'445
2009	Mean	1'974	1'952	1'386	1'428
	Median	1'896	1'896	1'375	1'408
2010	Mean	1'970	1'942	1'402	1'436
	Median	1'896	1'896	1'385	1'415
2011	Mean	1'963	1'929	1'417	1'443
	Median	1'896	1'870	1'395	1'422
2012	Mean	1'957	1'916	1'433	1'450
	Median	1'896	1'799	1'410	1'430

In appendix 2, Table 30, we compare the number of observations merged and values of engine size, curb weight and age of the original dataset and the CEPE dataset at the cantonal level in 2012. The share of cars with successful merges is quite similar across cantons. The only exception is canton Basel-Stadt where only 57% of original amount of observations are remaining (Swiss average 82%, see also Table 1). Nation-wide statistics are not affected by this, since Basel-Stadt accounts for only 1.6% of the total stock of cars, but caution is necessary when interpreting the results displayed in maps (see below).

3.2.4. Variable construction

Some variables were not available in the MOFIS dataset or they were not up to date. The following modifications were undertaken:

- Curb weight: In the received MOFIS data only the total weight and the load weight of the car are available. In order to get the curb weight of the car, we subtracted the load of the total weight. Unfortunately, we found some records in MOFIS where the total weight and load weight were equal (which would give a curb weight of zero). Where possible, we solved the problem by using the TARGA data otherwise we excluded the observations for our statistics.
- Energy-label: The energy label categories are revised periodically and automatically updated in the MOFIS and TARGA datasets. To obtain the energy label category for each car of its first registration year, we consulted the historical energy ordinances and wrote STATA code to impute the energy efficiency category for each specific car and year. To do this, it is necessary to have the curb weight and fuel consumption of the car. Since information about fuel consumption is only available in the TARGA data set, the energy efficiency category can be added only when the MOFIS observation was correctly merged with the TARGA dataset.
- Car class: To the best of our ability and existing information, we impute car class based on the system used by auto-schweiz and TCS. This is comprised of the following categories:
    - Micro car (MC)
    - Subcompact car (SC)
    - Compact car (CC)
    - Midsize car (MS)
    - Full-size car (FC)
    - Luxury car (LC)
    - Convertible or Roadster (CR)
    - Sport coupé (CS)
    - Multi-purpose van (MV)
    - Sport utility vehicle (SUV)

4. The Swiss passenger vehicle fleet: Descriptive Statistics

This section presents the composition of the Swiss passenger car fleet. In the first subsection, we study trends in the entire Swiss fleet (at the national level) from 2005 to 2012. The second subsection focuses on the 2012 car fleet and presents detailed statistics of vehicle characteristics at the national, cantonal and regional level. The third subsection focuses on the geographical distribution of different types of cars, and looks for correlations with topography and income.

4.1. Trends in the Swiss car fleet at the national level

We begin this subsection with summary statistics by year for five key variables—weight, engine size, engine power (in kW), fuel economy and CO_2 emissions. Over the eight years covered by our study period, the average curb weight, engine size, and emissions have very slightly decreased. Engine power, which we measure in Kilowatt (kW), has increased despite the reduction in weight, and fuel economy has improved. This is shown in Table 3.

Table 3: Summary statistic – Evolution of main car characteristics (CEPE dataset)

Year	Curb weight Kg	Engine Size ccm	Engine power kW	CO_2 g/km	FE l/100km gasoline equivalent	FE (Gasoline) l/100km gasoline	FE (Diesel) l/100km diesel
2005	1'484	1'964	97	204	8.5	8.7	6.9
2006	1'473	1'962	98	202	8.4	8.6	6.9
2007	1'474	1'964	99	200	8.4	8.5	6.9
2008	1'473	1'956	100	196	8.2	8.4	6.8
2009	1'428	1'952	101	194	8.1	8.3	6.8
2010	1'436	1'942	101	191	8.0	8.2	6.7
2011	1'443	1'929	102	189	7.9	8.1	6.7
2012	1'450	1'916	103	185	7.8	8.0	6.6

Due to technological progress, one would expect the emissions from the car fleet to depend crucially on the rate at which the fleet turns over and on the age composition of the fleet itself. We examine vehicle age in

Table 4. On comparing the earliest and the most recent year in our study period, it would seem that the share of new vehicles (aged 0-2 years) and the share of older vehicles (15-plus-year-old cars) have very slightly increased.

Table 4: Share of car age per observation year (original dataset)[27]

Year	Total registrations	0-2 years	3-5 years	6-8 years	9-11 years	12-14 years	15 years and older	unknown
2005	3'861'267	17.95%	22.60%	20.14%	15.93%	11.26%	11.49%	0.63%
2006	3'890'106	18.09%	21.37%	21.23%	16.15%	11.21%	11.95%	0.00%
2007	3'946'758	17.98%	19.94%	21.42%	16.61%	11.47%	12.57%	0.00%
2008	3'984'403	18.34%	18.99%	20.65%	17.37%	11.84%	12.81%	0.00%
2009	4'009'367	18.40%	19.07%	19.63%	18.27%	11.96%	12.66%	0.00%
2010	4'075'558	18.29%	19.26%	18.45%	18.41%	12.40%	13.19%	0.00%
2011	4'164'721	18.69%	19.43%	17.56%	17.65%	13.04%	13.63%	0.00%
2012	4'255'452	20.17%	19.13%	17.36%	16.36%	13.36%	13.63%	0.00%

A trend towards an increasing share of Diesel cars has been noted in other countries, such as Italy and France, in recent years (ICCT, 2013). At the same time, hybrid or all-electric vehicles are being promoted because of their low emissions. Table 5 presents the shares of various fuel types in Switzerland. The share of gasoline cars decreased by almost 11 percentage points, but continues to dominate the fleet, as three-quarters of all passenger vehicles were gasoline powered in 2012. The share of Diesel cars has increased by 10 percentage points. Diesel cars now account for almost one quarter of the fleet. The share of hybrid cars has increased nearly ten-fold but is still less than one percent of the stock of cars. We examine hybrid and electric vehicles in more detail below.

[27] In order to compare the age of the whole car fleet, we use the original dataset with all observations for this table.

Table 5: Share of fuel types of whole fleet from 2005 to 2012 (CEPE dataset)

Year	Observations	Gasoline	Diesel	Hybrid	Electric	Other[28]
2005	2'353'979	85.99%	13.87%	0.08%	0.01%	0.05%
2006	2'560'354	84.26%	15.51%	0.15%	0.00%	0.08%
2007	2'768'071	82.53%	17.06%	0.25%	0.00%	0.17%
2008	2'730'454	80.26%	19.12%	0.37%	0.00%	0.25%
2009	2'963'526	79.12%	20.16%	0.44%	0.01%	0.28%
2010	3'170'212	78.06%	21.11%	0.53%	0.01%	0.30%
2011	3'361'930	76.85%	22.19%	0.64%	0.02%	0.31%
2012	3'516'752	75.28%	23.61%	0.77%	0.03%	0.31%

As of 2012, the average CO_2 emissions rate in the Swiss fleet was 185 g of CO_2 per km. The average CO_2 emissions rate among new cars was 151 g of CO_2 per km. This is well above the target for 2015 (130 g of CO_2 per km).

In Figure 2 and Table 6, we examine the composition of the fleet by emissions levels. While in 2005 only 9.8% of the fleet emitted less than 150 g of CO_2 per km, by 2012 this share has grown to about 23.7%. The rest of the distribution, however, has shifted somewhat towards lower CO_2 values.

[28] Other fuel types are: Natural gas, liquid gas, hydrogen or ethanol.

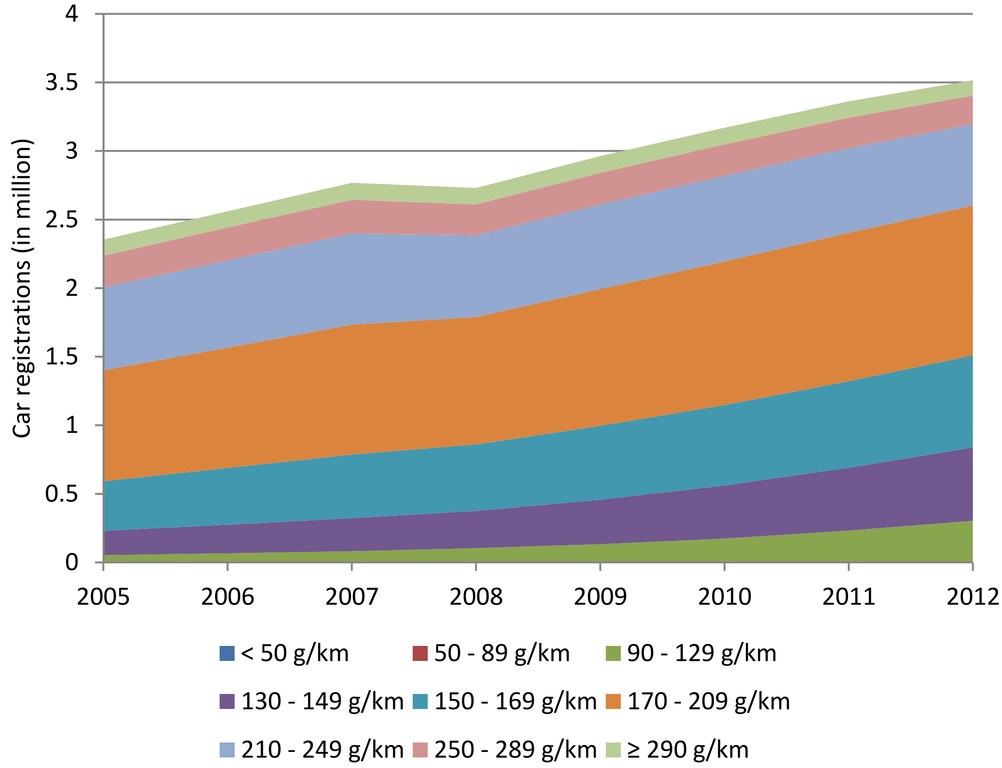

Figure 2: Evolution of CO_2 emission groups (CEPE dataset)

Table 6: Evolution of CO_2 emission groups (CEPE dataset)

	2005	2006	2007	2008	2009	2010	2011	2012
Observations	2'353'979	2'560'354	2'768'071	2'740'404	2'972'787	3'178'607	3'361'930	3'516'752
< 50 g/km	0.01%	0.00%	0.00%	0.00%	0.01%	0.01%	0.02%	0.03%
50 - 89 g/km	0.08%	0.07%	0.07%	0.07%	0.07%	0.09%	0.12%	0.15%
90 - 129 g/km	2.15%	2.50%	2.88%	3.71%	4.40%	5.37%	6.78%	8.45%
130 - 149 g/km	7.59%	8.17%	8.72%	9.99%	10.97%	12.25%	13.64%	15.18%
150 - 169 g/km	15.33%	16.16%	16.74%	17.73%	18.17%	18.46%	18.76%	19.10%
170 - 209 g/km	34.34%	34.24%	34.24%	34.04%	33.64%	33.06%	32.19%	31.07%
210 - 249 g/km	25.72%	24.90%	23.98%	21.82%	20.83%	19.69%	18.37%	16.87%
250 - 289 g/km	9.82%	9.33%	8.89%	8.24%	7.76%	7.21%	6.60%	5.95%
≥ 290 g/km	4.96%	4.62%	4.48%	4.39%	4.15%	3.85%	3.53%	3.19%

Some cantons offer tax rebates for hybrid and electric vehicles as an incentive to improve the energy efficiency in the car fleet. Figure 3 shows the trends for hybrid and electric vehicles registrations compared to the total new passenger car registrations from 2005 to 2012.[29]

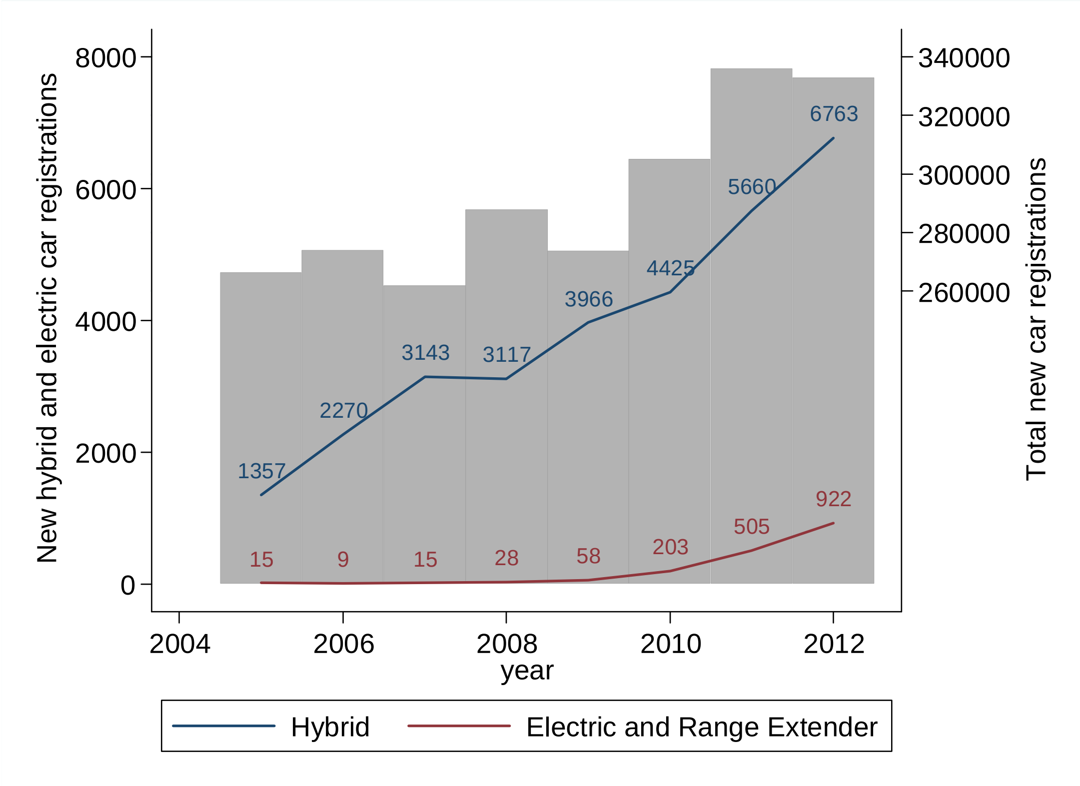

Figure 3: Evolution of new registered hybrid and electric vehicles in Switzerland 2005 – 2012

The graph shows clearly that there was a strong increase of hybrid and electric vehicles over the last eight years. New electric car registrations increased from 15 in 2005 to 922 in 2012 (+6'147%). New hybrid car registrations increased from 1'357 to 6'763 (+498%) while total new car registrations increased by 25% between 2005 and 2012. Despite these strong increases the share of new registrations is still very small – 2% percent for hybrid cars and 0.3% for electric cars in 2012. If we consider the total stock of cars, these technologies have only a share of 0.8% (as shown in Table 5).

4.2. The Swiss car fleet of 2012

In this subsection the car fleet characteristics for the year 2012 are described at the national, cantonal and municipal level. We focus on 2012 because this is the most recent year for which the data are available.

[29] We count Range Extenders together with electric vehicles.

The passenger vehicle fleet is grouped by weight, engine size, engine power (in kW), fuel type and age as well as CO_2 emissions, fuel economy, energy efficiency labels and car classes. We first present summary statistics for these variables at the national level. We then compute the median values at the cantonal and municipal level. These medians are sorted by size and used to allocate the cantons (or municipalities respectively) to three even groups (terciles), which we map in an effort to understand whether there are geographical patterns in these car characteristics. We work with the medians, rather than the means, because the medians are robust to outliers and other unduly influential observations. They are therefore suited for municipalities with relatively small populations and fleets.

4.2.1. Car fleet overview

The total of matriculated passenger vehicles in 2012 reached 4.26 million. Our descriptive statistics are based on the 3.52 million cars (82.5%) that we were able to merge correctly with a TGN (CEPE-dataset). For these 3.52 million cars we have reliable and detailed information about all important vehicle characteristics.

Table 7: 2012 car fleet summary statistics

Variable	Mean	Median	Std. Dev.	Min	Max
Engine size (ccm)	1'916	1'799	680.12	0	8'285
Curb weight (kg)	1'435	1'416	310.40	550	3120
Age (a)	6.7	6	4.40	0	17
Engine power (kW)	103	96	46.03	11	515
Fuel efficiency, FE[30] (l/100km)	7.8	7.5	1.99	0	26.6
CO_2 emissions (g/km)	185	178	47.85	0	624
Observations			3'516'752		

Table 7 shows that in 2012 the average car in Switzerland consumes 7.8 liters of fuel per 100 kilometers (in gasoline equivalent) and emits 185 grams of CO2 per kilometer (g CO2/km). The average curb weight is 1'435 kilogram, and the average engine size just

[30] In the remainder of this document, FE is expressed as gasoline equivalent, unless stated otherwise.

below two liters (1'916 ccm), generating 103 kilowatt of power. The median values are smaller than, but generally close to, the means.

There is, of course, quite a bit of variation across the fleet. The engine size in the dataset varies between 0 and 8.3 liters. An engine size of 0 generally denotes an electric vehicle. The other end of the scale captures luxury and sports cars with predominantly American makes. Pure electric vehicles and luxury sports cars are also the extremes of the distribution of fuel economy, CO2 emissions and engine power. The heaviest polluter emits 624 grams of CO2 per kilometer, which is roughly four times the amount of the average vehicle.

Caution should be used in examining and interpreting the information about the age of the vehicle. This variable exhibits very little variation, but it should be kept in mind that the CEPE dataset includes only vehicles that are 17 years old or younger. Vehicles that are older than 17 exist and are legally driven on Swiss roads, but are not included in the CEPE dataset due to the merge between the different sources of data discussed in the earlier chapter.

4.2.2. Curb weight

Table 8: 2012 Car fleet grouped by curb weight[31]

Weight group	Vehicles		FE	CO_2	Engine size	Curb weight
	Freq.	%	l/100km	g/km	ccm	kg
≤ 999 kg	199'589	5.68	5.6	134	1'075	918
1'000 - 1'099 kg	276'661	7.87	6.3	150	1'319	1'054
1'100 - 1'199 kg	357'039	10.15	6.5	155	1'445	1'146
1'200 - 1'299 kg	335'412	9.54	7.1	169	1'599	1'250
1'300 - 1'399 kg	461'359	13.12	7.4	176	1'743	1'348
1'400 - 1'499 kg	442'453	12.58	7.9	187	1'938	1'442
1'500 - 1'599 kg	434'065	12.34	8.2	194	2'055	1'536
1'600 - 1'699 kg	363'929	10.35	8.5	201	2'224	1'633
1'700 - 1'799 kg	190'415	5.41	8.9	211	2'440	1'715
≥ 1'800 kg	455'830	12.96	10.0	238	2'807	1'965
Total/Average	3'516'752	100.00	7.8	185	1'916	1'435

Table 8 displays mean fuel economy (FE), CO_2 emissions, engine size and curb weight by curb weight class. It is apparent that fuel consumption, CO_2 emissions and engine size increase with the weight of the car. It is also noteworthy that 13% of the cars are heavier than 1'800 kg.

31 The weight groups correspond to the classifications used by auto-schweiz (BFE, 2013).

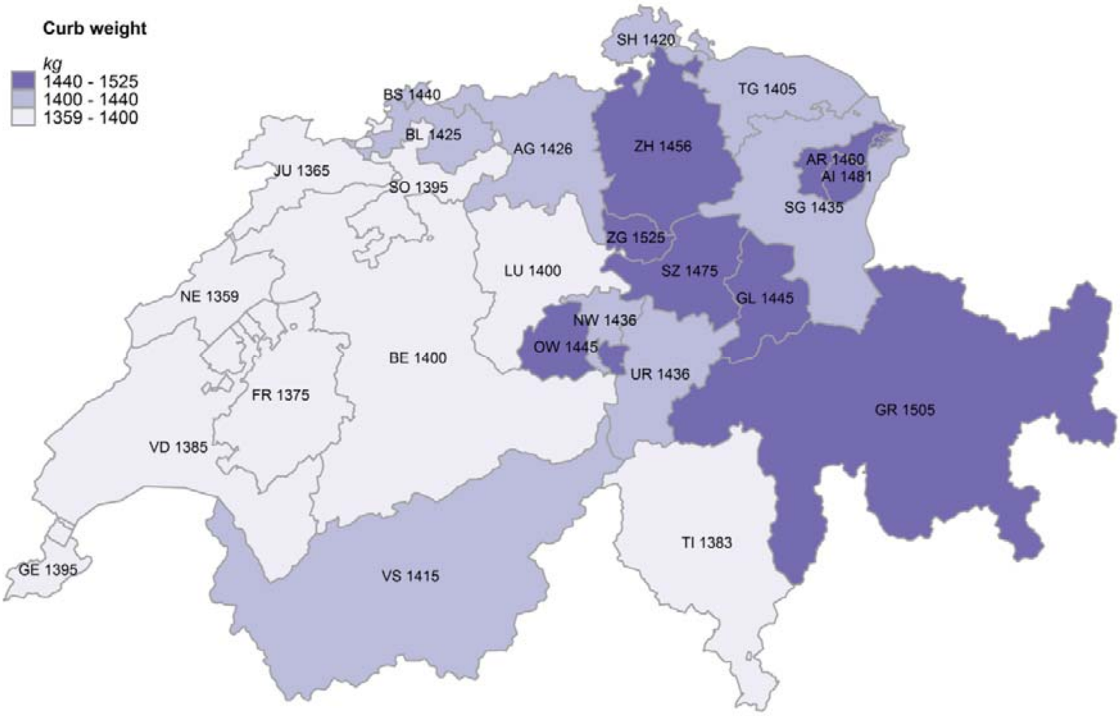

Figure 4: Map illustrating the 2012 car fleet curb weight at the cantonal level[32]

Figure 4 displays curb weight across Switzerland. Recall that median values are adopted. The three colors represent the terciles grouping the median values into regions with relatively low, medium and high curb weights.

Looking at the cantonal distribution of the national car fleet, regional differences become evident. The weight distribution follows the language divides. The French and Italian speaking areas exhibit low median curb weights; In the German speaking regions the car fleets display larger curb weights. Graubünden (GR) and Zug (ZG) are the only two cantons with a median curb weight greater than 1'500 kilogram, Zug reporting the highest median value of 1'525 kilogram.

[32] The boundaries of the terciles in this and all the following figures should be interpreted as follows: In the lowest tercile the values can be equal or greater (≥) than the lower boundary or smaller or equal (≤) than the higher boundary, while the values in the other two terciles are greater (>) than the lower boundaries or smaller or equal (≤) than the higher boundaries.

4.2.3. Engine size

Table 9: 2012 Car fleet grouped by engine size[33]

Engine size group	Vehicles		FE	CO_2	Curb weight	Engine size
	Freq.	%	l/100km	g/km	kg	ccm
≤ 999 ccm	110'703	3.15	5.0	119	906	893
1'000 - 1'399 ccm	757'196	21.53	6.2	147	1'136	1'310
1'400 - 1'799 ccm	891'738	25.36	7.3	172	1'334	1'649
1'800 - 1'999 ccm	962'847	27.38	7.8	187	1'535	1'972
2'000 - 2'499 ccm	344'581	9.80	9.2	219	1'692	2'330
2'500 - 2'999 ccm	271'591	7.72	10.0	238	1'825	2'868
3'000 - 4'499 ccm	139'942	3.98	11.7	280	1'860	3'578
≥ 4500 ccm	38'154	1.08	14.3	340	2'080	5'176
Total/Average	3'516'752	100.00	7.8	185	1'435	1'916

33 The engine size groups correspond to the classifications used by auto-schweiz (BFE, 2013).

Engine size

Table 9 presents the averages of several values by engine size. Fuel consumption, CO2 emissions and curb weight increase consistently with engine size. In Switzerland 77% of the passenger vehicles draw their power from an engine smaller than two liters, and about 5% from an engine equal to or larger than three liters. It is interesting that even among the smallest-engined vehicles (1000 ccm or less, including all-electric vehicles, which have an engine size equal to zero) the emissions rate is relatively high. In other words, a small engine alone doesn't guarantee per se low CO2 emissions.

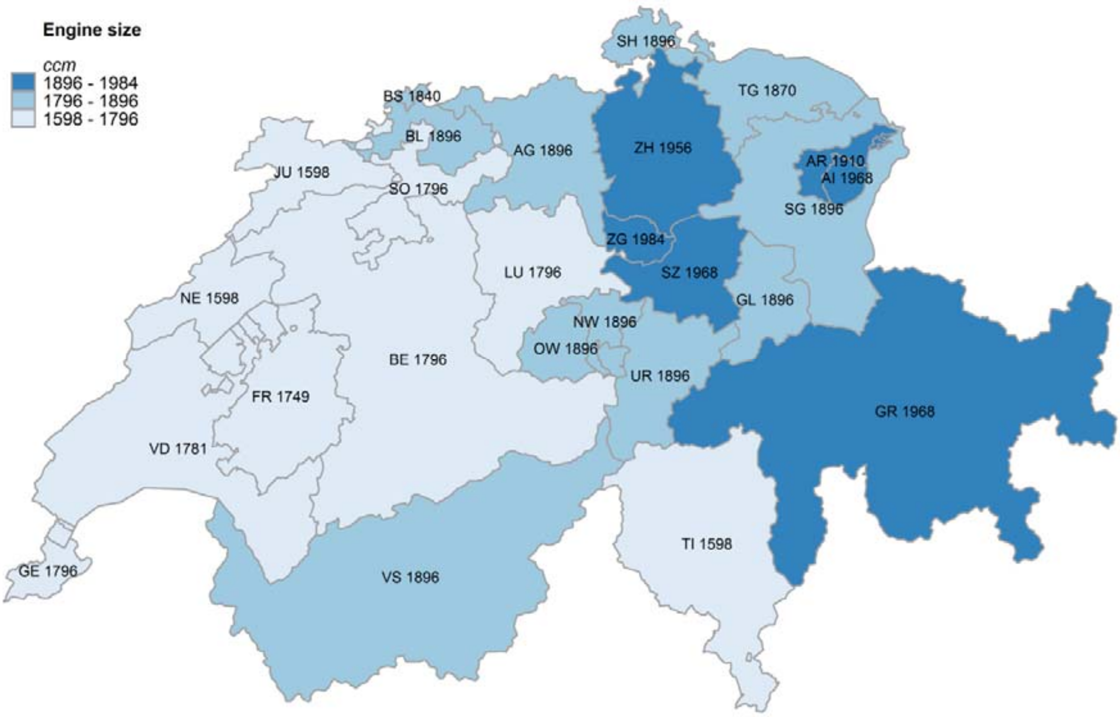

Figure 5 Map illustrating the 2012 car fleet engine size at the cantonal level

At the cantonal level the engine size distribution is nearly identical to the curb weight distribution. In the North and East of Switzerland heavier cars with larger engines are preferred, while in the South and West of Switzerland people tend to favor lighter cars with smaller engines. Passenger vehicles in the Cantons of Ticino (TI), Neuchâtel (NE) and Jura (JU) display very similar engine displacement and curb weight values. The median engine size is below 1.6 liters at a median curb weight less than 1'400 kg. In the Cantons of Genève (GE), Vaud (VD), Fribourg (FR), Bern (BE), Solothurn (SO) and Luzern (LU) people seem to own similarly light cars as well, but with a slightly larger engine. An unusual difference between curb weight and engine size is observed in Thurgau (TG). Its car fleet nearly falls in the lowest curb weight tercile, and curb weight is lower than that in the neighboring cantons, but the median engine size in Thurgau is relatively high compared to regions with similarly low median curb weight, such as Bern (BE) or Luzern (LU). In Thurgau motorists seem to prefer light cars with relatively large engines given their curb weight.

4.2.4. Engine power

Table 10: 2012 Car fleet grouped by engine power[34]

Engine power group	Vehicles		FE	CO_2	Curb weight	Engine power
	Freq.	%	l/100km	g/km	kg	kW
< 40 kW	12'928	0.37	5.6	138	895	35
40 – 59 kW	438'115	12.46	6.0	142	1'036	51
60 – 79 kW	704'294	20.03	6.6	156	1'232	71
80 – 99 kW	693'862	19.73	7.5	179	1'409	88
100 – 119 kW	750'245	21.33	8.0	189	1'548	107
120 – 139 kW	336'371	9.56	8.6	205	1'648	127
140 – 159 kW	224'780	6.39	9.4	223	1'650	147
≥ 160 kW	356'157	10.13	10.7	255	1'823	204
Total/Avereage	3'516'752	100.00	7.8	185	1'435	103

Table 10 shows that roughly 70% of the car fleet has between 40 kilowatt and 119 kilowatt of engine power, for an average of 103 kilowatt, corresponding to roughly 140 horsepower. More than 10 percent of the cars belong to the most powerful group—that with 160 kW or more. Fuel consumption, CO_2 emissions and curb weight consistently increase with engine power.

[34] The performance groups are classified in a manner that a consistent distribution is achieved while incorporating certain benchmark values.

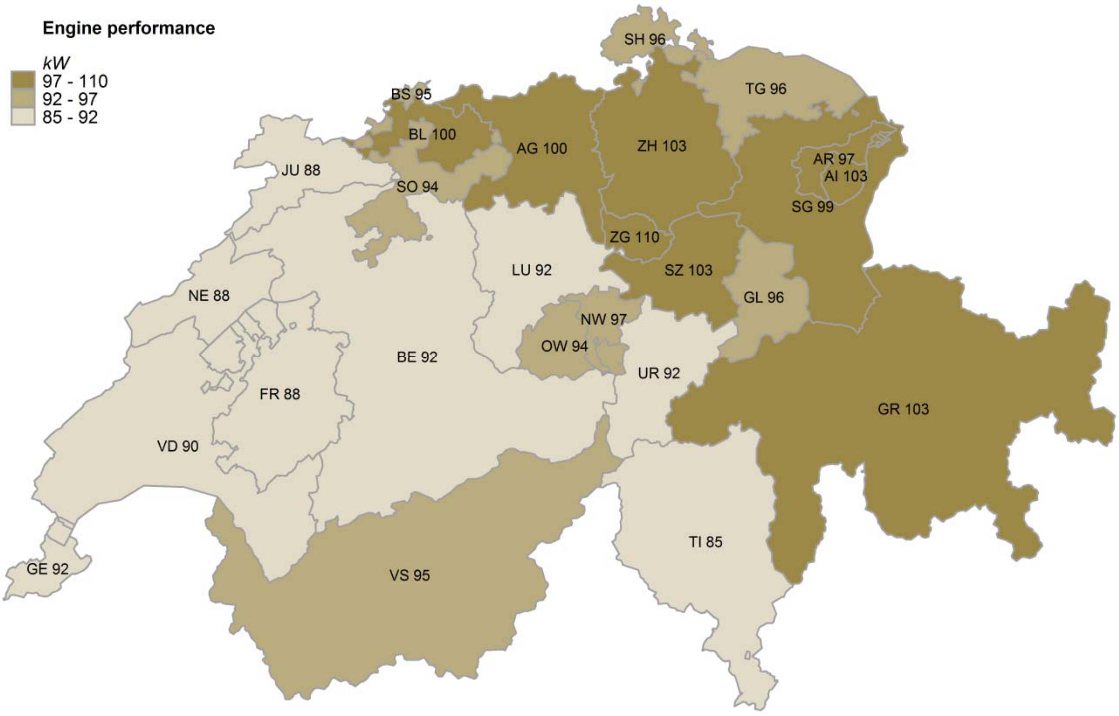

Figure 6: Map illustrating the 2012 car fleet engine power at the cantonal level

The pattern of engine power distribution at the cantonal level supports the previous results indicating regional differences between the German, French and Italian speaking community. In the North and East of Switzerland, where cars are on average relatively heavy and equipped with large engines, engine power is greater than in the South and West of Switzerland. The most powerful vehicle fleet is found in Zug (ZG), where it averages 110 kilowatt or 150 horsepower. For comparison, the lowest median engine power at the cantonal level is 85 kilowatt or 116 horsepower in the Ticino (TI).

4.2.5. Fuel type

Table 11: 2012 car fleet grouped by fuel type[35]

Fuel type	Vehicles		FE	CO_2	Age	Engine power	Engine size	Curb weight
	Freq.	%	l/100km	g/km	a	kW	ccm	kg
Gasoline	2'651'227	75.39	8.0	189	7.33	102	1'860	1'358
-Hybrid$_G$	26'359	0.75	4.9	115	3.00	88	1'932	1'554
Diesel	830'210	23.61	7.3 (6.6)*	174	4.95	107	2'100	1'677
-Hybrid$_D$	707	0.02	4.5 (4.0)*	105	0.01	120	1'997	1'824
Alternative	8'249	0.23	7.0	135	4.03	75	1'371	1'472
Total/Average	3'516'752	100	7.8	185	6.72	103	1'916	1'435

* Diesel-equivalent fuel efficiency

With an aggregate market share of 76.1% gasoline is still, clearly, the dominant fuel type (see Table 11). Diesel accounts for 22% of the fleet, and alternative fuels are still very infrequent. The young average ages of Diesel and alternative-fuel vehicles suggest that these types of cars were bought most recently and that their rate of adoption is likely to continue increasing over time.

Diesel vehicles are noticeably more fuel efficient, even if on average they are heavier. With a fuel consumption of 7.3 liters per 100 kilometers they use 0.7 liters (9%) less than their gasoline counterparts, despite being 24% heavier than them (about 319 kilograms). Looking at the CO_2 emissions, Diesel passenger vehicles emit on average 174 grams per kilometer, whereas gasoline cars emit on average 189 grams per kilometer. The evidence from the existing fleet confirms the point made by auto-schweiz in its annual report that *new* diesel vehicles are more fuel efficient than new gasoline cars, despite their heavier weight. Our findings for the entire fleet, however, are in contrast with the auto-schweiz report, in that we find that Diesel car have lower CO_2 emissions rates, while they find that *new* diesel vehicles

[35] Electric vehicles with range extenders are assigned to alternative fuels alongside pure electric, CNG, LPG, ethanol, methanol and hydrogen propulsion systems.

emit more CO_2 than new gasoline vehicles (BFE, 2013), as they have a lower emissions rate per unit of weight, but they are heavier than new gasoline cars.[36]

Hybrid systems account for 0.8 percent of the car stock. Almost the entire hybrid fleet runs on gasoline, averaging less than 5 liters per 100 kilometers. Hybrid cars are heavier than conventional cars due to the additional engine, drivetrain and battery. Likewise, Diesel hybrids are more fuel efficient and environmentally friendly despite an even higher curb weight: 4.5 liters are sufficient to drive 100 kilometers. Counterintuitively, hybrids display an above-average engine size and in the case of the diesel version also a very high engine power.

In general, the data indicates that diesel cars are on average younger, heavier and equipped with a larger engine but still more fuel efficient than their gasoline counterparts.

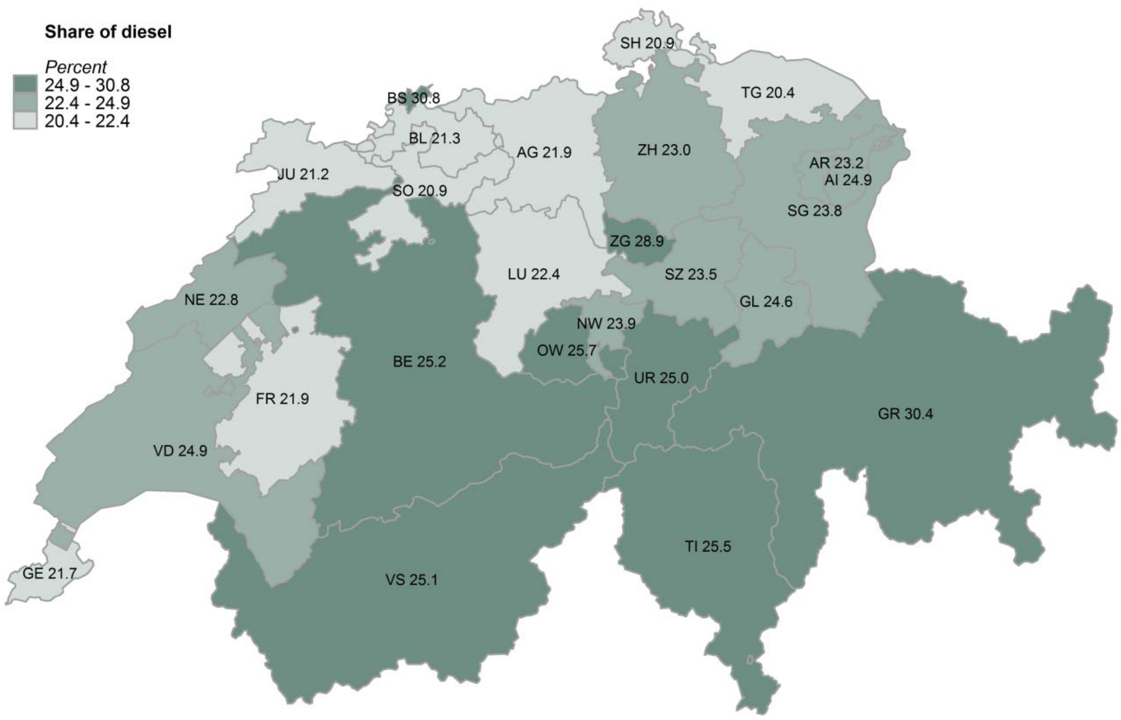

Figure 7: Map illustrating the diesel share of the 2012 car fleet at the cantonal level

At the cantonal level the share of diesel fuel varies between 20.4 percent (Thurgau, TG) and 30.8 percent (Basel-Stadt, BS) with two thirds of the cantons displaying shares less than 25 percent. The Cantons of Basel-Stadt, Graubünden (GR) and Zug (ZG) display clearly higher

[36] If we conduct the same analysis only for new vehicle registrations in 2012, we observe the same results as in BFE (2013).

shares of diesel fueled cars than the rest (see Figure 7). In canton Zug the large share of diesel vehicles (with their high weight, large and powerful engines) is consistent with the patterns we earlier commented on.

As shown in Table 12, the average age of a car is 6.7 years. Roughly 44% of the cars are 5 years old or younger. The youngest vehicles are the most fuel efficient, but not the lightest. We remind the reader that caution must be used to interpret results for the age distribution of the fleet: The CEPE dataset only includes vehicles that are 17 years old or newer.

4.2.6. Car age

Table 12: 2012 car fleet grouped by age[37]

Age group	Vehicles		FE	CO_2	Engine size	Curb weight	Age
	Freq.	%	l/100km	g/km	ccm	kg	a
0-2 years	782'261	22.24	6.7	156	1800	1463	1.1
3-5 years	762'660	21.69	7.5	177	1915	1474	4.0
6-8 years	688'983	19.59	8.0	191	1993	1472	7.0
9-11 years	649'738	18.48	8.3	199	1967	1409	10.0
12-14 years	508'246	14.45	8.7	208	1928	1346	12.9
15-17 years	124'864	3.55	8.9	211	1914	1307	15.3
Total/Average	3'516'752	100.00	7.8	185	1916	1435	6.7

In sum, Table 12 suggests that new cars tend to be heavier but more fuel-efficient – a trend also observed in auto-schweiz (2012). The effects of engine downsizing have been documented in various research studies including the recent papers of Galloni et al. (2013), Sprei and Karlsson (2013) or Nozawa et al. (1994).

[37] The age groups are formed according to the approach applied by the Federal Statistics Office in the analysis of the 2010 micro census on mobility and traffic (BFS, 2013a). Keep in mind that the dataset only contains personal vehicles matriculated after 1995, thus the final cut-off is set at 17 years of age.

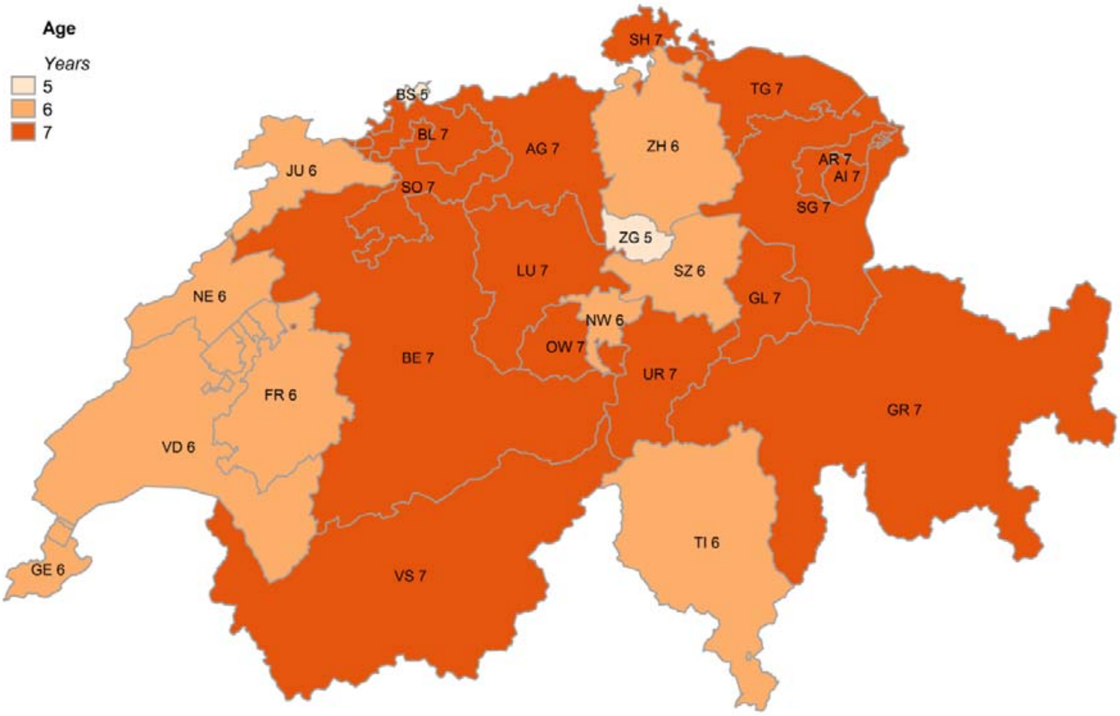

Figure 8: Map illustrating the 2012 car fleet age at the cantonal level

At the cantonal level the median age ranges between 5 years and 7 years (see Figure 8). The newest car fleets are found in Basel-Stadt (BS) and Zug (ZG).[38] The young age of the vehicles is consistent with the observed large shares of diesel vehicles found in both cantons.

[38] Keep in mind that results of BS have to be interpreted with caution since only 57% of original amount of observations are remaining (see subsection 3.2.3.)

4.2.7. CO_2 emissions

Table 13: 2012 car fleet grouped by CO_2 emissions[39]

CO_2 group	Vehicles		FE	Diesel	4WD	CO_2
	Freq.	%	l/100km	%	%	g/km
< 50g/km	1'172	0.03	1.9	0.0	0.0	8
50 - 89g/km	5'429	0.15	3.8	44.7	0.0	88
90 - 129g/km	297'274	8.45	5.0	28.6	1.5	117
130 - 149g/km	533'959	15.18	6.0	27.5	8.4	141
150 - 169g/km	671'781	19.10	6.7	30.5	13.4	160
170 - 209g/km	1'092'596	31.07	7.9	22.7	22.8	188
210 - 249g/km	593'154	16.87	9.5	16.1	40.1	226
250 - 289g/km	209'236	5.95	11.1	17.6	55.1	266
≥ 290g/km	112'151	3.19	13.8	10.3	68.9	328
Total/Average	3'516'752	100.00	7.8	23.6	23.3	185

Table 13 shows that in 2012 only 23.7 percent of all matriculated cars emit less than 150 grams of CO_2 per kilometer. The majority of cars produces CO_2 emissions ranging from 150 to 210 grams CO_2 per kilometer (50.2%), which leads to a car fleet average of 185 grams of CO_2 per kilometer. Table 13 shows that Diesel vehicles are heavily represented among the low-emitting groups: Almost half of the cars emitting from 50 to 90 grams of CO_2 per kilometer are diesel-powered. Four-wheel drives (4WD) contribute significantly to the high emitting CO_2 groups: The higher the CO_2 emission group the larger the share of 4WD. 4WDs account for more than two-thirds of the highest CO_2 emissions group.

[39] The CO_2 groups are classified in a manner that a consistent distribution is achieved while incorporating certain benchmark values.

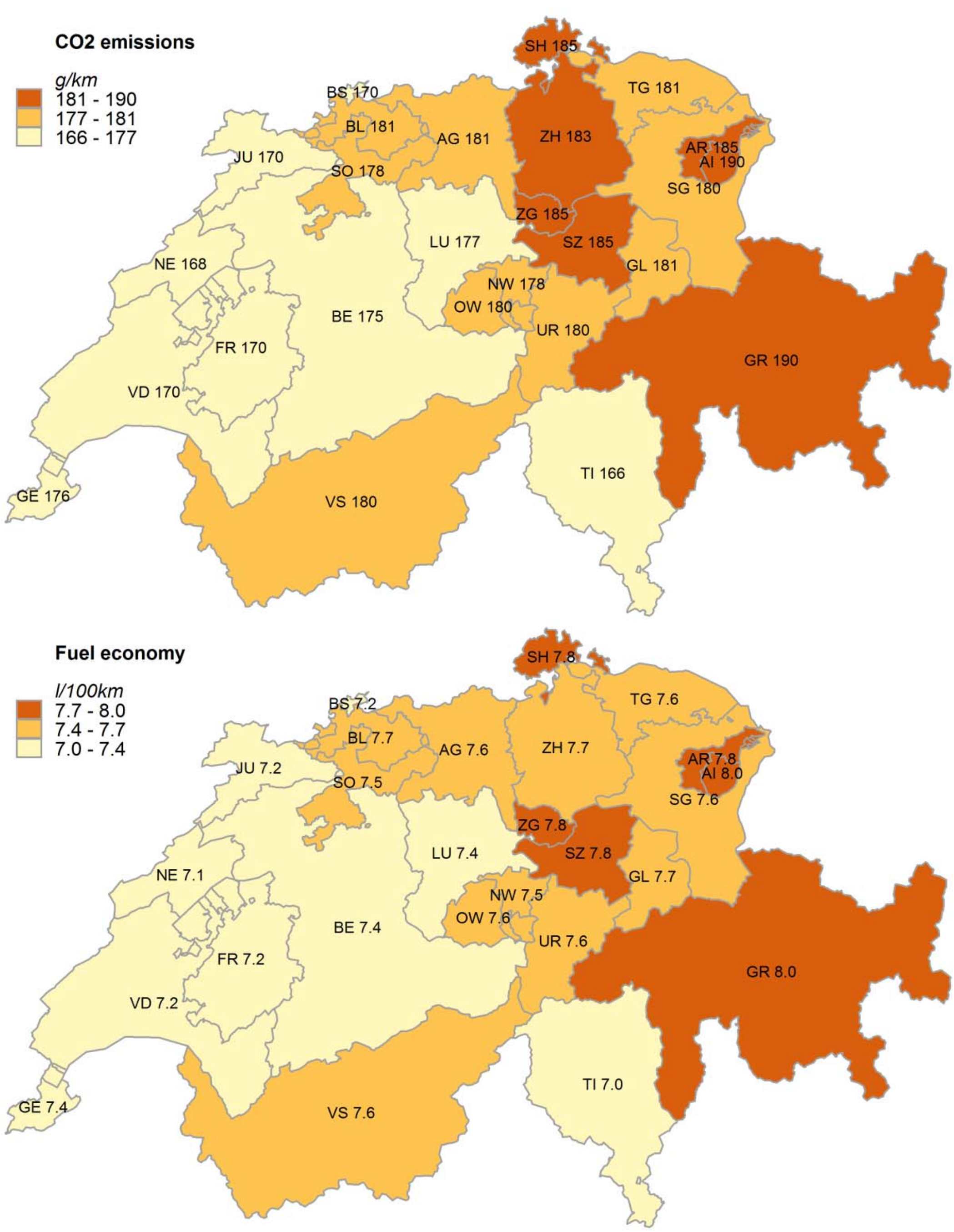

Figure 9: Maps illustrating the 2012 car fleet CO_2 emissions and fuel efficiency at the cantonal level

Figure 9 shows CO_2 emissions and fuel consumption follow the same pattern we identified earlier. In the Northeast of the country cars are more fuel inefficient and produce more CO_2 emissions compared to the Southwest. The Cantons of Graubünden (GR), Appenzell Innerrhoden (AI) and Ausserrhoden (AR), Schwyz (SZ), Zug (ZG), Zürich (ZH) and Schaffhausen (SH) have the most polluting car fleets. At the inefficient end of the scale are

Graubünden and Appenzell Innerrhoden, where passenger vehicles emit 190 gram CO_2 per 100 kilometers. The same is true for fuel consumption. Appenzell Innerrhoden and Graubünden have the worst fuel economy, followed by Schwyz, Appenzell Ausserrhoden and Schaffhausen. For Schaffhausen to belong to the most inefficient cantons – in terms of CO_2 emissions and fuel consumption – is slightly surprising, since it otherwise reports average parameter values. The fuel-efficient end of the scale includes the Cantons of Ticino (TI), Neuchâtel (NE), Fribourg (FR), Vaud (VD), Jura (JU), Basel-Stadt (BS), Bern (BE), Genève (GE) and Luzern (LU). Passenger vehicles in Ticino and Neuchâtel achieve the most environmentally friendly rates of CO_2 emissions and fuel consumption, as both have values below 170 grams per kilometer at less than 7 liters per 100 kilometers.

Note that the differences between the cantonal median CO_2 emissions and fuel efficiencies are generally small, but consistent with the notion that topography and socio-demographics may influence the composition of the fleet.

4.2.8. Relative CO_2 emissions and fuel efficiency

In this section, we examine the composition of the fleet in terms of relative CO_2 emissions and fuel consumption. In other words, we look at emissions and fuel consumption per unit of weight. Statistics are presented per 100 kg of curb weight and illustrated in Figure 10 below.

The distributions of relative CO_2 emissions and fuel consumption are similar to those of the absolute emissions and fuel consumption. The small range of relative CO_2 emissions and fuel efficiency values indicate that technological standards for small and large vehicles are very similar. Within weight and size classes technological differences although are apparent. Graubünden (GR) and Zug (ZG), which both have comparable curb weight, engine size and power as well as the share of diesel, display clear differences in relative terms (see Figure 10). This kind of technological advantage is also captured in the age distribution. Keeping the opposing trend of more fuel efficient but heavier new vehicles in mind (see Table 12), it is not surprising to find the cantons with the youngest fleets to also be the very fuel efficient in relative terms. Next to Basel-Stadt (BS) and Zug the group of cantons that displays low absolute efficiency values (Ticino (TI), Neuchâtel (NE), Fribourg (FR), Vaud (VD), Jura (JU) and Bern (BE)) also shows low CO_2 and fuel efficiency to curb weight ratios. Nidwalden (NW) switched positions with Luzern (LU) and Genève (GE) in terms of absolute efficiency distribution and belongs to the most efficient tercile in relative terms. Appenzell Innerrhoden (AI) and Ausserrhoden (AR) as well as Graubünden, Basel-Land (BL), Schaffhausen (SH), Thurgau (TG), Valais (VS), Glarus (GL) and Uri (UR) demonstrate high CO_2 and fuel efficiency per unit of curb weight.

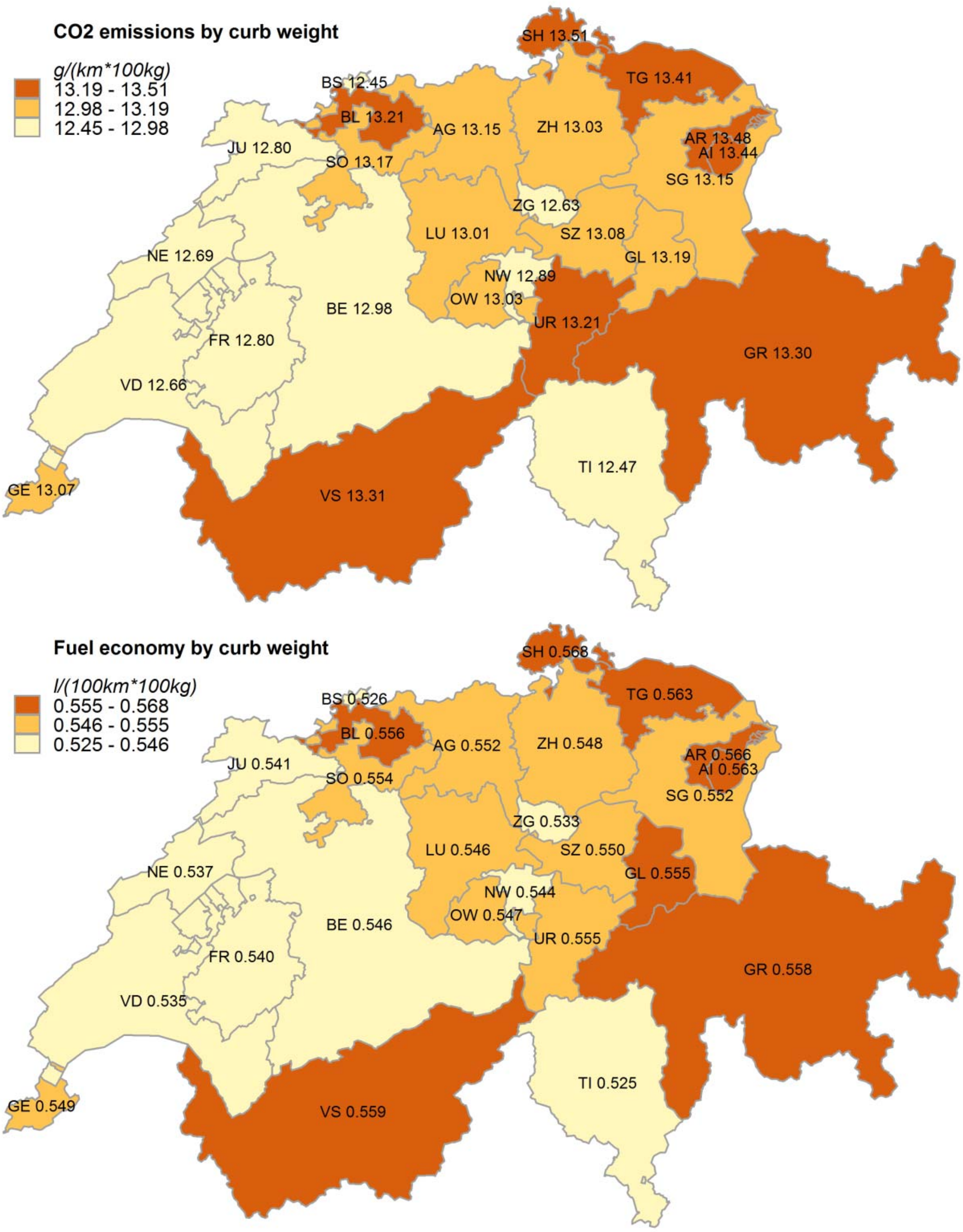

Figure 10: Maps illustrating the 2012 car fleet CO_2 emissions and fuel efficiency per curb weight at the cantonal level

4.2.9. Energy efficiency labels

In this report, we distinguish between the actual energy efficiency label and what we term the "historical" energy efficiency label (EEL).[40] [41] The actual label is the one attained by applying the 2012 efficiency criteria. The "historical" label is based on the standards valid at the time of the vehicle's first matriculation. The energy efficiency label system has been in place since 2003. Hence the amount of observations used to determine the statistics of the "historical" label is limited to the passenger vehicles younger than 2003.

Table 14: 2012 car fleet grouped by 2012 energy efficiency label

EEL_A	Vehicles		FE	CO_2	Diesel	4WD	Engine size	Curb weight	Engine power
	Freq.	%	l/100km	g/km	%	%	ccm	kg	kW
A	112'787	3.21	4.8	112	76.7	1.9	1'551	1'356	77
B	263'226	7.48	5.6	133	60.9	14.4	1'614	1'342	84
C	390'875	11.11	6.2	146	46.6	13.7	1'629	1'373	87
D	440'634	12.53	6.6	155	29.9	17.9	1'604	1'339	86
E	442'795	12.59	7.1	169	24.2	16.5	1'710	1'389	91
F	717'587	20.40	7.7	184	12.2	19.6	1'781	1'387	95
G	1'148'848	32.67	9.9	236	6.6	37.7	2'402	1'569	132
Total/ Average	3'516'752	100.00	7.8	185	23.6	23.3	1'916	1'435	103

Applying the 2012 energy efficiency criteria forces the majority of the fleet in groups F and G, with only 10.7 percent achieving an efficiency label A or B (see Table 14). The difference between A- and G-labeled cars is striking. The most efficient class consists mainly of diesel and uses on average 4.8 liters per 100 kilometers; the associated emissions are 112

[40] The energy efficiency label corresponds to the classification decreed in Annex 3.6 of the energy ordinance (SR 730.01: Energieverordnung vom 7. Dezember 1998 (Stand am 1. Oktober 2012)).

[41] The energy efficiency of passenger vehicles has improved over the years. The energy label criteria are revised periodically to make sure that category A is always awarded only to the most efficient vehicles. Vehicles are ranked by a combination of absolute fuel consumption (liters per 100 kilometers) and relative fuel efficiency (fuel consumption by unit of weight). At the reference date, the bottom seventh of this ranking is awarded with label A. For more details see www.energieetikette.ch.

grams of CO_2 per kilometer. The most inefficient cars are in group G and use on average 9.9 liters per 100 kilometers, producing 236 grams of CO_2 per kilometer.

Interestingly, engine size and curb weight do not increase monotonically as we move from class A to G. Cars with label D exhibit inconsistent patterns. They have the second smallest engine block and carry the least amount of weight; yet they use more fuel and emit more CO_2 than the heavier labels B and C. A closer look reveals that the engine power of the D-label car group lies in the same range as the more efficient labels A to C, hence eliminating increased engine power as an explanatory factor. Another possible reason for the observed patterns might be the age difference between the labels A to D. Categories A to C are all roughly the same age (on average, 3.5 years), whereas D-labeled cars are on average 4.5 years old. In addition, the share of diesel cars is lower and the share of four-wheel drives is larger.

The picture changes if the "historical" energy efficiency labels are applied, as shown in Table 15. At the time of matriculation 43.6% of the cars are labeled A or B, and less than 10% — mostly 4WD - must settle for labels F and G.

Table 15: 2012 car fleet grouped by historic energy efficiency label

EEL_H	Vehicles		FE	CO_2	Diesel	4WD	Engine size	Curb weight	Engine power
	Freq.	%	l/100km	g/km	%	%	ccm	kg	kW
A	513'454	20.16	5.8	138	62.5	8.9	1'643	1'385	83
B	597'736	23.47	6.6	156	33.1	17.3	1'667	1'389	90
C	575'314	22.59	7.3	174	23.6	21.9	1'789	1'444	99
D	408'669	16.04	8.2	195	15.6	33.7	1'956	1'505	111
E	235'538	9.25	9.2	218	8.6	49.6	2'277	1'587	132
F	120'091	4.71	9.8	234	5.2	50.5	2'566	1'651	155
G	96'479	3.79	12.1	287	1.3	60.1	3'618	1'781	230
Total/ Average	2'547'281	100.00	7.5	177	29.3	25.5	1'909	1'465	106

The thermal efficiency parameters CO_2 emissions and fuel efficiency, which are published to sensitize car customers, increase consistently from A to G. The variation in the benchmark values CO_2 emissions between the actual and historic label, support the fact that the general evaluation criteria have become stricter over time and that the gap amongst efficiency labels, especially B through F, has decreased.

A comparison of 2012-current and historical A and B label percentages at the cantonal level (see Figure 11) shows that the difference in the values is striking. Using the present perspective and applying the 2012 efficiency label criteria, the amount of A- and B-labeled cars ranges between 8% in Graubünden (GR) and 17% in Basel-Stadt (BS). In the case of historical energy efficiency labels the matriculated A- and B-labeled car fleet per canton varies between 30.9% in Appenzell Innerrhoden (AI) and 42.9% in Ticino (TI). The distribution of terciles across cantons is in both cases similar, but not identical.

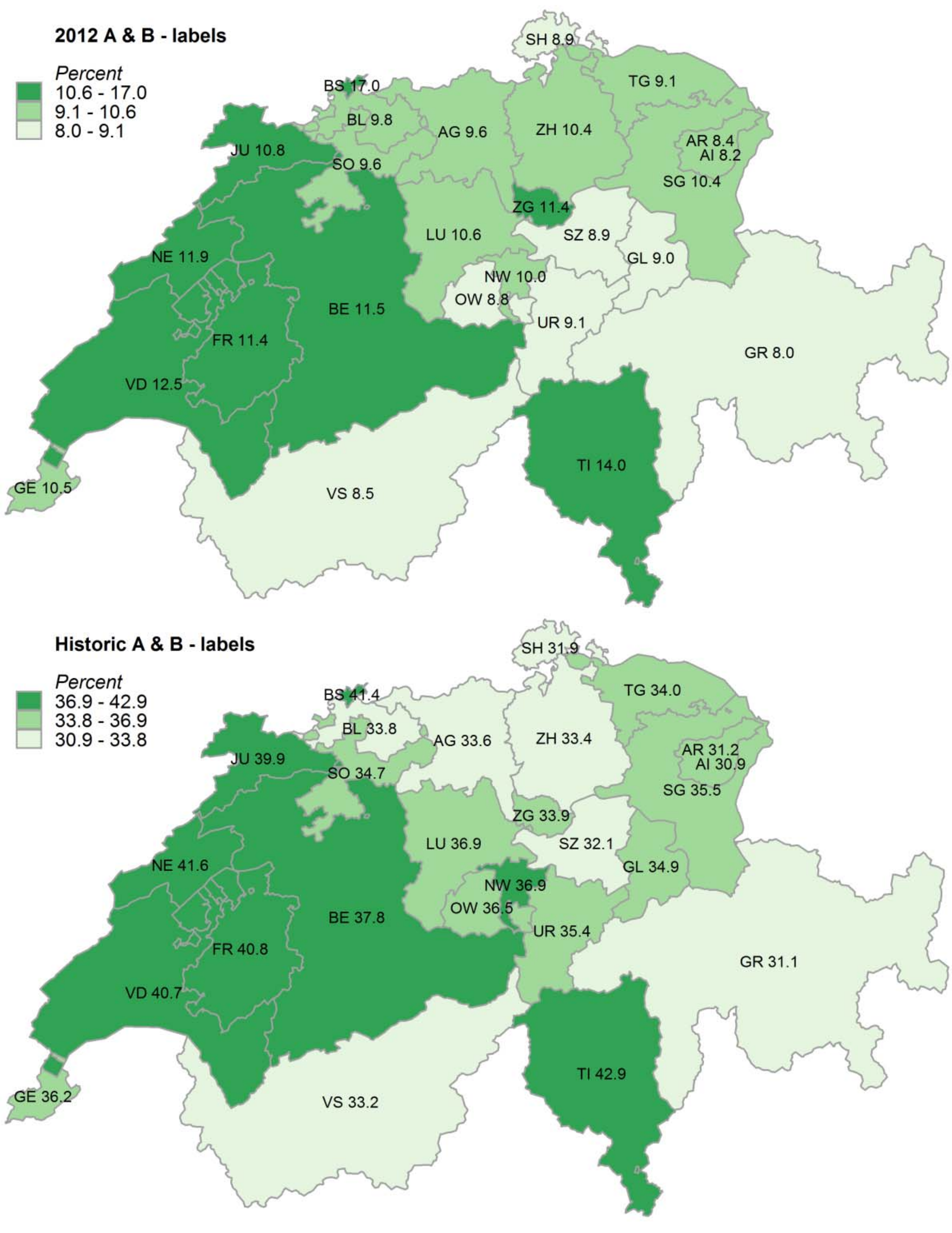

Figure 11: Maps illustrating the percentages of the 2012 A and B labels compared to the historic A and B labels at the cantonal level

As anticipated from previous results Basel-Stadt, Ticino, Vaud (VD), Neuchâtel (NE), Fribourg (FR), Bern (BE) and Jura (JU) have the highest shares of A- and B-labeled cars — whether we use the current or historical energy efficiency labels. The fact that Zug (ZG) appears in the group with high shares of 2012 A and B labels and low shares of historic A and B labels might be due to the young car fleet age and up to date technology. Other cantons which display vehicle characteristics similar to those in Zug range predominantly in the lower two terciles with small shares of efficient energy labels, such as Graubünden, Appenzell Innerrhoden and Ausserrhoden (AR), Schaffhausen (SH), Schwyz (SZ), Glarus (GL), Uri (UR), Obwalden (OW) and Valais (VS).

4.2.10. Car class

To the best of our ability and existing information, we grouped the car fleet into the conventional market segments, namely micro car (MC), subcompact (SC), compact (CC), midsize (MS), full-size (FS), luxury (LC), convertible or roadster (CR), sports coupé (CS), multi-purpose van (MV) and sport utility vehicle (SUV).

The most numerous class in 2012 is the compact car class, followed closely by the subcompact and midsize car classes (see Table 16). The two functional categories multi-purpose van and sport utility vehicle also enjoy large popularity in Switzerland. Especially the relatively young average age of SUV suggests that SUVs are a recent trend. The vehicle parameters differ considerably throughout the car segments. Within the car classes determined by length (MC, SC, MS, FS, LC) fuel consumption per 100 km, CO_2 emissions, curb weight, engine size and power increase consistently with size. Age also increases until to the full-size segment, then drops slightly in the luxury car class. From an efficiency point of view, three car classes stand out. Micro cars consume 5.5 liters per 100 kilometers and emit 129 grams of CO_2 per kilometer, while luxury and full-size cars are at the opposite end of the scale. Full-size cars produce 234 grams of CO_2 per kilometer and use 9.8 liters per 100 kilometers, which is only topped by the luxury car segment, with its 287 grams per kilometer and 12.1 liters per 100 kilometers. It is therefore not surprising that a third of the micro cars attain the efficiency labels A and B. More sport utility vehicles and multi-purpose vans than full-size cars make the A or B energy efficiency labels.

Table 16: 2012 car fleet grouped by car class[42]

Car class	Vehicles		FE	CO_2	A&B[43]	Age	Engine size	Engine power	Curb weight
	Freq.	%	l/100km	g/km	%	a	ccm	kW	kg
MC	161'412	4.59	5.5	129	32.8	6.1	1'087	51	959
SC	692'678	19.70	6.3	150	11.7	6.6	1'395	69	1'121
CC	710'730	20.21	7.4	176	12.7	7.3	1'747	96	1'359
MS	623'462	17.73	8.3	197	11.0	7.5	2'158	120	1'545
FS	147'503	4.19	9.8	234	3.6	8.0	2'813	159	1'733
LC	18'638	0.53	12.1	287	0.0	7.6	4'186	237	2'014
CR	149'883	4.26	8.7	207	2.1	7.7	2'208	131	1'432
CS	75'549	2.15	8.8	210	11.4	6.6	2'376	155	1'359
MV	485'825	13.81	8.0	190	9.2	6.2	1'888	94	1'595
SUV	451'072	12.83	9.2	219	4.7	5.1	2'414	130	1'775
Total/ Average	3'516'752	100	7.8	185	10.7	6.7	1'916	103	1'435

Comparing the spatial distribution of the three most popular car segments (subcompact, compact and midsize) with the trendy SUV car class, regional preferences are apparent. They are similar to those presented in earlier figures (see Figure 12).

Note that in this case municipal statistics are used to illustrate regional differences at a higher spatial resolution. The approach is the same; the relative frequencies of the car segments are computed at the municipal level, sorted and divided into terciles. The three colors represent relatively small, medium and large shares of the individual car classes.

[42] The generation of car segments follows the classification used by Touring Club Switzerland (TCS, 2012).
[43] Note that A and B labels correspond to the 2012 labels.

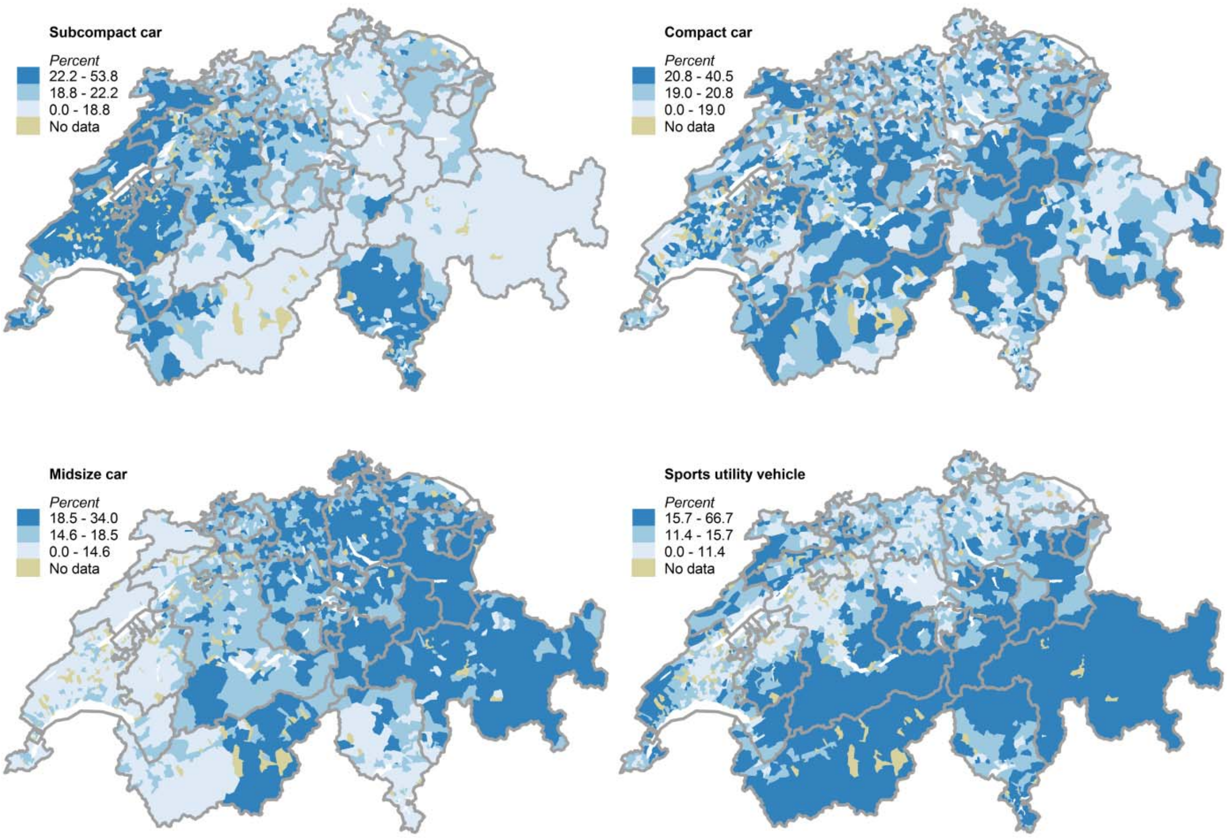

Figure 12: 2012 distribution of the subcompact, compact, midsize and SUV car segments

As illustrated in Figure 12, subcompact cars – the second largest vehicle class in Switzerland – are very popular in the Cantons of Vaud (VD), Genève (GE), Fribourg (FR), Neuchâtel (NE), Jura (JU), Ticino (TI), the majority of Bern (BE) and parts of Luzern (LU). Scattered local hotspots are also found in the Rhône valley (VS) and at the border between Uri (UR) and Graubünden (GR). In all these areas subcompact cars account for 22.2 to 53.8% of the municipal car fleet. In the German speaking Cantons of Schaffhausen (SH), Zürich (ZH), Zug (ZG), Schwyz (SZ), Glarus (GL), Appenzell Innerrhoden (AI) and Graubünden considerably fewer subcompact cars are found at the municipal level. In these cantons midsize vehicles enjoy great popularity, contributing between 18.5 to 34.0% to the municipal vehicle fleet. In general, subcompact and midsize vehicles display an opposing bimodal spatial distribution. Compact cars on the other hand, are more regularly distributed across Switzerland. They are present to a significant extent in all cantons with minor regional differences. The SUV segment has the widest spread of the displayed car classes with a range from 0.0 to 66.7% of the municipal passenger vehicles, meaning that there are communities where two out of three cars are sport utility vehicles. Figure 12 indicates that the majority of the SUVs are confined to the mountainous regions of the Alps and Jura formation. Local hotspots with high shares of SUVs can be found on the outskirts of the cities Zürich, Genève, Basel and Lugano.

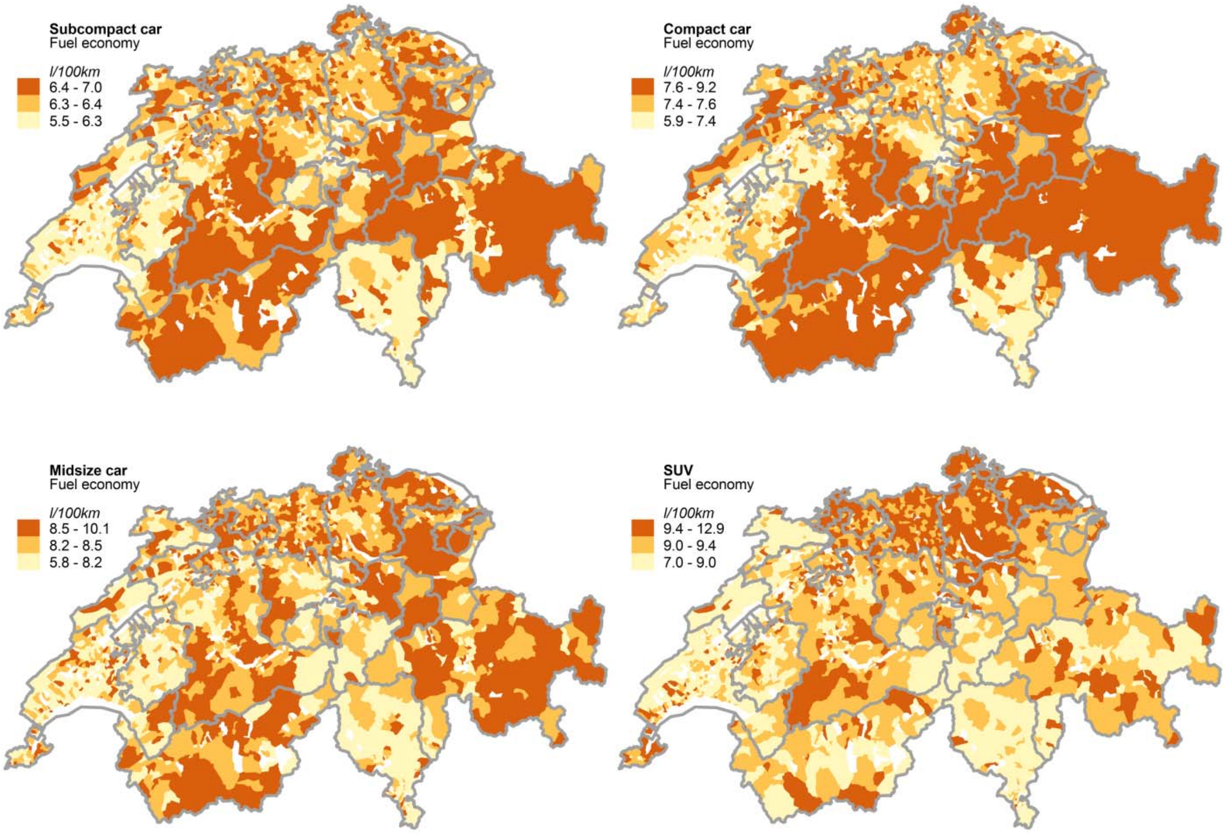

Figure 13: 2012 fuel efficiency distribution of subcompact, compact, midsize and SUV car segments

Figure 13 illustrates the spatial distribution of fuel efficiency for the four car classes subcompact, compact, midsize and SUV. Comparing Figure 12 and Figure 13 we observe that the regions with the largest shares of subcompacts (the French and Italian speaking parts of Switzerland) display the lowest fuel consumption rates for subcompacts. In regions where subcompact cars are generally not preferred, their fuel consumption is considerably higher, meaning that the relatively few subcompacts matriculated in these areas are less environmentally friendly than in the subcompact strongholds. SUVs show a similar pattern. The majority of SUVs is registered in the mountainous regions, where they seem to exhibit moderate fuel consumption rates. The heavy polluting SUVs on the other hand are found in the midlands, especially near the cities Zürich, Schaffhausen, Zug, Basel and Genève. In the case of compact and midsize vehicles the respective frequency distributions and the fuel consumption distributions look alike. In both cases the regions exhibiting the largest segment shares also display the highest fuel consumption values.

4.3. The Swiss car fleet of 2012 vs. topography and income

In this section we seek for possible associations between the characteristics of the car fleet and topography and income. The median values of the car fleet characteristics are computed by municipality. Then, the municipalities are sorted by their average taxable income per capita or their elevation level, respectively. As before the vehicle parameter median values are calculated, sorted and divided into three even terciles. The terciles are colored and displayed on a map to distinguish regions with low, medium and high parameter values accordingly. The topography and income conditions are superimposed on the map, identifying urban and mountainous areas as well as high-income regions.

In the first subsection we focus on urban areas, whereas in the second subsection we look at mountainous areas. The third subsection focuses on the income distribution and high-income communities in particular.

4.3.1. Urban area

Based on their owners' municipality, we place the passenger vehicles into one of four groups[44]: Urban, semi-urban, isolated cities and rural. Table 17 summarizes the vehicle characteristics by degree of urbanity.

[44] The four groups correspond to the categories used by FSO. Their definitions are based on statistical criteria, such as population, economic structure, the ratio of employed residents to the total residents and the integration of the municipality within its neighborhood. For more information please visit: http://www.bfs.admin.ch/bfs/portal/de/index/regionen/11/geo/analyse_regionen/04.html

Table 17: 2012 car fleet grouped by degree of urbanity (median values)

Degree of urbanity	Vehicles	A&B	Diesel	4WD	Age	Engine size	Engine power	Curb weight	FE	CO_2
	Freq.	%	%	%	a	ccm	kW	kg	l/100km	g/km
Urban	822´349	11.7	24.6	20.4	6.0	1'799	96	1420	7.4	176
Semi-urban	1´647´829	10.9	23.2	21.3	6.0	1'840	97	1421	7.5	177
Isolated cities	31´719	10.1	25.6	30.6	6.0	1'896	96	1434	7.5	178
Rural	1´014´413	9.6	23.5	28.7	7.0	1'798	92	1408	7.5	178

From Table 17, we observe that the largest share of the car fleet is matriculated in municipalities classified as semi-urban, whereas the fewest cars are found in isolated municipalities. But despite the difference in car numbers, fuel economy, age, power, engine size, curb weight and CO_2 emissions are very similar across the land use classes. Only the share of 4WDs is larger in rural areas than in urban areas.

Looking at the geographical distribution of urban areas in Figure 14 and Figure 15, one recognizes that urban regions are predominantly concentrated in the midlands and the Southern part of Ticino.

The fuel economy distribution and the occurrence of urban clusters (see Figure 14) indicate a moderate correlation between fuel efficiency and degree of urbanity. Urban areas display relatively fuel efficient car fleets. In the Italian and French speaking parts of Switzerland most of the urban areas display high fuel efficiency, but then again so do the rural areas. In the German speaking region the fuel economy is generally higher, but in urban areas mostly in the medium and not in the upper tercile. Noticeably, in several areas the urban community displays lower fuel consumption than surrounding rural municipalities. This can be observed for example for the cities Winterthur, Schaffhausen, Basel, Genève and Lugano, but also along rivers in major valleys – Rhône Valley, Rhine Valley and Thur Valley for instance. Similar results and patterns are found for engine size. Most urban areas have cars with small engines whereas neighboring communities commonly prefer larger engines. Interestingly, this isn't the case for Zürich. The city of Zürich is the only one out of the five major cities Bern, Genève, Basel, Lugano and Zürich that displays a median larger than 1896 cubic centimeters.

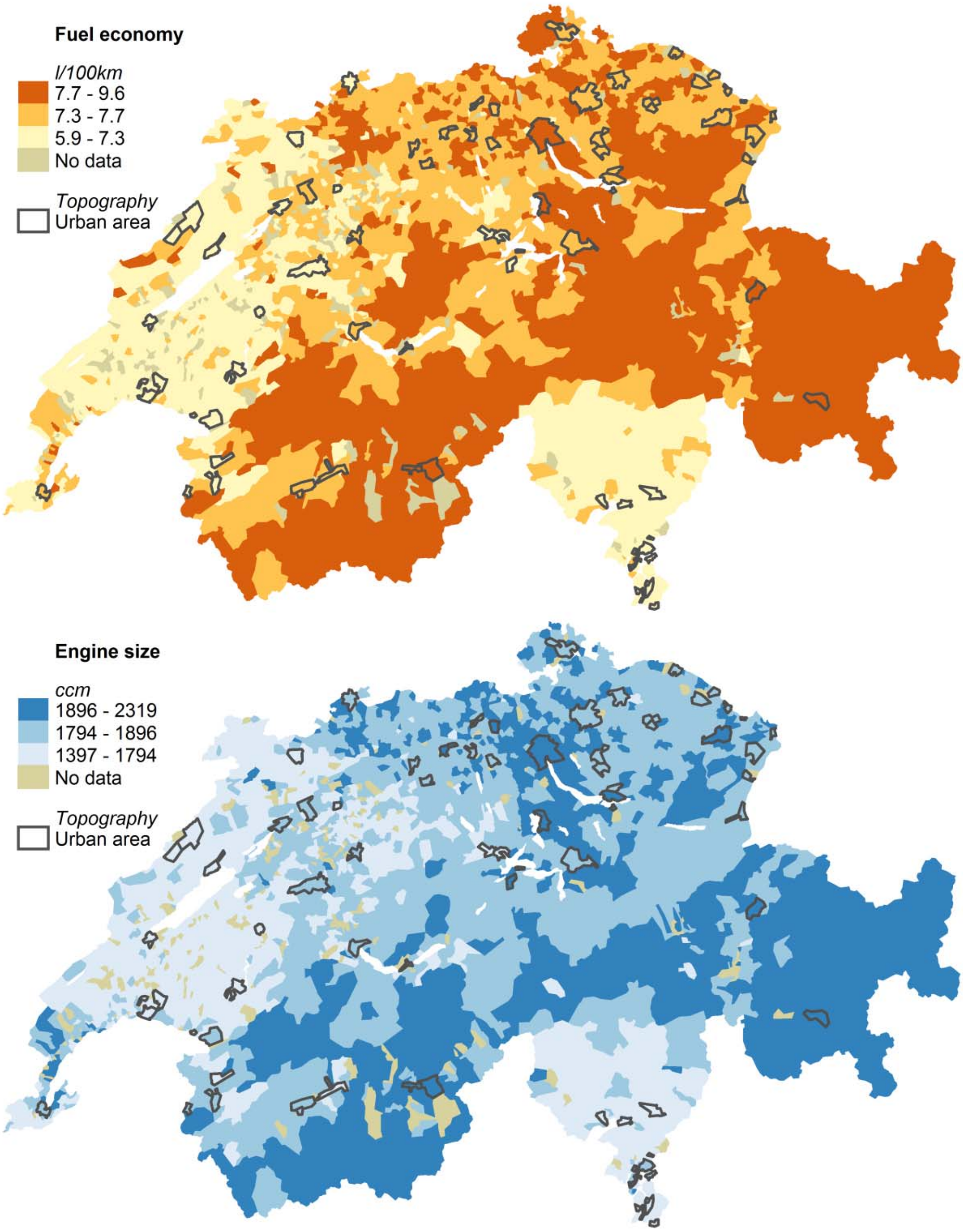

Figure 14: Maps illustrating the 2012 car fleet fuel efficiency and engine size at the municipal level with urban areas highlighted

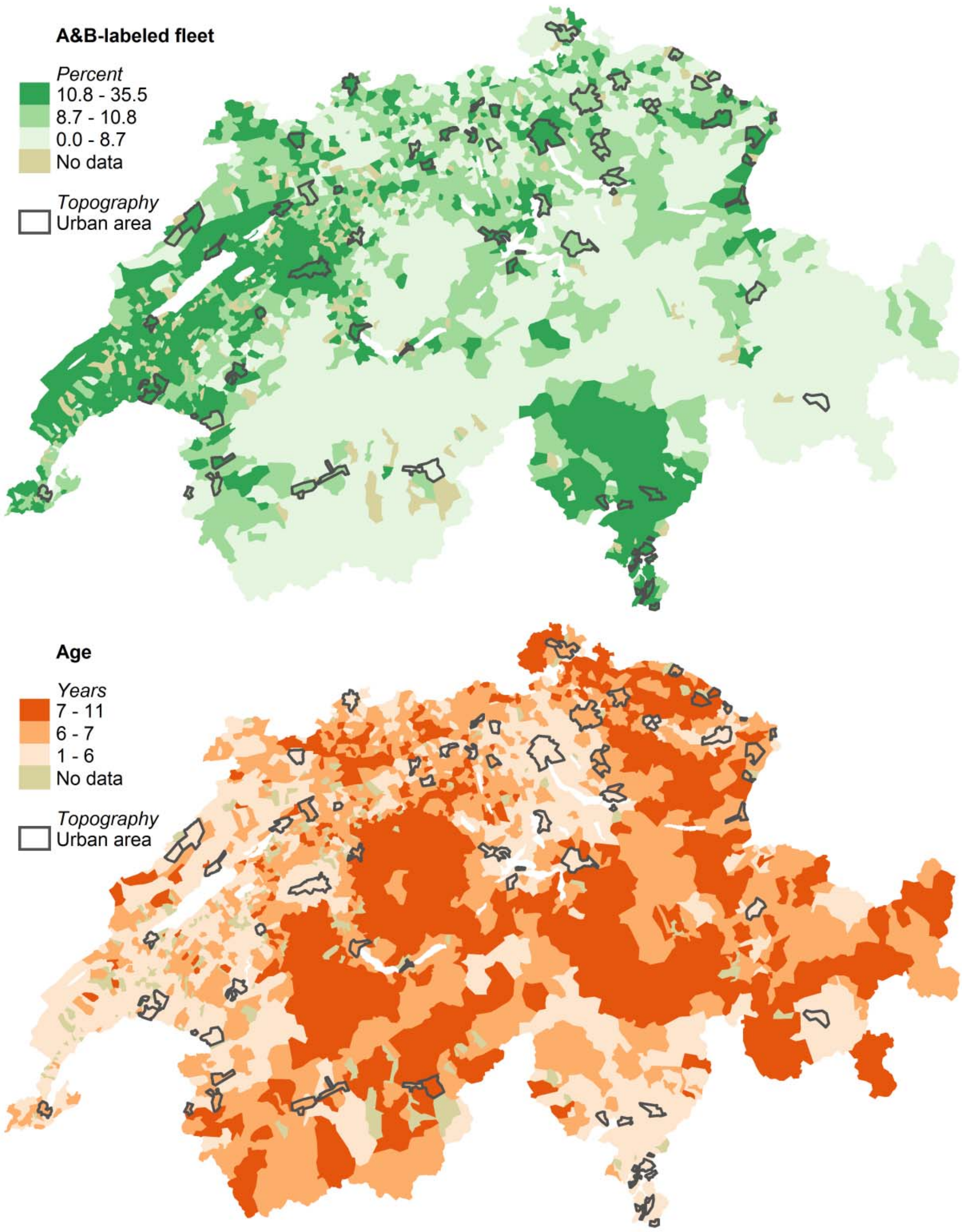

Figure 15: Maps illustrating the percentages of the 2012 A and B labels and age distribution at the municipal level with urban areas highlighted

Focusing on the distribution of A- and B-labeled cars and the age structure in urban municipalities (see Figure 15) suggests that a relatively high share of the urban population in Switzerland owns a “young” vehicle in category A or B. Virtually all urban areas have at least 9% or more of their fleet in the A or B-label classes. In addition, most of the cars in urban areas display a median age ranging between 1 year and 6 years. And new car fleets generally tend to be more fuel efficient due to technological advances; hence it is not surprising to see a negative correlation between vehicle age and share of A and B cars. Note that there are few regions – mostly near urban centers – where vehicle fleets are observed to be very young and nonetheless highly inefficient. Municipalities on the right shoreline of Lake Zürich are such examples.

4.3.2. Mountainous area

We are interested in checking if there is a connection between altitude and vehicle characteristics. Table 18 summarizes the vehicle characteristics by the elevation of the municipality of residence of the owner.

Table 18: 2012 car fleet grouped by elevation (median values)

Elevation	Vehicles	A&B	Diesel	4WD	Age	Engine size	Engine power	Curb weight	FE	CO_2
a.s.l.	Freq.	%	%	%	a	ccm	kW	kg	l/100km	g/km
< 440 m	1´484´153	11.2	23.5	19.7	6.0	1'834	96	1'420	7.5	177
440 – 525 m	954´668	10.6	23.1	20.6	6.0	1'799	96	1'415	7.5	178
526 – 706 m	678´599	10.9	23.8	23.1	7.0	1'798	94	1'408	7.5	177
> 706 m	399´332	8.8	25.4	43.3	7.0	1'896	92	1'435	7.6	180

The majority of the Swiss car fleet is found at lower altitudes throughout the midlands. The fleet is relatively similar across the first three altitude categories. The car fleet matriculated in regions more than 706 meter above sea level – which is classified as mountainous – differs from the rest, e.g. the shares of A- and B-labeled cars decreases in high altitude whereas the share of four-wheel drives increases.

For further analysis the municipalities of the mountainous forth elevation group (>706 m) are highlighted in the following graphs. The identified municipalities in Figure 16 and Figure 17 belong either to the geological formation of the Jura in the north-west of Switzerland or the Alps, stretching from the west-south-west to the east of the country covering roughly two thirds of the nation.

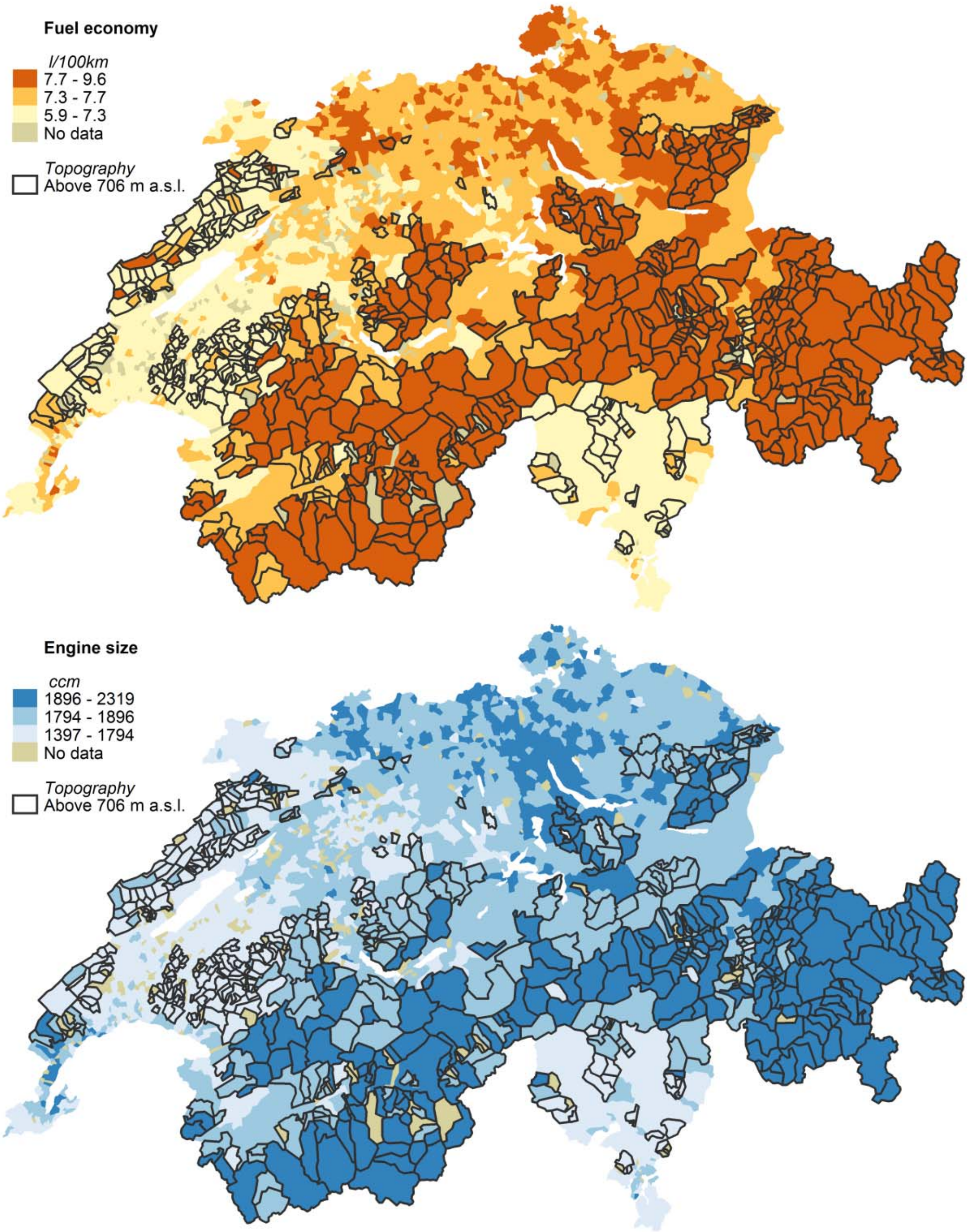

Figure 16: Maps illustrating the 2012 car fleet fuel efficiency and engine size at the municipal level with the mountainous regions highlighted

Most of the mountainous region coincides with the high fuel consuming fraction of the car fleet, as shown in Figure 16. Especially throughout the Alps the fuel efficiency distribution is highly correlated with the mountainous areas. The fact that municipalities along the main valleys through the mountains – Rhône Valley in VS and Rhine Valley in GR and SG for instance – display lower values than their neighboring communities located on the mountainside is nicely captured. In general, low fuel efficiencies are common in the alpine region whereas in the Jura only a handful of municipalities exhibit low fuel efficiency. In addition to this mismatch of high topography and low fuel consumption, fuel inefficient fleets can be observed even outside of the mountainous landscape. There are numerous communities with high fuel consumption in the German speaking midlands as well as alongside Lake Geneva.

The engine size distribution confirms the fuel efficiency results. Predominantly above-average engine blocks are found throughout the mountainous regions, but not everywhere and also not exclusively. Clusters near Zürich, Basel and Genève as well as individual municipalities near Lugano have large engine blocks although they are not considered mountainous.

In the Alps the pattern of A- and B-labeled cars visibly follows the landscape conditions to a large extent, showing that the shares of passenger vehicles certified with an A or B label are consequentially low in the mountainous regions (see Figure 17). And similar to fuel efficiency and engine size, the observed negative correlation between the shares of A- and B-labeled cars and mountainous landscape is missing in the Jura highlands.

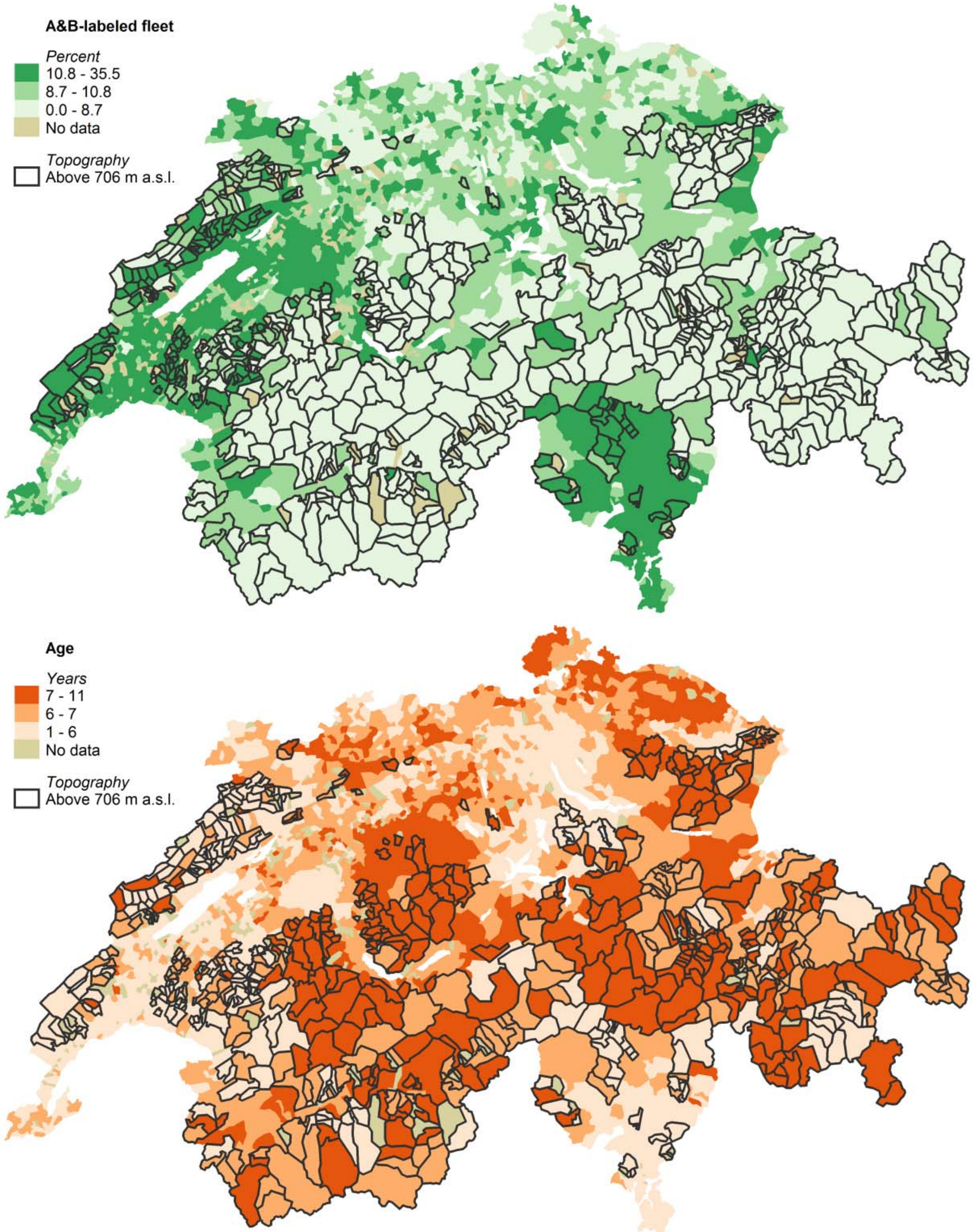

Figure 17: Maps illustrating the 2012 car fleet A and B label percentage at the municipal level with the mountainous region highlighted

Compared to the other car characteristics, the distribution of vehicle age matches the topographic distinction the least (see Figure 17). A moderate positive correlation seems to exist, at least in the Alps. In the cantons Bern (BE), Appenzell Innerrhoden and Ausserrhoden (AI, AR) and St. Gallen (SG) the patterns coincide nicely, indicating that passenger vehicles in mountainous landscape are commonly older than in the midlands. On the other hand there are several clusters in the Alps with very new car fleets – the regions around St. Moritz and Andermatt for instance. Interestingly, these car fleets are new and at the same time inefficient. The correlation between topography and vehicle age is less visible in the Jura formation compared to the Alps. Most of the municipalities at high altitude display low median vehicle ages as does the rest of the region. The same pattern is observed for the other vehicle parameters.

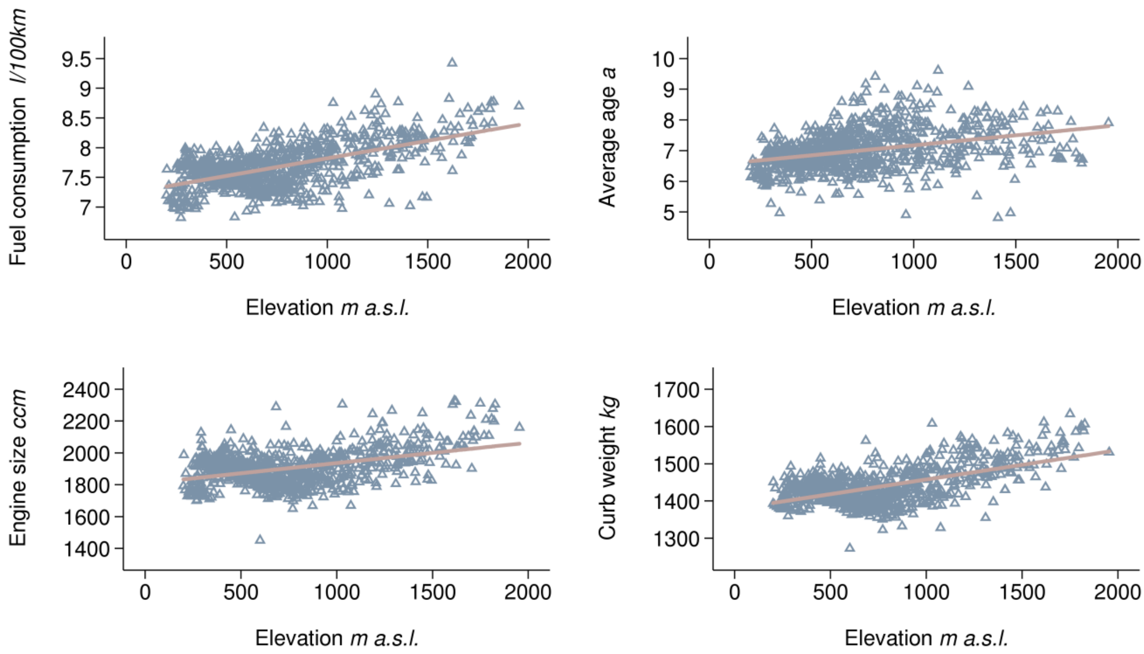

Figure 18: Correlation between elevation and 2012 vehicle parameters

In general, topography seems to play an important role in the composition of the car fleet. A positive correlation between elevation and selected vehicle characteristics in the maps is confirmed in Figure 18. However, the difference in car fleets between the south-west and north-east of the country in mountainous areas, which reduces the correlation between topography and car fleet parameters. The mountainous landscape alone cannot account for the vehicle characteristics found in Switzerland.

4.3.3. Income level

In this subsection we examine the possible correlation between income and the composition of the car fleet. The municipalities and their car fleets are ordered according to the average taxable income per capita and year and then divided into groups.[45] The median values of the vehicle characteristics corresponding to the different income classes are summarized in Table 19.

Table 19: 2012 car fleet grouped by taxable income per capita of 2009 (median values)

Income group	Vehicles	A&B	Diesel	4WD	Age	Engine size	Engine power	Curb weight	FE	CO_2
	Freq.	%	%	%	a	ccm	kW	kg	l/100km	g/km
≤ 50'000	19'904	6.3	23.7	53.6	9.0	1'896	90	1'427	8.0	190
50'001-55'000	89'499	8.2	24.6	42.2	8.0	1'896	92	1'420	7.7	183
55'001-60'000	335'720	9.9	23.7	26.3	7.0	1'798	92	1'400	7.5	177
60'001-65'000	716'877	10.4	23.5	22.3	7.0	1'796	92	1'396	7.4	176
65'001-70'000	796'197	11.2	23.7	20.2	6.0	1'798	94	1'405	7.4	176
70'001-75'000	455'041	11.5	24.3	21.5	6.0	1'798	96	1'419	7.4	176
75'001-80'000	507'565	11.0	23.2	21.3	6.0	1'896	99	1'430	7.5	178
80'001-85'000	107'325	11.1	24.0	22.5	6.0	1'895	98	1'430	7.5	178
85'001-90'000	126'011	10.2	22.4	23.0	6.0	1'896	100	1'434	7.6	179
90'001-95'000	40'802	9.8	23.0	28.6	6.0	1'896	100	1'450	7.6	180
> 95'000	321'811	10.3	23.7	28.2	5.0	1'968	103	1'478	7.7	182

45 Data for average taxable income per capita dates back to 2009, because these are the most recent data available.

The statistics displayed in Table 19 indicate that income per capita is highly correlated with many, but not all, vehicle characteristics. Moreover, the sign of the correlation varies depending on the vehicle characteristic. The shares of cars labeled A or B, Diesel or 4WD exhibit little correlation with income level. By contrast, vehicle power increases monotonically, and vehicle age decreases monotonically, with income. The data also suggest that fuel consumption and CO_2 emissions are highly correlated with income, although the shape of the relationship is non-linear.

Looking at the highest average income level (greater than 95´000 CHF per capita and year, which roughly corresponds to the top 5% municipalities concerning their income level) in Figure 19 and Figure 20, five distinctive clusters of wealthy municipalities emerge surrounding the economic centers Zürich, Zug, Genève, Basel and Lugano.

Figure 19 suggests that municipalities with higher income per capita generally tend to have cars with larger engines. Even in the municipalities with a high level of income per capita, however, there seem to be opposing trends along language divides. In the German speaking part of Switzerland the fuel consumption rates and engine sizes strongly match the income level patterns; high earning municipalities generally display higher fuel consumption and larger engine sizes than regions with the less income per capita. This is not the case in Ticino. Here the municipalities with high levels of income per capita display low fuel consumption just as the rest of the canton. The high income cluster along the coastline of Lake Geneva provides mixed results. A significant amount of wealthy municipalities appear to have an efficient car fleet with small engine size just as their neighboring communities.

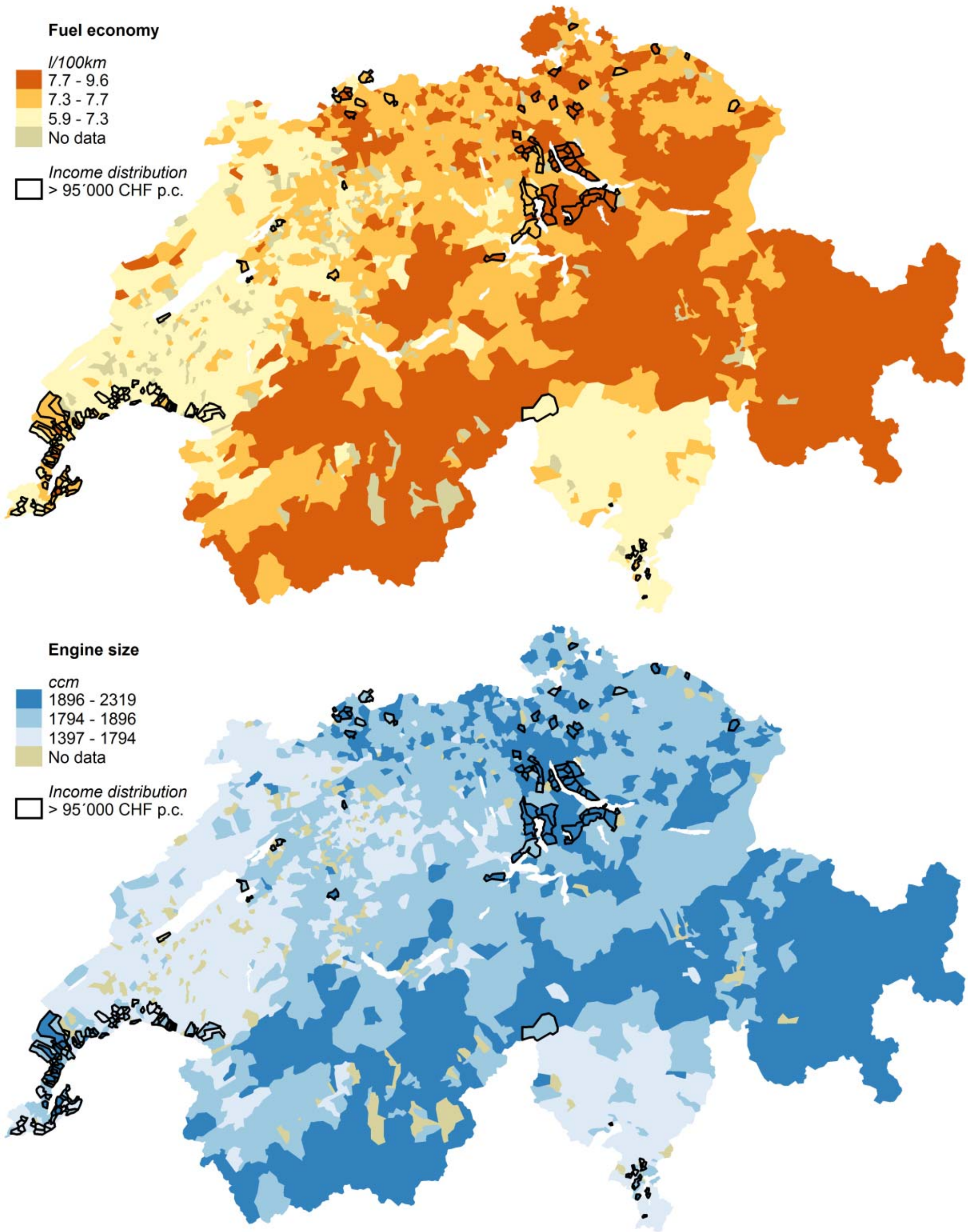

Figure 19: Maps illustrating the 2012 car fleet fuel efficiency and engine size at the municipal level with high income regions highlighted

Figure 20 shows that in the Italian and French speaking parts of the country there are numerous cars with energy efficiency label A or B, regardless of the level of income per capita. In the German speaking region the percentages of A- and B-labeled cars are noticeably lower in high-income communities.

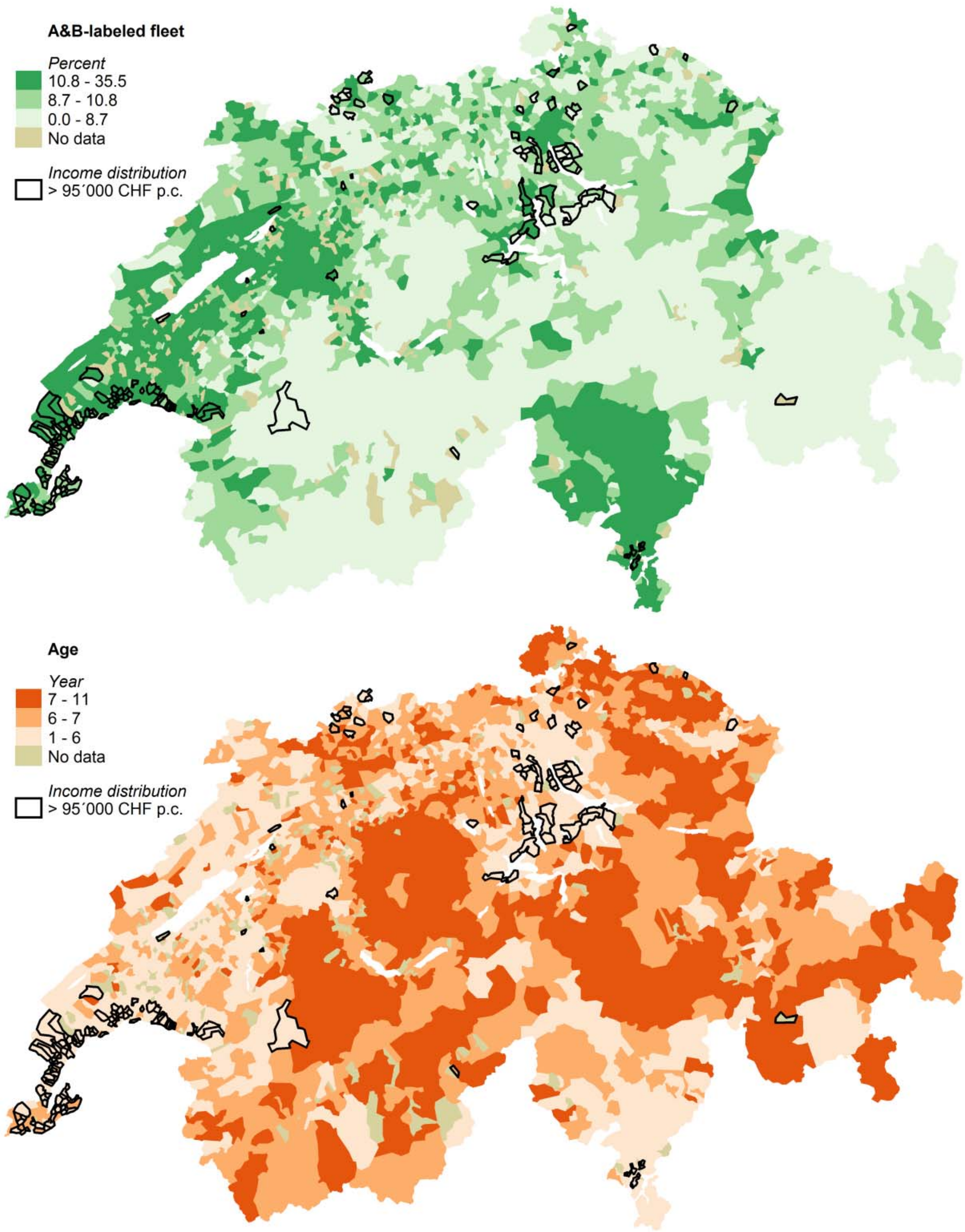

Figure 20: Maps illustrating the 2012 car fleet A and B label percentage and vehicle age at the municipal level with high income regions highlighted

The vehicle age structure appears to be roughly the same in high-income municipalities. All high-income municipalities generally have young fleet. A clearly negative correlation between vehicle age and income per capita can be observed in Figure 21.

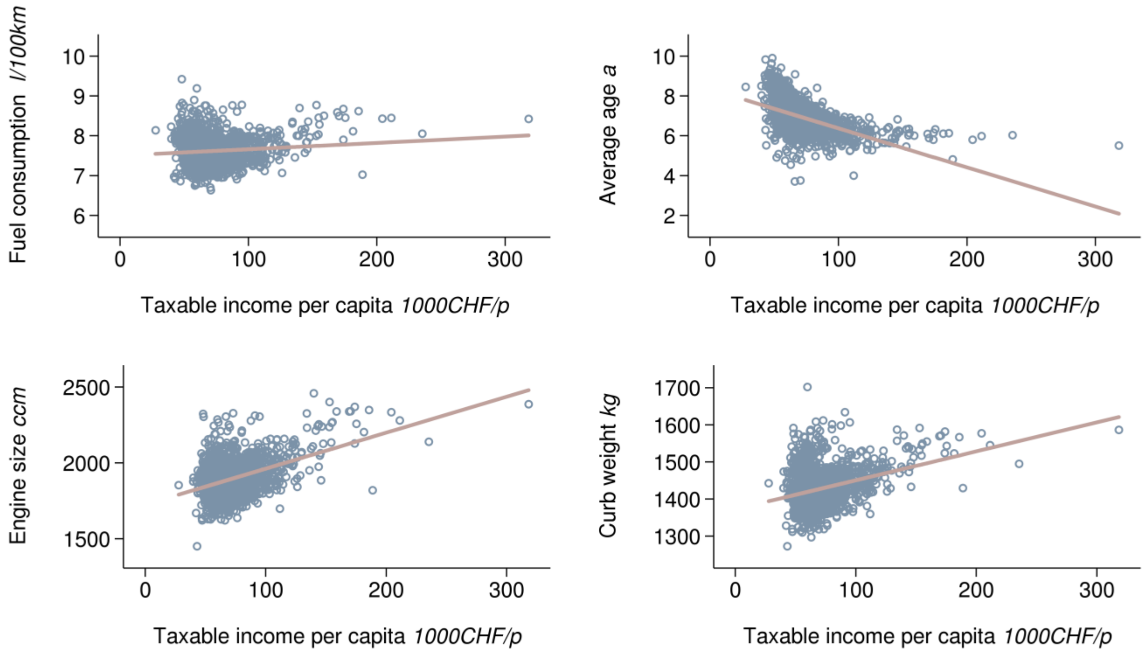

Figure 21: Correlation between income and 2012 vehicle parameters

In general, the data suggest that income is correlated with vehicle characteristics and may play an important role in explaining the car fleet composition. Differences along the language divides appear to be associated with car characteristics, regardless of income.

4.4. Policy measure

Plotting the data reveals no obvious correlation between CO_2- or fuel-economy-linked registration fee policies and the shares of A or B vehicles (see Figure 22). However, this report presents only a snapshot of the car fleet in 2012, and a detailed examination of the impact of different policy measures on the fleet composition will follow in Module 2 of this project.

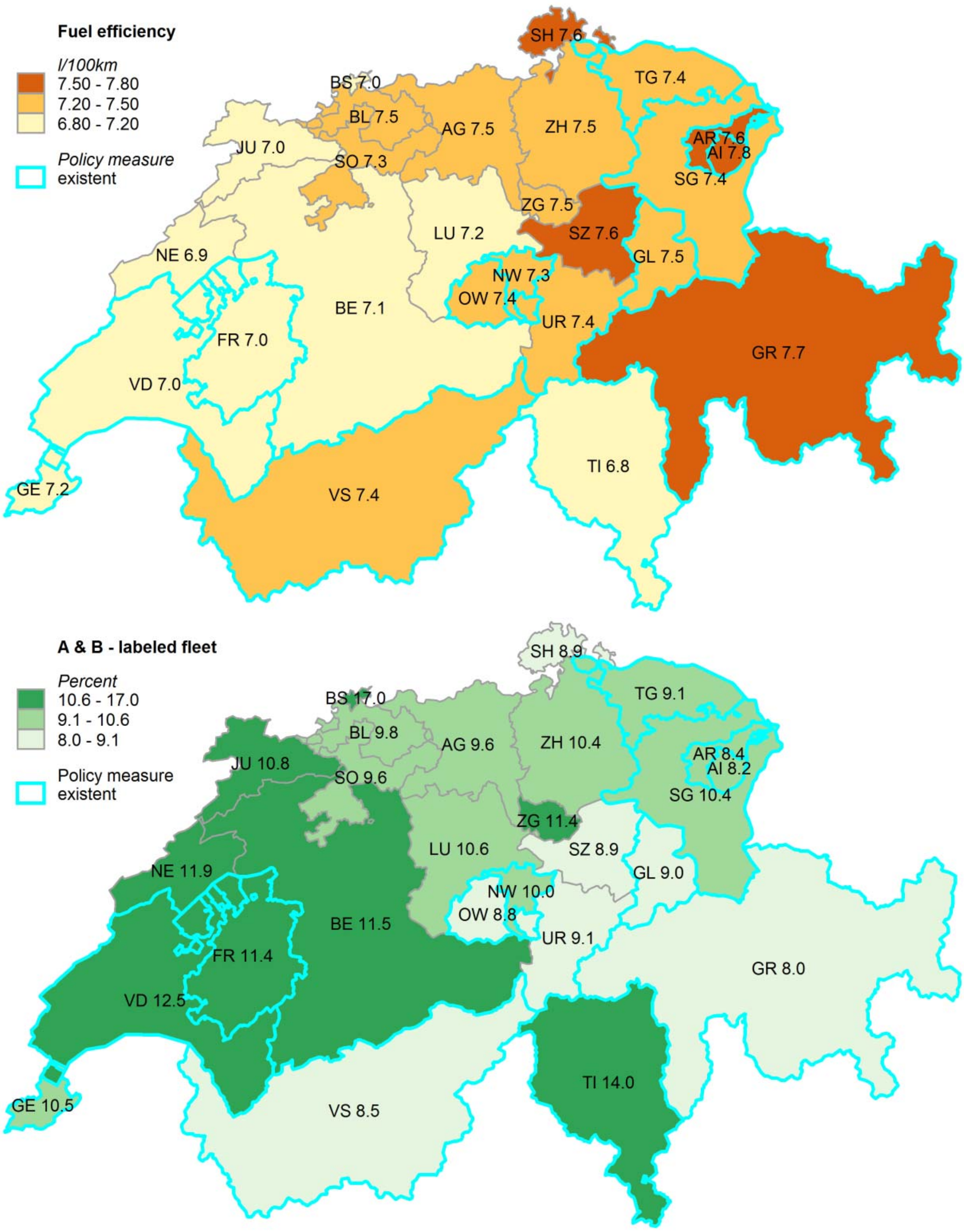

Figure 22: Maps illustrating the 2012 car fleet fuel efficiency and A & B label percentages at the cantonal level with the cantons granting general MVT reductions highlighted

4.5. Vehicle owner

In this subsection, we examine if the car is registered by a woman, a man or another party (such as a company) and show how these registrations are distributed over Switzerland.

Table 20: 2012 car fleet grouped by car owner[46]

Car owner	Vehicles		FE	Age	CO_2	A label*	Curb weight	Engine Power	Engine Size
	Freq.	%	l/100km	a	g/km	%	kg	kW	ccm
Men	1’874’591	55.37	7.8	7	190	0.14	1’468	108	1’985
Women	1’087’489	32.12	7.2	6.8	173	0.15	1’322	89	1’707
Company	405’869	11.99	7.5	4.7	186	0.2	1’575	116	2’101
Unknown	17’844	0.53	7.5	4.5	186	0.18	1’573	117	2’097
Total/Average	3’385’793	100.00	7.6	6.7	184	0.15	1’435	103	1’911

* A label at first registration

Table 20 shows that around 87% of the cars are registered by private persons (55% men, 32% women). A substantial amount of passenger cars are registered by companies (12%) in Switzerland. The latter include cars owned by rental car companies, and cars owned by other companies (which are used by employees to perform their regular work duties or are given to employees as fringe benefits). Our statistics indicate that companies hold newer and heavier cars with a bigger engine size and more horsepower than private persons. If we look at the energy efficiency expressed by the share of A-labelled cars at the date of first registration and the CO_2 emissions, we see that women drive the cars with the lowest CO_2 emissions, although companies have the highest share of A-labelled cars. We believe that this means that women buy smaller cars with low CO_2 emissions rate, but not necessarily the most efficient cars within that segment. Companies are probably more sensitive to fuel cost savings and try to buy

46 The information about the car owner was not available in the original dataset of the FSO and was delivered in a second step by the FEDRO. Unfortunately the two datasets where not absolutely identical wherefore the total figures of the summary statistic differ slightly.

segment-specific fuel-efficient cars. Many A-label cars are have diesel powertrain, which is appealing to companies because of its lower fuel costs. Men hold the oldest, most energy inefficient and highest CO_2 emitting car fleet.

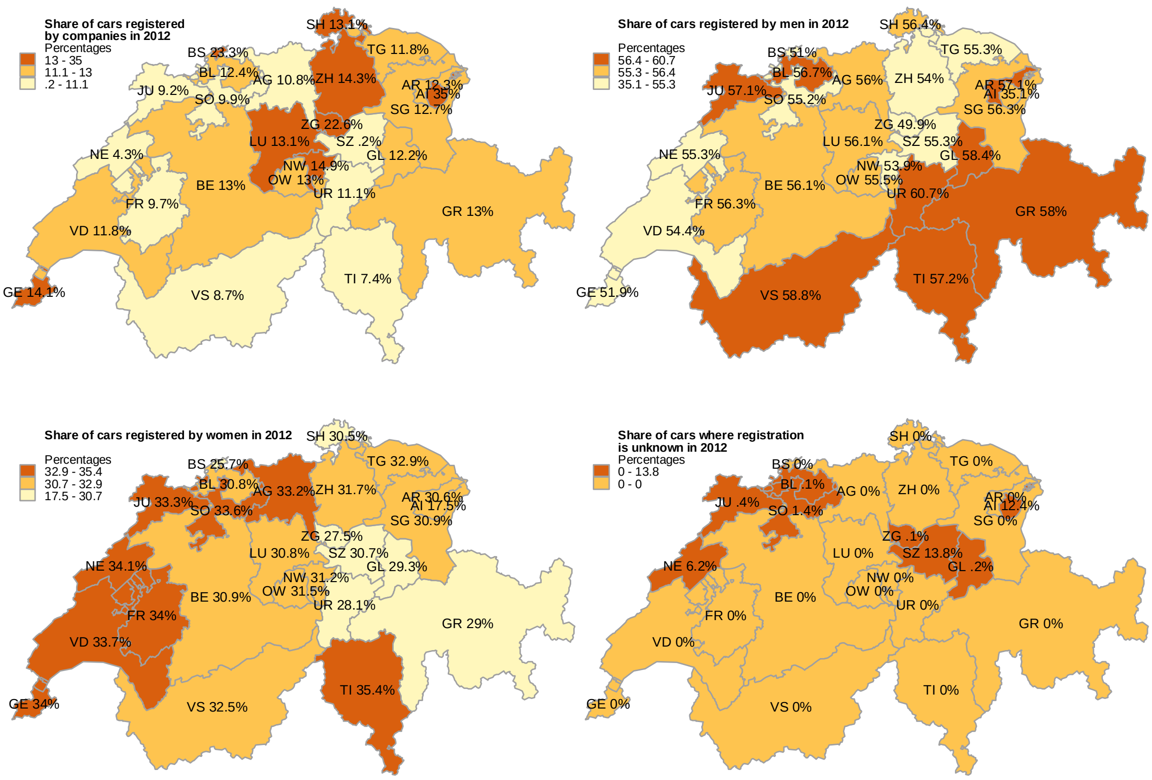

Figure 23: Map illustrating car owners of the 2012 car fleet at the cantonal level

Figure 24 displays the distribution of car owners across Switzerland. It shows that in cantons with high economic power such as Zurich (ZH), Geneva (GE) or Basel Stadt (BS) the share of company cars is rather high. In Appenzell-Innerrhoden (AI) the share is exceptionally high with 35%.[47] The underlying reason is that most of the car rental companies are located in AI because the cantonal road traffic licensing department offers a special tax treatment for these companies. Looking at the private car owners, it can be seen that in the western part of Switzerland a higher share of cars is registered by women. This coincides with the regions where the most energy efficient fleets are driven (compare with figure 24). It is possible that cultural differences between the German and Latin language-speaking parts of Switzerland lead to these different outcomes. It is also possible that the different shares of car registrations by men and women is an artifact due to "household cars," where we do not know if the person

[47] This share might be even higher if the high share of unknown registrations of 12% is considered in AI.

driving the car is the same person who registers the car. The map of unknown car owner might be an indicator of data inquiry problems in some cantons. For example in Schwyz (SZ) the share of company cars is only 0.2% but the share of unknown car owners is almost 14%.

5. Comparison of the Swiss new passenger car fleet with the European Union

This section presents a simple comparison of new passenger cars in Switzerland with those in neighboring countries and the European Union. In Figure 24, we show the trends for average CO_2 emissions rates and curb weight in Switzerland, its neighboring countries and the EU average.

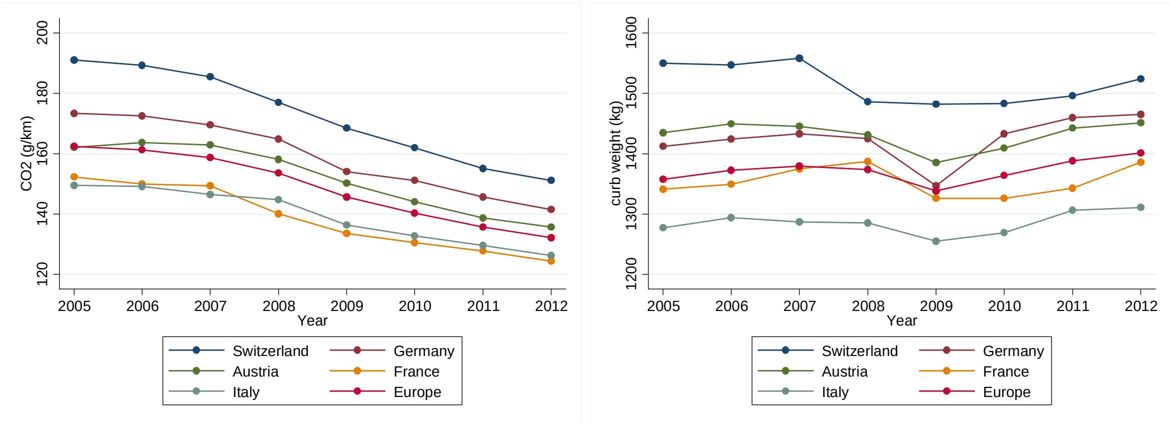

Figure 24: Trend of average CO_2 Emissions and curb weight of selected countries and the EU (Source: EEA, 2013 and own calculations)

Figure 24 shows clearly that new cars sold in Switzerland every year have the highest average CO_2 emissions and curb weight compared to its neighboring countries and the European Union. Germany and Austria buy higher emitting cars than France and Italy. France and Italy historically had smaller cars and larger shares of Diesel vehicles. Diesel cars account for some 70% of the new car sales in France (see in Figure 27 appendix 5). Germany, Austria and France have recently implemented registration fee systems based on CO_2 emissions, which we summarize in Table 21.

Table 21: Overview of CO_2-Based Motor Vehicle Taxes (Source: ACEA, 2013)

Austria	A fuel consumption tax (Normverbrauchsabgabe or NoVA) is levied upon the first registration of a passenger car. It is calculated as follows: Gasoline cars: 2% of the purchase price x (fuel consumption in liters – 3 liters) Diesel cars: 2% of the purchase price x (fuel consumption in liters – 2 liters) In July 2008 a bonus-malus system was implemented. Cars emitting less than 120g/km receive a maximum bonus of €300. Cars emitting more than 150g/km pay a penalty of €25 for each gram emitted in excess of 150g/km. There is an additional penalty of €25 for each gram emitted in excess of 170g/km and another penalty of €25 for each gram emitted in excess of 210g/km. These penalties are cumulative. Alternative fuel vehicles attract a bonus of maximum €500. In addition, diesel cars emitting more than 5mg of particulate matter per km pay a penalty of maximum €300. Diesel cars emitting less than 5mg of particulate matter per km and less than 80g of NOx per km attract a bonus of maximum €200. The same applies to gasoline cars emitting less than 60g of NOx per km.
France	France implemented the following system on January 1st 2008: Under a bonus-malus system, a premium is granted for the purchase of a new car when its CO2 emissions are 105g/km or less. The maximum premium is €7,000 (20g/km or less). An additional bonus of €200 is granted when a car of at least 15 years old is scrapped and the new car purchased emits maximum 105g/km. A malus is payable for the purchase of a car when its CO2 emissions exceed 135g/km. The maximum tax amounts to €6,000 (above 200g/km). In addition to this one-off malus, cars emitting more than 190g/km pay a yearly tax of €160. The regional tax on registration certificates (“carte grise”) is based on fiscal horsepower, which includes a CO_2 emissions factor. Tax rates vary between €27 and €51.20 per horsepower according to the region. The company car tax is based on CO_2 emissions. Tax rates vary from €2 for each gram emitted between 50 and 100g/km to €27 for each gram emitted above 250g/km.
Germany	The annual circulation tax for cars registered as from 1 July 2009 is based on CO_2 emissions. It consists of a base tax and a CO_2 tax. The rates of the base tax are €2 per 100cc (petrol) and €9.50 per 100 cc (diesel) respectively. The CO_2 tax is linear at €2 per g/km. Cars with CO_2 emissions below 110g/km are exempt.
Italy	None

Concerning the CO_2 emission target by 2015, Figure 24 shows that the EU is on the right path and some member states like Italy and France have already reached the target. In Switzerland the car importers still need to reduce the average CO_2 emissions by around 21 grams to meet the target requirements. We note here that the EU goals apply to manufacturers in the EU. Automakers can average emissions over all of Europe, but as Switzerland is not part of the EU and its car importers must meet the target in Switzerland, regardless of other countries.

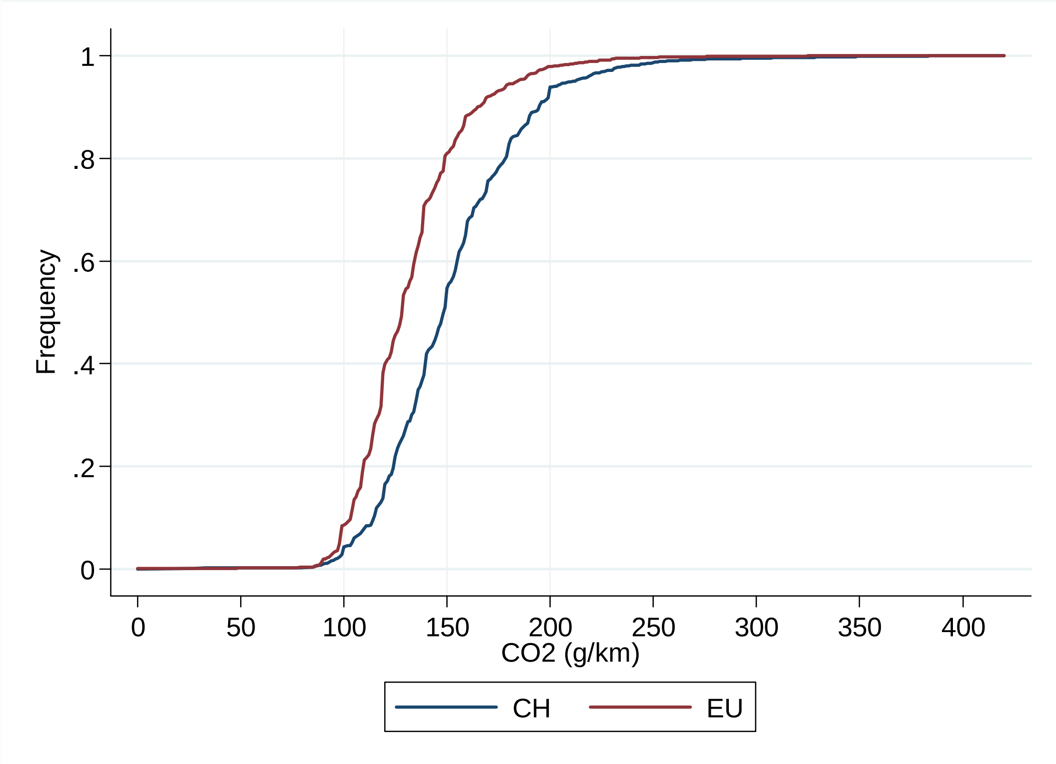

Figure 25: Cumulative distribution function of CO_2 emissions of CH and EU in 2012

Figure 25 compares the distribution of CO_2 emissions of new passenger cars in the EU and Switzerland in 2012. The cumulative distribution function in the EU rises much earlier and sharper which clearly indicates that the share of low emitting cars is much higher in the EU than in Switzerland. The graph shows that only around 50% of new registrations have CO_2 emissions below 150 g/km in Switzerland while it is around 80 % in the EU. It can also be seen that the amount of new passenger cars with CO_2 emissions above 200 g/km in Switzerland is much higher than in the EU. This distributions lead to a 19 g/km higher average of CO_2 emissions in Switzerland in 2012. Possible reasons for the higher average CO_2 emissions in Switzerland could be the low fuel prices, the topography and the high purchasing power.

Detailed tables about number of new car registrations, average CO_2 emissions and average curb weight in Switzerland and the EU member states can be found in appendix 5, Table 32 - Table 34.

6. Conclusion

We have examined the stock of passenger vehicles in Switzerland from 2005 to 2012 to identify trends in CO_2 emissions, fuel economy, and other vehicle characteristics, such as weight, engine size, and horsepower. We have used the vehicle registration data supplied by the individual cantons to the Swiss federal government (MOFIS) and merged them with vehicle emissions and technical characteristics from the TARGA dataset.

The data indicate that at this time about three-quarters of the Swiss passenger vehicles are gasoline-powered. Diesel-injection cars currently account for about 24% of the stock of passenger vehicles; their share has been growing over the years. Hybrid and plug-in electric vehicles have been growing in recent years, but still account for a very tiny share of the stock.

The growing popularity of Diesel engines has helped to improve the fuel economy of the fleet and to reduce CO_2 emissions rate. In 2012, the average emissions rate across the fleet was 185 grams of CO_2 per km, and the overall average fuel consumption was 7.6 gasoline-equivalent liters per 100 km. When attention is restricted to new car sales, however, the average CO_2 emissions rate in 2012 was about 151 grams per km, which means that Switzerland is still above the 130 grams per km goal set for 2015. Further analyses indicate that average weight, engine size, and horsepower of cars in Switzerland have been stable over the last eight years.

It is important to understand whether there are geographical patterns in the adoption of the especially heavy and high-emitting vehicles. We have produced a number of maps that indicate that cars owned by households in the Canton of Ticino and the cantons along the border with France tend to be smaller and lighter, and have better fuel economy and lower CO_2 emissions than in other parts of the country. We have also found preliminary evidence of correlation with income. Cars tend to be larger, heavier, emit a higher rate of CO_2 and use more fuel per unit of distance driven in the wealthier areas of the country. In fact, the emissions and fuel economy profile of the fleet seems to follow closely the language divides within Switzerland.

Caution should be used in interpreting these results because we have no data on the income of the individual vehicle owner: all we know is the average household income of the municipality where each vehicle owner resides. Moreover, our maps are based on simple univariate or bivariate analyses (no causality). Our goal for the next module of this research project is to model vehicle type ownership (and the associated fuel economy and emissions) in each area as a function of socioeconomic characteristics of the area, plus any policies adopted by the cantons to encourage a fuel-efficient, low-CO_2 emissions fleet.

References

ACEA (2013). *Overview of CO_2-based Motor Vehicle Taxes in the EU*. European Automobile Manufacturers' Association, Brussels.

BAFU (2012). Verordnung über die Reduktion der CO_2-Emissionen (CO_2-Verordnung): Erläuternder Bericht. Bundesamt für Umwelt, Bern, 30.11.2012. Abrufbar unter http://www.bafu.admin.ch/co2-abgabe/05311/index.html?lang=de&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1acy4Zn4Z2qZpnO2Yuq2Z6gpJCGfX94gmym162epYbg2c_JjKbNoKSn6A--

BAFU (2013). *Emissionen nach CO_2-Gesetz und Kyoto-Protokoll.* Letzte Aktualisierung 3.07.2013, Bundesamt für Umwelt, Bern. Abrufbar unter http://www.news.admin.ch/NSBSubscriber/message/attachments/31304.pdf

BFE (2003): *Bundesrat Leuenberger lanciert energieEtikette für Autos*. Medienmitteilung vom 24.02.2003, Bundesamt für Energie, Bern. Available from http://www.news.admin.ch/message/index.html?lang=de&msg-id=1473

BFE (2002). *EnergieSchweiz unterzeichnet erste Zielvereinbarung: Treibstoffverbrauch neuer Autos wird gesenkt.* Medienmitteilung vom 19.02.2002, Vereinigung Schweizer Automobil-Importeure (auto-schweiz), Bern. Abrufbar unter http://www.uvek.admin.ch/dokumentation/00474/00492/?lang=de&msg-id=1951

BFE (2009): *Schweizer Autos sind immer noch zu durstig*. Medienmitteilung vom 7.05.2009, Bundesamt für Energie, Bern. Abrufbar unter http://www.news.admin.ch/message/index.html?lang=de&msg-id=26779

BFE (2011). *CO_2-Zielwerte für Personenwagen gelten ab Mitte 2012*. Medienmitteilung vom 16.12.2011, Bundesamt für Energie, Bern. Abrufbar unter http://www.news.admin.ch/message/index.html?lang=de&msg-id=42730

BFE (2013). *17. Berichterstattung im Rahmen der Energieverordnung über die Absenkung des spezifischen Treibstoff-Normverbrauchs von Personenwagen 2012*. Erstellt von auto-schweiz im Auftrag vom Eidg. Departement für Umwelt, Verkehr, Energie und Kommunikation (UVEK), Bern.

BFS (2013a). *Mobilität in der Schweiz – Ergebnisse des Mikrozensus Mobilität und Verkehr 2010.* Erschienen am 8.05.2012, Bundesamt für Statistik, Neuchâtel.

BFS (2013b). *Synthesebericht Mobilität und Verkehr*. Erschienen am 20.08.2013, Bundesamt für Statistik, Neuchâtel.

EEA (2013). *Monitoring CO_2 emissions from new passenger cars in the EU: summary of data for 2012.* Published 30.04.2013, European Environment Agency (EEA), Copenhagen.

ESTV (2012). *Steuerbelastung in der Schweiz - Kantonshauptorte - Kantonsziffern 2012.* Eidgenössische Steuerverwaltung, Neuchâtel.

Galloni, E., Fontana, G., Palmaccio, R. (2013). *Effects of exhaust gas recycle in a downsized gasoline engine.* Applied Energy 2013;105:99-107

ICCT (2013). *European Vehicle Market Statistics, 2013: Pocketbook 2013*. Published 28.10.2013 by Peter Mock, International Council on Clean Transportation Europe (ICCT), Berlin

Najjar, Kevin (2013). *Analysis of the effect of cantonal motor vehicle tax discount measures on vehicle demand: the Swiss case*. (not published) Bachelor Thesis at the Center for Energy Policy and Economics (CEPE), Zürich

Nozawa, R., Morita, Y. and Shimizu, M. (1994). *Effects of engine downsizing on friction losses and fuel economy*. Tribology International, 1994;27:31-37

Sprei, F. and Karlsson, S. (2013). *Shifting fuels, downsizing or both? The Swedish example.* Transportation Research Part D: Transport and Environment, 2013;18:62-69

TCS (2012). *Verbrauchskatalog – Fahrzeugliste mit Verbrauchsangaben 2012*. Touring Club Schweiz, Emmen.

Appendix 1: Datasets

Table 22: MOFIS variables

MOFIS data

Available years: 2005-2012

Body design	Engine size	Particle filter	TG number
Canton	Fuel type	Payload	Total weight
Catalytic converter	Make code	Engine power	Use code
COC	Mileage at last service	Pseudo ID	Vehicle type
Drive	Nr of cylinders	Registration date	Zip code
Emission code	Nr of seats	Tag color	
Energy efficiency label	Nr of seats in front	Tag type	

Table 23: TARGA variables

TARGA data

Available years: 2005-2012

Air pollutants* **	Exhaust gas treatment	Nr of axes	Torque
Body type	Extension date	Nr of cylinders	Total weight range
Breaks	Fuel economy*	Nr of doors	Track width
CO_2 emissions*	Fuel type	Nr of seats	Transmission type
Curb weight range	Gearbox	Nr of strokes	UBP
Decommissioning code	Height	Nr of wheels	Vehicle type
Decommissioning date	Homologation date	On-Board-Diagnose	Version
Drive	Length	Engine power	Vmax
Driving noise	Make	Standing noise	Wheelbase
Emission code	Make code	Steering	Width
Energy efficiency label	Model	Suspensions	
Engine size	Nominal rotation speed	TG number	

* Primary fuel (PF) and secondary fuel (SF)

** including HC, NO_x, HC + NO_x, CO, CH_4, NMHC, PM and PZ

Table 24: Parameter of vehicle registration tax according to each canton in 2010 (ESTV, 2012)

Canton	Engine-size	Tax Horsepower	kW	Total weight
Aargau (AG)		X		
Appenzell A.Rh. (AR)				X
Appenzell I.Rh. (AI)				X
Basel-Landschaft (BL)				X
Basel-Stadt (BS)		X		
Bern (BE)				X
Fribourg (FR)	X			
Genève (GE)			X	
Glarus (GL)	X			
Graubünden (GR)		X		
Jura (JU)				X
Luzern (LU)		X		
Neuchâtel (NE)	X			X
Nidwalden (NW)	X			
Obwalden (OW)	X			
Schaffhausen (SH)	X			
Schwyz (SZ)	X			
Solothurn (SO)	X			
St. Gallen (SG)				X
Thurgau (TG)		X		
Ticino (TI)			X	X
Uri (UR)				X
Valais (VS)		X		
Vaud (VD)			X	X
Zug (ZG)	X			
Zürich (ZH)	X			

Table 25: Differentiation of vehicle registration tax according to each canton in 2012 (Source: Naijar, 2013)[48]

	HEV	Energy efficiency label	CO_2 emissions
AG			
AI			
AR	50% since 2005		50% if <130g/km since 2011
BL	50% but with 'A' since 2009		
BS			
BE			
FR	30% on hybrids since 2011	100% on A, Malus on 'D'/'E'/'F'/'G' since 2011	
GE			50% if <121g/km, Malus 50% if >200g/km since 2010
GL		50% on 'A' and 10%/20%/30% malus on 'E'/'F'/'G' since 2012	
GR			80% since 2009 (if <140g/km until 2010, if <120g/km until 2012)
JU	50% on hybrids since 2004		
LU	80% on lowest tax since 2006		
NE			
NW	50% since 2009	100% on 'A' since 2009	
OW	50% since 2009	100% on 'A', 50% on 'B' since 2009	
SH			
SZ	50% for 2008-2011 period		
SO			
SG		100% on 'A' label with CO_2 exhaust <130g/km since 2009	
TG		50% on 'A', 25% on 'B', Malus 50% on 'F','G', since 2011	
TI	50% cumulative discount since 2009	50% on 'A' with CO_2 exhaust <140g/km since 2009	
UR			
VD			50% if <120g/km since 2005
VS		50% on 'A' with CO_2 exhaust <130g/km since 2010	
ZH	50% since 2004		
ZG			

48 Electric cars and alternative fuels are not considered because of its small share on the overall car fleet.

Table 26: Topography variables

Topography data

Available years: 2005-2013

BFS Nr	IHG-region	Spatial planning region	ZIP code
Agglomeration	Language region	Tourism region	ZKX
Agglomeration grouped by capita	Metropolitan area	Typology of MS region	ZKY
Area_ha	Mountain region	Urban/rural	ZKZ
ASE region	MS region	WEG 2001	ZMAX
Canton	Municipality grouped by capita	XMAX	ZMEAN
District	Municipality name	XMIN	ZMED
Employment region	Municipality type (22)	YMAX	ZMIN
Grand region	Municipality type (9)	YMIN	

Table 27: Income variables

Income data

Available years: 2005-2009

BFS Nr	Net income_20-29.9	Partner deduction	Taxable income_30-39.9
Canton	Net income_30-39.9	Support deduction	Taxable income_40-49.9
District	Net income_40-49.9	Tax district	Taxable income_50-74.9
Insurance deduction	Net income_50-74.9	Tax revenue	Taxable income_75+
Municipality name	Net income_75+	Taxable income	Taxable income_total
Net income	Net income_total	Taxable income_16-19.9	
Net income_16-19.9	Nr of tax payers	Taxable income_20-29.9	

Table 28: Demographic variables

Demographic data

Available years: 2000; 2005-2011; 2009; 2010-2011; 2011

BFS Nr	Language by nat. _civil domicile	Nr of hh per size _non-family	Nr of non-residential buildings _building period
Age	Language by nat. _econ. domicile	Nr of hh per size _private	Nr of residential buildings _building period
Employ. Category _sex & nationality	Municipality name	Nr of hh per size _shared	Nr of single-family-houses _building year
Employment category _tot	Nationality	Nr of hh per size _total	Political party strength
Inhabitants	Nr of hh per size _family	Nr of multi-family-houses _building year	Sex

Table 29: Regional accessibility variables

Regional accessibility data

Available years: 2011

Source: Verkehrsmodellierung VM-UVEK (ARE), INFOPLAN-ARE, swisstopo

BFS Nr
ÖVaccess_quality
TraveltoCity_MIV
TraveltoCity_ÖV
TraveltoAgglo_MIV
TraveltoAgglo_ÖV

Appendix 2: Comparison of original dataset and CEPE dataset

Table 30: Comparison of original and final CEPE dataset per canton in 2012 (mean values and median values in parentheses)

Canton	Observations (original)	Observations (CEPE dataset)	Share	Engine Size (original)	Engine Size (CEPE)	Curb weight (original)	Curb weight (CEPE)	Car age (original)	Car age (CEPE)
				ccm	ccm	kg	kg	a	a
AG	357'159	299'905	83.97%	1'984	1'942	1'423	1'439	8.5	6.9
				(1'896)	(1'896)	(1'409)	(1'426)	(7)	(7)
AI	8'656	7'338	84.77%	2'071	2'025	1'467	1'482	8.7	7.1
				(1'968)	(1'968)	(1'465)	(1'481)	(8)	(7)
AR	29'141	24'312	83.43%	2'006	1'961	1'436	1'450	8.8	7.0
				(1'968)	(1'910)	(1'440)	(1'460)	(8)	(7)
BE	496'997	380'749	76.61%	1'912	1'869	1'396	1'418	9.1	6.9
				(1'799)	(1'796)	(1'383)	(1'400)	(8)	(7)
BL	141'543	119'426	84.37%	1'999	1'956	1'424	1'439	8.6	7.0
				(1'905)	(1'896)	(1'405)	(1'425)	(7)	(7)
BS	67'357	38'437	57.06%	2'015	1'960	1'439	1'462	8.8	5.9
				(1'910)	(1'840)	(1'420)	(1'441)	(8)	(5)
FR	164'233	146'118	88.97%	1'817	1'794	1'376	1'390	7.8	6.6
				(1'769)	(1'749)	(1'360)	(1'375)	(7)	(6)
GE	219'841	181'001	82.33%	1'962	1'923	1'406	1'427	8.6	6.8
				(1'796)	(1'796)	(1'375)	(1'394)	(7)	(6)
GL	21'821	18'286	83.80%	1'943	1'915	1'427	1'446	8.6	7.1
				(1'896)	(1'896)	(1'421)	(1'445)	(8)	(7)

Canton	Observations (original)	Observations (CEPE dataset)	Share	Engine Size (original) ccm	Engine Size (CEPE) ccm	Curb weight (original) kg	Curb weight (CEPE) kg	Car age (original) a	Car age (CEPE) a
GR	104'543	85'731	82.01%	2'036	2'012	1'475	1'498	8.7	7.0
				(1'968)	(1'968)	(1'480)	(1'505)	(8)	(7)
JU	40'077	31'714	79.13%	1'801	1'768	1'362	1'383	8.4	6.5
				(1'761)	(1'598)	(1'350)	(1'368)	(7)	(6)
LU	196'150	169'720	86.53%	1'911	1'874	1'411	1'423	8.2	6.9
				(1'798)	(1'796)	(1'395)	(1'400)	(7)	(7)
NE	93'511	74'047	79.19%	1'803	1'770	1'364	1'380	8.1	6.4
				(1'761)	(1'598)	(1'345)	(1'359)	(7)	(6)
NW	24'835	21'476	86.47%	2'023	1'969	1'451	1'456	7.9	6.6
				(1'896)	(1'896)	(1'428)	(1'437)	(7)	(6)
OW	20'700	17'649	85.26%	1'955	1'915	1'441	1'455	8.7	7.2
				(1'896)	(1'896)	(1'423)	(1'445)	(8)	(7)
SG	259'600	213'865	82.38%	1'988	1'944	1'426	1'441	8.6	7.0
				(1'896)	(1'896)	(1'415)	(1'435)	(8)	(7)
SH	42'344	33'779	79.77%	1'983	1'941	1'414	1'434	9.3	7.5
				(1'905)	(1'896)	(1'400)	(1'422)	(8)	(7)
SO	145'959	121'194	83.03%	1'922	1'884	1'394	1'414	8.8	7.0
				(1'798)	(1'796)	(1'382)	(1'395)	(8)	(7)
SZ	91'154	72'771	79.83%	2'106	2'052	1'492	1'501	8.5	6.6
				(1'968)	(1'968)	(1'479)	(1'485)	(7)	(6)
TG	151'992	124'162	81.69%	1'971	1'927	1'405	1'422	9.1	7.5
				(1'896)	(1'870)	(1'392)	(1'405)	(8)	(7)
TI	211'723	184'943	87.35%	1'846	1'816	1'664	1'687	7.8	6.2
				(1'699)	(1'598)	(1'615)	(1'643)	(6)	(6)

Canton	Observations (original)	Observations (CEPE dataset)	Share	Engine Size (original)	Engine Size (CEPE)	Curb weight (original)	Curb weight (CEPE)	Car age (original)	Car age (CEPE)
				ccm	ccm	kg	kg	a	a
UR	18'441	15'693	85.10%	1'920	1'890	1'420	1'439	8.7	7.3
				(1'896)	(1'896)	(1'410)	(1'435)	(8)	(7)
VD	384'752	337'052	87.60%	1'876	1'846	1'397	1'412	7.7	6.3
				(1'781)	(1'781)	(1'375)	(1'385)	(6)	(6)
VS	197'768	166'693	84.29%	1'948	1'922	1'415	1'436	8.9	7.2
				(1'896)	(1'896)	(1'394)	(1'415)	(8)	(7)
ZG	71'055	60'910	85.72%	2'210	2'152	1'533	1'541	7.2	5.8
				(1'984)	(1'984)	(1'517)	(1'528)	(5)	(5)
ZH	694'008	569'773	82.10%	2'043	1'997	1'452	1'467	8.2	6.5
				(1'968)	(1'956)	(1'440)	(1'456)	(7)	(6)
Total	4'255'452	3'516'752	82.64%	1'957	1'916	1'433	1'450	8.4	6.7
				(1'896)	(1'799)	(1'410)	(1'430)	(7)	(6)

Appendix 3: Aggregated cantonal data

Table 31: Mean and Median value of vehicle parameters at the cantonal level in 2012

Canton	A&B	Diesel	4WD	Age	Engine size	Engine power	Curb weight	FE	CO_2	FE/kg	CO_2/kg
	%	%	%	a	ccm	kW	kg	l/100km	g/km	l/(100km*100kg)	g/(km*100kg)
AG											
-mean	9.6	21.9	18.1	6.9	1'942	105	1'439	7.9	187	0.553	13.2
-median				7	1'896	100	1'426	7.6	181	0.552	13.1
AI											
-mean	8.2	24.9	54.1	7.1	2'025	110	1'482	8.2	195	0.559	13.3
-median				7	1'968	103	1'481	8	190	0.562	13.4
AR											
-mean	8.4	23.2	46.8	7.1	1'960	105	1'450	8	191	0.56	13.3
-median				7	1'910	97	1'460	7.8	185	0.566	13.5
BE											
-mean	11.5	25.2	22.4	6.9	1'869	99	1'418	7.7	182	0.548	13
-median				7	1'796	92	1'400	7.4	175	0.546	13
BL											
-mean	9.8	21.3	18.6	7	1'956	105	1'438	7.9	188	0.555	13.2
-median				7	1'896	100	1'425	7.7	181	0.556	13.2
BS											
-mean	17	30.8	17.4	5.9	1'960	105	1'461	7.7	182	0.531	12.6
-median				5	1'840	95	1'440	7.2	170	0.526	12.5

Canton	A&B	Diesel	4WD	Age	Engine size	Engine power	Curb weight	FE	CO_2	FE/kg	CO_2/kg
	%	%	%	a	ccm	kW	kg	l/100km	g/km	l/(100km*100kg)	g/(km*100kg)
FR											
-mean	11.4	21.9	17.4	6.6	1'794	95	1'390	7.4	177	0.542	12.9
-median				6	1'749	88	1'375	7.2	170	0.54	12.8
GE											
-mean	10.5	21.7	19.8	6.8	1'923	103	1'427	7.8	185	0.552	13.1
-median				6	1'796	92	1'395	7.4	176	0.549	13.1
GL											
-mean	9	24.6	36.4	7.1	1'915	102	1'445	7.9	188	0.552	13.1
-median				7	1'896	96	1'445	7.7	181	0.555	13.2
GR											
-mean	8	30.4	59	7	2'012	108	1'498	8.2	196	0.555	13.2
-median				7	1'968	103	1'505	8	190	0.558	13.3
JU											
-mean	10.8	21.2	19.4	6.5	1'768	94	1'382	7.4	176	0.545	12.9
-median				6	1'598	88	1'365	7.2	170	0.541	12.8
LU											
-mean	10.6	22.4	18.8	6.9	1'874	100	1'422	7.7	183	0.547	13
-median				7	1'796	92	1'400	7.4	177	0.546	13
NE											
-mean	11.9	22.8	20.2	6.4	1'770	95	1'380	7.4	175	0.542	12.9
-median				6	1'598	88	1'359	7.1	168	0.537	12.7

Canton	A&B	Diesel	4WD	Age	Engine size	Engine power	Curb weight	FE	CO_2	FE/kg	CO_2/kg
	%	%	%	a	ccm	kW	kg	l/100km	g/km	l/(100km*100kg)	g/(km*100kg)
NW											
-mean	10	23.9	25.4	6.6	1'970	106	1'456	7.8	186	0.544	12.9
-median				6	1'896	97	1'436	7.5	178	0.544	12.9
OW											
-mean	8.8	25.7	33.7	7.2	1'914	101	1'454	7.9	187	0.548	13
-median				7	1'896	94	1'445	7.6	180	0.547	13
SG											
-mean	10.4	23.8	25.7	7	1'943	104	1'441	7.9	187	0.552	13.1
-median				7	1'896	98	1'435	7.6	180	0.552	13.2
SH											
-mean	8.9	20.9	19.6	7.4	1'937	103	1'433	8	190	0.563	13.4
-median				7	1'896	96	1'420	7.8	185	0.568	13.5
SO											
-mean	9.6	20.9	17.7	7	1'883	101	1'414	7.8	184	0.555	13.2
-median				7	1'796	94	1'395	7.5	178	0.554	13.2
SZ											
-mean	8.9	23.5	34.3	6.6	2'051	114	1'484	8.1	193	0.551	13.1
-median				6	1'968	103	1'475	7.8	185	0.55	13.1
TG											
-mean	9.1	20.4	17	7.5	1'927	103	1'422	7.9	188	0.56	13.3
-median				7	1'870	96	1'405	7.6	181	0.563	13.4

Canton	A&B	Diesel	4WD	Age	Engine size	Engine power	Curb weight	FE	CO_2	FE/kg	CO_2/kg
	%	%	%	a	ccm	kW	kg	l/100km	g/km	l/(100km*100kg)	g/(km*100kg)
TI											
-mean	14	25.5	24.5	6.2	1'816	97	1'410	7.4	175	0.531	12.6
-median				6	1'598	85	1'383	7	166	0.525	12.5
UR											
-mean	9.1	25	34.9	7.3	1'891	99	1'439	7.8	186	0.551	13.1
-median				7	1'896	92	1'436	7.6	180	0.555	13.2
VD											
-mean	12.5	24.9	20.5	6.3	1'846	99	1'411	7.5	178	0.539	12.8
-median				6	1'781	90	1'385	7.2	170	0.535	12.7
VS											
-mean	8.5	25.1	34.7	7.2	1'922	102	1'436	7.9	188	0.558	13.2
-median				7	1'896	95	1'415	7.6	180	0.559	13.3
ZG											
-mean	11.4	28.9	30.5	5.8	2'152	122	1'539	8.2	194	0.536	12.7
-median				5	1'984	110	1'525	7.8	185	0.533	12.6
ZH											
-mean	10.4	23	22.2	6.5	1'996	110	1'466	8	189	0.549	13
-median				6	1'956	103	1'456	7.7	183	0.548	13
Total											
-mean	10.8	23.6	22.1	6.7	1'927	104	1'439	7.8	185	0.548	13

Appendix 4: Comparison of mean and median

For the spatial description of the car fleet, median instead of mean statistics are utilized to give an insight to the variety observed in the regional car fleets. The application of the median rather than the mean is advantageous in this case.

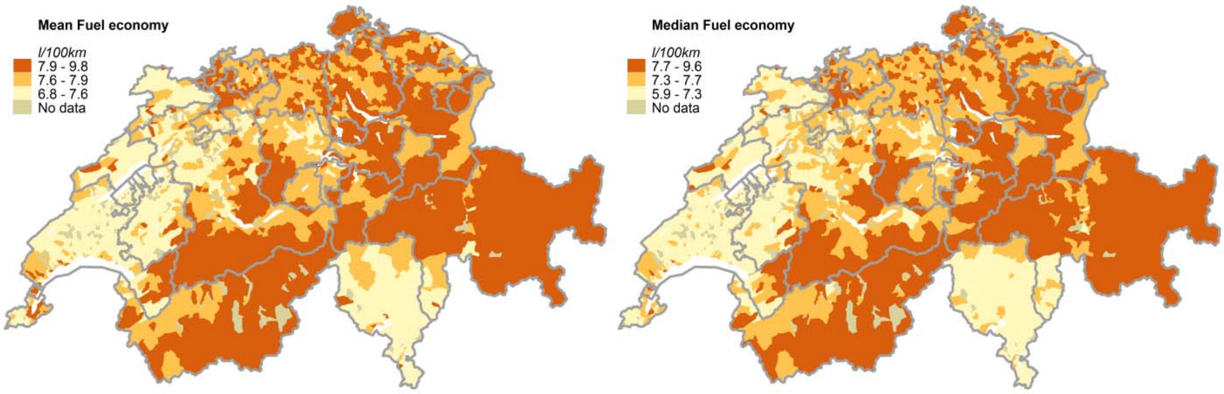

Figure 26: Comparison of the mean and median 2012 car fleet fuel efficiency at the municipal level

The median is very robust and forgiving towards outliers. It represents the most frequently observed value of a parameter and in the case of skewed data provides a good indicator of the actual condition. Small groups exhibiting extreme values are not captured by the median they might though considerably influence the mean. Figure 26 shows the difference between the two statistics using the fuel economy at the municipal level. In general, the mean values are slightly larger than the median values, thus fuel economy is skewed to the right. Nonetheless, to a large extent the patterns drawn by the different statistics are very similar. In these regions the mean and median fuel efficiency are very close, meaning that there are only few for that region relatively fuel inefficient vehicles. The group of municipal car fleets displaying noticeably different mean and median fuel consumption rates are found predominantly in the Cantons of Zürich, Thurgau, Aargau, Schaffhausen and Genève. Here fuel efficiency is more heavily skewed to the right and the highly inefficient outliers influence the mean value. In these regions the mean value isn't representative and shouldn't be used to describe the observed car fleet.

Appendix 5: Aggregated Statistics of EU and Switzerland

Table 32: Number of new car registrations (in thousands)[49]

Country	2005	2006	2007	2008	2009	2010	2011	2012
Austria	308	309	298	294	319	328	356	336
Belgium	480	526	525	536	475	551	577	490
Bulgaria			86	91	21	14	14	14
Cyprus	18	20	25	24	16	15	15	11
Czech Republic	105	107	126	134	159	165	169	170
Denmark	147	154	160	148	111	151	170	171
Estonia	20	25	31	24	10	10	17	19
Finland	146	143	123	137	89	109	122	108
France	2'059	1'986	2'050	2'037	2'259	2'250	2'174	1'932
Germany	3'319	3'445	3'126	3'067	3'786	2'873	2'933	3'063
Greece	274	279	294	279	221	140	97	58
Hungary	199	193	167	163	66	43	47	52
Ireland	171	177	186	151	56	89	90	73
Italy	2'237	2'325	2'494	2'163	2'160	1'954	1'745	1'404
Latvia	16	25	31	19	5	6	10	10
Lithuania	11	15	21	22	7	7	12	12
Luxembourg	49	51	51	52	47	50	50	50
Malta	7	6	6	5	6	4	6	6
Netherlands	452	478	494	493	396	480	554	500
Poland	230	223	264	305	221	219	275	274
Portugal	208	199	204	215	159	223	154	96
Romania			313	286	115	94	82	66
Slovakia	45	65	65	57	70	65	69	70
Slovenia	64	62	69	72	60	60	55	50
Spain	1'640	1'622	1'606	1'165	964	976	810	704
Sweden	269	278	300	248	209	277	289	265
Switzerland	**266**	**274**	**262**	**288**	**274**	**305**	**336**	**333**
United Kingdom	2'386	2'295	2'390	2'112	1'968	2'026	1'937	2'037

49 Source: EEA (2013) and own calculations for Switzerland

Table 33: Average CO_2 emissions of new registered passenger cars in the EU and Switzerland[50]

Country	2005	2006	2007	2008	2009	2010	2011	2012
Austria	162.1	163.7	162.9	158.1	150.2	144	138.7	135.6
Belgium	155.2	153.9	152.8	147.8	142.1	133.4	127.2	127.9
Bulgaria			171.6	171.5	172.1	158.9	151.4	149.2
Cyprus	173	170.1	170.3	165.6	160.7	155.8	149.9	144.5
Czech Republic	155.3	154.2	154.2	154.4	155.5	148.9	144.5	140.8
Denmark	163.7	162.5	159.8	146.4	139.1	126.6	125	117
Estonia	183.7	182.7	181.6	177.4	170.3	162	156.9	150.1
Finland	179.5	179.2	177.3	162.9	157	149	144	139.1
France	152.3	149.9	149.4	140.1	133.5	130.5	127.7	124.4
Germany	173.4	172.5	169.5	164.8	154	151.1	145.6	141.5
Greece	167.4	166.5	165.3	160.8	157.4	143.7	132.7	121.1
Hungary	156.3	154.6	155	153.4	153.4	147.4	141.6	146.9
Ireland	166.8	166.3	161.6	156.8	144.4	133.2	128.3	124.8
Italy	149.5	149.2	146.5	144.7	136.3	132.7	129.6	126.2
Latvia	187.2	183.1	183.5	180.6	176.9	162	154.4	151.9
Lithuania	186.3	163.4	176.5	170.1	166	150.9	144.4	144.2
Luxembourg	168.6	168.2	165.8	159.5	152.5	146	142.2	137
Malta	150.5	145.9	147.8	146.9	135.7	131.2	124.7	121.5
Netherlands	169.9	166.7	164.8	156.7	146.9	135.8	126.1	118.5
Poland	155.2	155.9	153.7	153.1	151.6	146.2	144.5	141.9
Portugal	144.9	145	144.2	138.2	133.8	127.2	122.8	117.6
Romania			154.8	156	157	148.5	140.7	139
Slovakia	157.4	152	152.7	150.4	146.6	149	144.9	140.9
Slovenia	157.2	155.3	156.3	155.9	152	144.4	139.7	133.4
Spain	155.3	155.6	153.2	148.2	142.2	137.9	133.8	128.6
Sweden	193.8	188.6	181.4	173.9	164.5	151.3	141.8	135.4
Switzerland	**191**	**189.3**	**185.5**	**176.9**	**168.5**	**161.9**	**155.1**	**151.1**
United Kingdom	169.7	167.7	164.7	158.2	149.7	144.2	138	132.9

[50] Source: EEA (2013) and own calculations for Switzerland

Table 34: Average curb weight of new registered passenger cars in the EU and Switzerland[51]

Country	2005	2006	2007	2008	2009	2010	2011	2012
Austria	1'435	1'449	1'445	1'431	1'385	1'409	1'442	1'451
Belgium	1'396	1'407	1'423	1'425	1'406	1'406	1'416	1'441
Bulgaria						1'454	1'462	1'484
Cyprus	1'277	1'316	1'354	1'372	1'367	1'388	1'377	1'369
Czech Republic	1'242	1'247	1'261	1'275	1'335	1'380	1'368	1'368
Denmark	1'324	1'328	1'370	1'320	1'313	1'335	1'312	1'249
Estonia	1'408	1'433	1'465	1'456	1'471	1'473	1'502	1'514
Finland	1'381	1'401	1'437	1'442	1'447	1'426	1'452	1'455
France	1'341	1'349	1'375	1'387	1'326	1'326	1'343	1'386
Germany	1'412	1'424	1'433	1'425	1'347	1'433	1'460	1'465
Greece	1'287	1'304	1'314	1'311	1'423	1'252	1'231	1'244
Hungary	1'203	1'237	1'264	1'288	1'330	1'370	1'396	1'388
Ireland	1'341	1'372	1'441	1'440	1'440	1'380	1'378	1'415
Italy	1'277	1'294	1'287	1'285	1'255	1'269	1'306	1'311
Latvia	1'445	1'468	1'502	1'498	1'535	1'522	1'543	1'563
Lithuania	1'448	1'483	1'481	1'467	1'486	1'481	1'498	1'500
Luxembourg	1'487	1'504	1'498	1'490	1'462	1'473	1'519	1'529
Malta				1'317	1'182	1'200	1'216	1'580
Netherlands	1'337	1'332	1'350	1'324	1'295	1'254	1'249	1'265
Poland	1'242	1'271	1'304	1'260	1'261	1'317	1'378	1'383
Portugal	1'329	1'352	1'365	1'352	1'344	1'333	1'354	1'361
Romania			1'268	1'286	1'291	1'281	1'325	1'382
Slovakia	1'174					1'386	1'418	1'419
Slovenia	1'305	1'316	1'340	1'350	1'346	1'332	1'355	1'357
Spain	1'374	1'395	1'416	1'400	1'394	1'399	1'413	1'400
Sweden	1'470	1'488	1'503	1'488	1'490	1'497	1'510	1'521
Switzerland	**1'550**	**1'547**	**1'558**	**1'486**	**1'482**	**1'483**	**1'496**	**1'524**
United Kingdom	1'374	1'390	1'394	1'380	1'358	1'384	1'410	1'398

[51] Source: EEA (2013) and own calculations for Switzerland

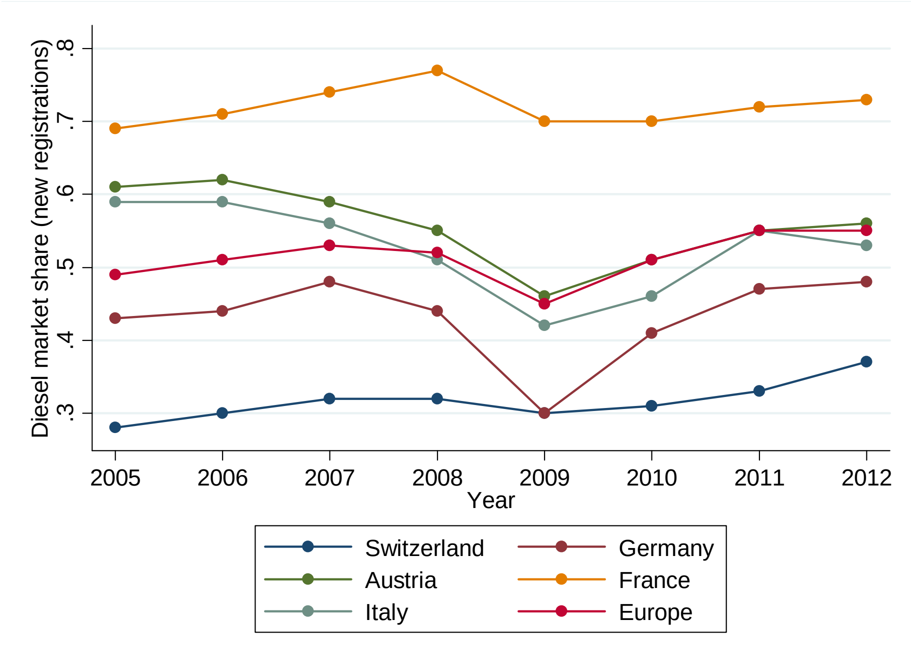

Figure 27: Diesel share of selected countries and the EU[52]

[52] Source: EEA (2013) and own calculations for Switzerland

Module 2:

The Effect of Registration Taxes on New Car Registrations:
Evidence from Switzerland

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1. Introduction

Switzerland is a federal republic consisting of 26 cantons. The political power and duties are divided between the federal government, the cantons and the municipalities. The constitution defines the jurisdictions and assigns authorities for various matters. In this federal context, the Swiss energy policy is defined and implemented both at the federal and as well at the cantonal level. For instance, in the private transport sector the federal government has introduced a national energy label system which informs the car buyers about the characteristics and fuel-efficiency of a car. Further, the federal government has the authority to impose energy taxes, e.g. a CO_2 tax on fuel. On the other side, the cantons are in charge of levying an annual registration tax and have the possibility to give subsidies or modify this tax in order to promote the adoption of fuel-efficient cars. Therefore in Switzerland there exist 26 different car registration tax systems which differ in their calculation base (e.g., engine size, horsepower, weight, etc.) and rates.

At the national level, Switzerland ratified the Kyoto Protocol and committed to reduce its emissions by eight percent between 2008 to 2012 compared to 1990. Switzerland reached its Kyoto Protocol targets by buying CO_2 emissions certificates from abroad (BAFU, 2014a). However, it did not succeed in reaching all of the individual targets it had set for itself. Switzerland stipulated in its CO_2 act to reduce heating fuels by 15 percent and motor fuels by eight percent with respect to the 1990 level (BAFU, 1999) but it (barely) failed to meet the prescribed reductions in CO_2 emissions for heating fuels, and failed badly with motor fuels (BAFU, 2014b).

The major policy instruments to enhance the reduction of CO_2 emissions in the transport sector are CO_2 emissions standards, which aim to improve the technological progress on the supply side, or different tax systems, which focus to influence the demand side, such as a CO_2 tax on fuel price, which encourages car drivers to drive less and/or to buy a more efficient car. Alternatively, an excise tax or an annual registration tax with rebates and penalties for efficient and inefficient cars, or directly based on a car's CO_2 emissions, can be imposed. These tax incentives lead to a change in the relative lifetime costs of buying and owning low- and high-emitting cars.

In order to reach the subordinate target for motor fuels, a voluntary agreement between the Federal Department of the Environment, Transport, Energy and Communications (DETEC) and the association of Swiss car importers (auto-schweiz) was established in 2002 with the goal of reducing CO_2 emissions rates and improving the fuel economy of vehicles by

2008. These efforts failed to produce results and the agreement is generally regarded as a failure (BFE, 2009). It was thus replaced by mandatory CO_2 emissions standards, similar to those adopted in the European Union (EU), which oblige car importers to reduce the average CO_2 emissions of their new cars fleet to 130 grams per kilometer by 2015. This new program was introduced in July 2012 (BFE, 2011).

In addition, between 2005 and 2011, several cantons adopted a reform of the car registration tax system with the goal to provide incentives to buy fuel efficient cars and therefore to reduce the average CO_2 emissions per car. For instance, several cantons are offering discounts to fuel efficient, "clean" (i.e., low-emissions) cars and raising the fees for "guzzlers" and high-emitting vehicles. These discounts differ in their amount (e.g., total tax exemption, 50% reduction, CHF 200 bonus, etc.) and in the eligibility criteria used to give these discounts (e.g., incentives for A-label cars, incentives for cars emitting less than 130 grams of CO_2 per kilometer, a combination of label and CO_2 incentives, etc.). Further, some cantons have implemented special tax bonuses for cars with alternative fuels, like hybrid electric vehicles, vehicles running on natural gas or battery electric vehicles.

In order to assess the impact of these different policy measures, the Swiss Federal Office for the Environment (FOEN) and the Swiss Federal Roads Office (FEDRO) commissioned the Center for Energy Policy and Economics of ETH Zurich (CEPE) to conduct a study with the title "Economic analysis of policy measures to reduce CO_2 emissions of passenger cars in Switzerland." The study shall help the federal government assess the existing policies and further use these experiences for potential further policy incentives for CO_2 emissions mitigation. This report is part of that study and evaluates the effects of the cantonal vehicle registration taxes.

The implementation of a bonus or bonus/malus policy can affect vehicle registrations in different ways. A bonus on the purchase of an efficient, low-emissions car reduces the relative cost of operating such a car compared to the others and provides a direct incentive to buy an efficient car. Hence, the expected direct effect of the bonus is an increase in the sales and/or market shares of efficient, low-emissions cars. Conversely, we would expect a malus to increase the relative cost of owning a fuel-inefficient, high-emissions car, and to discourage the purchase of one such new car.

In this report we exploit the variation in the registration tax rebates across cantons and over time to investigate whether these tax differentiations have resulted in a shift towards more fuel-efficient vehicles with lower emissions. In practice, we seek to estimate the increase (if any) in the share of A-label vehicles and/or the share of cars that meet a specified CO_2 emissions rate out of the new car registrations which can be correctly attributed to the car registration policies. We regard the different cantonal tax systems and their reforms as a natural experiment and deploy a study design known as “difference-in-difference”, which allows us to separate the effect of the registration fees from those of other factors. We also estimate the effect of the registration taxes, rebates and fees on the market share for each make-model-trim variant.

In addition, we present a preliminary analysis that examines the impact of the monetary incentives on the adoption of hybrid electric vehicles. However, because of econometric reasons, we had to partially limit the analysis, which is reported in Appendix 2.

Briefly, we find that a bonus on A-label vehicles increases the share of A-label cars by approximately 2 percentage points. A bonus based on a CO_2 emissions rate increases the share of cars emitting less than or equal to 130 grams per kilometer also by approximately 2 percentage points. The average bonus for a car affected by the policy is approximately CHF 225, that is in the range of 25-100% of the registration tax. Therefore these effects are rather small. Moreover, because all the registered cars that satisfy the eligibility criteria benefit from a reduction in the registration tax, the cantons experience a relatively high decrease in tax revenues. In cantons that introduced contemporaneously a fee (malus) for inefficient cars, this decrease is smaller or inexistent. In addition, we find a statistically significant effect of the policies on the market shares of specific make-model-trims. E.g. a rebate of CHF 100 increases the market share of an average car affected by the policy by about 1.6%. We did not find a significant effect of a penalty applied to inefficient or high emitting vehicles..

The remainder of this report is organized as follows. Section 2 summarizes related research. Section 3 presents background institutional information. Section 4 lays out the methodological approaches. Section 5 presents the data and an extensive descriptive statistic. Section 6 presents and discusses the estimation results, and section 7 offers concluding remarks.

2. Related Research

Examinations of policy incentives in the Swiss car sector are rare. Besides annual descriptive statistics about fuel consumption, CO_2 emissions and energy labels[1] (see, for example, BFE, 2013) we are aware of only two studies that focus on the energy label. Wüstenhagen and Sammer (2007) used discrete choice analysis to analyze the effect of the Swiss energy label on car purchases and Alberini et al. (2016) investigated the effect of the label on vehicle price above and beyond the fuel economy of the car.

The Swiss Federal Office of Energy (SFOE) commissioned several studies in order to develop new policy measures that reduce energy consumption in the passenger car sector (Maibach et al., 1998; Hammer and Maibach, 1999; Maibach, 2000; Hammer et al., 2001; Ott et al., 2002; Iten and Hammer, 2005; de Haan et al., 2007a, de Haan, 2009a; de Haan, 2009b and de Haan, 2009c; all in German). All of these studies are limited to descriptive statistics or ex ante analyses to examine potential future policy measures. De Haan et al. (2007b) conducted a survey to analyze if the purchase of a Toyota Prius hybrid car is accompanied by a rebound effect and if tax rebates lead to higher sales figures. While they did not identify a rebound effect, they found that the sales of Toyota Prius cars were 25.7% higher in cantons that offered a tax rebate for these cars.

Several studies in Europe, the US and Canada studied the effect of policy measures on new vehicles sales. Analyses have focused on both fuel economy regulations, such as the US Corporate Average Fuel Economy (CAFE), which was first established in the 1970s and has been revised several times since, and fuel taxes (see Anderson et al., 2011, for an overview of this research).

In this report on module 2, we focus on registration tax rebates or penalties for high-emitting vehicles. Rebates can be used to encourage the purchase of fuel-efficient vehicles, alternative-fuel vehicles, and hybrid cars. Chandra et al. (2010) estimate the effect of tax rebates offered by Canadian Provinces on the sales of hybrid electric vehicles. Much like Switzerland, the Provinces of Canada began offering rebates at different times and in different amounts. Chandra et al. model market shares as a function of the rebates and other attributes including model-year fixed effects, finding that rebates account for a sales increase of 26%. This result is similar to the one in de Haan (2007b) mentioned above.

[1] The energy label for passenger cars provides information about the fuel efficiency and other characteristics of the car. The new cars for sale are divided into seven energy efficiency categories from A (most efficient) to G (most inefficient). See chapter 3 for more information.

Gallagher and Muehlegger (2011) compare tax and non-tax incentives to induce consumer adoption of hybrid electric cars in the United States and find that the type of tax incentive offered is as important as the generosity of the incentive. They applied a difference-in-difference approach, finding that sales of hybrid electric cars increase by 22% with the average tax incentive. Beresteanu and Li (2011) find results in this range applying a random coefficient discrete choice model, while Diamond (2009) finds a strong relationship between gasoline price and hybrid adoption, but a much weaker relationship between incentive policies and hybrid adoption in a cross-sectional analysis.

In Europe, many countries introduced new policy incentives for fuel-efficient passenger cars in the last decade,[2] spurring a growing body of literature in this area. Without looking at tax incentives per se, Ryan et al. (2009) show that differences in vehicle and fuel taxes in the European Union (EU15) have different impacts on car sales and fleet CO_2 emissions intensity. Klier and Linn (2015), Zimmermannova (2012), Adamou et al. (2014), D'Haultfoeuille et al. (2014), Huse and Lucinda (2014) apply structural models to investigate the feebate scheme in Germany, France, Sweden and Czech Republic.[3] Ciccone (2014) examines the environmental effects of the tax reform for new vehicles in Norway in 2007 using a difference-in-difference approach. In practice, the majority of these studies have focused on a single, one-time, discrete change in the vehicle registration or sale tax that applies to the entire country. By contrast, we take advantage of the variation in registration taxes across cantons and over time to identify the effect of registration taxes on the fuel economy and emissions rates of new cars.

3. Institutional Background

Switzerland is one of the wealthiest countries of the world—and one where new cars are generally more fuel-inefficient and have higher emissions rates than in the rest of Europe (Alberini et al., 2016; ICCT, 2013). This is probably due to Switzerland's low fuel prices compared to other European countries, its special topography with a large share of mountainous areas, and its high purchasing power (see module 1 of this report). As a result,

[2] According to the European Automobile Manufacturer Association (ACEA) only seven countries of the European Union do not have tax incentives for cars with low CO_2 emissions (Source: http://www.acea.be/uploads/publications/CO_2_Tax_overview_2014.pdf, 01.04.2014)

[3] Feebates are a combination of rebate for efficient cars and an additional fee for inefficient cars. By finding the right pivot point for cars which profit from a rebate and cars which have to pay extra tax, a feebate system can be revenue neutral which can be desirable to prevent revenue loss and reduce public expenditures or the need to raise taxes.

passenger cars are responsible for a large share of the CO_2 emissions from the transport sector, which in turn accounts for some one-third of the overall greenhouse gas emissions in Switzerland (BAFU, 2014c).

With some 300,000 new cars sold each year, and a fleet of about 4.2 million passenger vehicles, the Swiss car market is small compared to those of neighboring countries like France, Germany and Italy. Switzerland has no domestic car manufacturing, and all cars are imported.

As discussed previously, in Switzerland, the responsibility to define and implement energy policies is shared between the federal government and the 26 cantons. For instance, the federal government has attempted to reduce the emissions rates and improve the fuel economy of passenger vehicles through a variety of programs and initiatives. In 2003, the Swiss federal government introduced an energy label system for passenger cars. This system divides cars sold in Switzerland into seven possible energy efficiency categories ranging from A (most efficient) to G (most inefficient). The purpose of the label is to inform consumers about the characteristics and fuel efficiency of each car. The categories make it possible to compare each vehicle to the other cars on the market. The rating system is based on a combination of the absolute fuel efficiency (expressed in primary[4] gasoline-equivalent fuel liters per 100 kilometers) and a relative measure (the fuel efficiency divided by the curb weight of the car). This rating system allows even larger and heavier vehicles to attain the "A" label.

Like the European Union, the federal Swiss government and the association of car importers agreed on a voluntary reduction target of the average fuel consumption by 24% between 2000 and 2008. In absolute terms this implied a reduction from 8.4 to 6.4 liters per 100 kilometers.[5] Despite improvements in the fuel economy of new cars, the voluntary target was missed by 1 l/100km (7.4 l/100km instead of 6.4 l/100km), which led to the mandatory CO_2 emissions targets introduced in July 2012 (BFE, 2011).

Some Swiss cantons apply additional incentives towards more fuel-efficient cars through their annual registration tax systems. In general, registration taxes provide incentives towards smaller cars, since registration taxes generally increase with engine size, horsepower, weight or combinations of these car characteristics. Over the last decade, several cantons have

4 As primary energy, we understand the energy form that has not been subjected to any conversion or transformation process. It is the energy contained in raw fuels or other forms of energy like renewable energy sources.

5 More information at: http://www.bfe.admin.ch/energie/00588/00589/00644/?lang=de&msg-id=1951

reformed their car registration tax systems, offering discounts (bonus) to fuel-efficient, "clean" cars and raising the fees (malus) for "guzzlers" and high-emitting vehicles over the last years. The effect of these "ecologically" oriented registration tax systems is what we study in this report.

In 2007, the Swiss cantons and the Association of the Swiss Road Traffic Licensing Departments (asa) suggested a rebate model to promote fuel-efficient passenger cars (Asa, 2007). They recommended a rebate system based on the energy label. Within this scheme, cars with an energy label A would get a rebate of 50 to 100 percent on the vehicle registration tax for the first two to three years. It was estimated that the cumulative rebate (about CHF 1,000) would be an adequate incentive. To make up for the loss of revenue the vehicle registration taxes of all cars would be increased, or fuel-inefficient cars of label F and G have to pay a penalty (malus).

During this time suggestions were made that the energy label should be replaced with an ecological label that displays information about CO_2 emissions and local air pollution. The goal was to base the cantonal rebate system on this ecological label.

This suggested harmonized rebate system has not been implemented by all cantons. Incentives vary in size across cantons and are mostly expressed as a percentage of the actual tax. Alternatively, all policy-affected cars pay the same low tax (e.g. CHF 60). While some cantons grant rebates for fuel-efficient cars, others cantons offer rebates and in addition impose a malus for fuel-inefficient cars depending either on the energy label or a CO_2 emissions threshold.[6] Because the energy label has only been adjusted but never been replaced by an ecological label, the eligibility criteria for a registration tax rebate vary across cantons. These rebates are based either on an alternative fuel type (hybrid electric vehicle [HEV], battery electric vehicles [BEV] or natural gas vehicle), or the energy label, a CO_2 emissions threshold or a combination of the two (e.g., 50% bonus for an A-label car emitting less than or just about 130 g CO_2/km).[7]

6 We remind the reader that CO_2 emissions are proportional to the fuel consumption rate, and that the proportionality factor depends on the fuel.

7 Besides the different bonus and malus scheme. Canton Neuchâtel decided in 2014 to base their annual registration entirely on the CO_2 emissions of the vehicles in 2014. Such a tax systems is considered to be very effective. At the time of writing this report, the required data to assess the impact of this policy have not been available yet.

Cantons that offer incentives to A-label vehicles presumably wish to promote fuel-efficient cars regardless of market segment and vehicle size.[8] This implies that in these cantons even cars with relatively high CO_2 emissions can receive a rebate on the registration tax. Other cantons offer rebates only to cars that meet a strict CO_2 emissions rate threshold. Other cantons yet have devised rebates that apply only to A-label vehicles that meet a strict CO_2 emissions rate threshold. We exploit this variation in the eligibility criteria and the tax rebate amount across cantons in our empirical analysis, which identifies three different groups of treated cantons.

Different cantons enacted these reforms at different times, and there are several cantons that kept their existing systems in place (i.e. that did not introduce any reforms at all). In this report, we regard the latter cantons as the "control group" and the cantons that revised their registration taxes to provide incentives for cleaner, more fuel-efficient cars as the "treated" cantons, where the "treatment" is the enactment of the ecological registration tax policy. The heterogeneity in the cantonal incentive schemes may be due to different energy policy goals, different fiscal goals, or different political preferences. In general, the choice of an incentive scheme may have important effects on tax revenues. Granting a bonus on a large group of cars reduces the tax revenues dramatically (see section 5c). Of particular concern is the possibility that the bonus might be cashed in by drivers who would have bought a fuel-efficient car anyway, or who already have bought a fuel-efficient car (and for that reason alone need no incentives). Free riding likely has a big impact on cantonal revenues. To reduce this problem, it is reasonable to restrict the bonus to a smaller group of cars and limit it to the first few years after first registration. By contrast, a malus for registrations of high-emitting or fuel-inefficient cars raises the cantonal tax revenues and compensates revenue losses of the granted bonus. A malus should be imposed on both new and current registrations and over the entire lifetime without temporal limitations. Such a malus increases the lifetime cost of an inefficient car substantially and makes new efficient cars more attractive.

Summaries of the different tax systems and incentive schemes that affect all fuel types during our study period (2005 to 2011) are displayed in table 1.[9] The table shows that not all cantons have put an ecological tax system in place yet. It can be seen that most of the cantons that have implemented a policy grant only a bonus for efficient or low-emitting cars without

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8 This is because the energy label is based on the absolute and relative measures of fuel consumption rate. This implies that also relatively large cars with efficient engines can attain the A label.

9 After the end of our study period in 2011, other cantons changed their tax systems and incentivize customers to buy efficient cars. These incentive schemes are not considered in table 1 and the rest of this module.

charging a penalty for inefficient or high-emitting cars. The policy measures for alternative fuel types are summarized in table 2. Application of different policies leads to a change in the registration tax. Table 3 provides an overview of registration taxes prior to policy and rebates in each canton. The highest average taxes had to be paid in Canton Bern (BE, average of CHF 624) and the lowest average taxes in Canton Wallis (VS, average of CHF 221). Out of the cantons which have an incentive scheme for fuel-efficient cars, St. Gallen (SG) is the canton with the highest average rebates (CHF 398) and Wallis (VS) with the lowest average rebate (CHF 85). The absolute highest rebate (CHF 633) is paid in Canton Fribourg (FR).

Table 1: Cantonal incentives based on registration tax for all fuel types from 2005 to 2011

Canton		Tax base*	Incentives for of fuel efficient cars of all fuel types between 2005 and 2011	
			Year of policy introduction	Incentive
Aargau	AG	Steuerps	no policy	
Appenzell A. Rh.	AI	Mass	no policy	
Appenzell I. Rh.	AR	Mass	2011	50% Bonus if $CO_2 \leq 130$g/km
Bern	BE	Mass	no policy	
Basel-Landschaft	BL	Mass	no policy	
Basel-Stadt	BS	Steuerps	no policy	
Freiburg	FR	Ed	2011	100% Bonus if label A; 2.2% additional tax if D, E, F, G or no label
Genf	GE	Steuerps	2010	50% Bonus if $CO_2 \leq 120$g; 50% Malus if CO_2 >200g
Glarus	GL	Ed	no policy	
Graubünden	GR	Ed	2009	2009: 80% Bonus if $CO_2 \leq 140$g & PM10≤0.01g; 60% Bonus if $CO_2 \leq 160$g & PM10≤0.01g; 2011: 80% Bonus if $CO_2 \leq 120$g & PM10≤0.01g; 60% Bonus if $CO_2 \leq 140$g & PM10≤0.01g
Jura	JU	Mass	no policy	
Luzern	LU	Steuerps	no policy	
Neuenburg	NE	mass & ed	no policy	
Nidwalden	NW	Ed	2009	100% Bonus (for first 3 years) if label A
Obwalden	OW	Ed	2009	100% Bonus (for first 3 years) if label A; 50% Bonus (for first 2 years) if label B; 60.- Malus if label G or no label
St. Gallen	SG	Mass	2009	100% Bonus if label A & $CO_2 \leq 130$g (for 3 years)
Schaffhausen	SH	Ed	no policy	
Solothurn	SO	Ed	no policy	
Schwyz	SZ	Ed	no policy	
Thurgau	TG	Ed	2011	50% Bonus if label A (max. 5 years); 25% Bonus if label B (max. 5 years); 50% Malus if label F or G
Tessin	TI	mass & perform	2009	50% Bonus if label A & $CO_2 \leq 140$g (+filter); 20% Malus if label F; 50% Malus if label G
Waadt	VD	mass & perform	2005	50% Bonus if $CO_2 \leq 120$g
Wallis	VS	Ed	2010	50% Bonus if label A & $CO_2 \leq 130$g
Uri	UR	Mass	no policy	
Zug	ZG	Ed	no policy	
Zürich	ZH	Ed	no policy	

* Explanation of the different bases:
- Steuerps: engine displacement × 0.005093
- Mass: total weight in kilogram
- Ed: engine displacement in ccm
- perform: Performance in kilowatt

Table 2: Cantonal incentives based on registration tax for alternative fuel types

Canton		**Incentives for alternative fuel types between 2005 and 2011**	
		Year of policy introduction	Incentive
Aargau	AG	no policy	
Appenzell A. Rh.	AI	no policy	
Appenzell I. Rh.	AR	2005	50% Bonus for HEV/BEV
Bern	BE	2005	50% Bonus for BEV
Basel-Landschaft	BL	2009	50% Bonus for BEV; 50% Bonus for HEV and gas if A labelled
Basel-Stadt	BS	no policy	
Freiburg	FR	2005 till 2010	30% Bonus if HEV/gas/BEV
Genf	GE	no policy	
Glarus	GL	no policy	
Graubünden	GR	no policy	
Jura	JU	2005	50% Bonus for HEV, BEV, or gas
Luzern	LU	2006	Tax of CHF 41.20 for BEV, HEV or gas
Neuenburg	NE	2005	50% Bonus for BEV, or gas
Nidwalden	NW	2009	75% Bonus if BEV; 50% Bonus if HEV
Obwalden	OW	2009	50% Bonus if HEV; 70% Bonus if BEV/gas
St. Gallen	SG	2009	100% Bonus if BEV; 100% Bonus if gas & CO_2<143g
Schaffhausen	SH	no policy	
Solothurn	SO	2005	100% Bonus if BEV
Schwyz	SZ	2008-2011	50% Bonus for HEV, BEV, or gas
Thurgau	TG	2011	Tax of CHF 48.- if BEV
Tessin	TI	2009	100% Bonus if BEV; 50% Bonus if HEV; 25% Bonus if gas
Waadt	VD	2005	Tax of CHF 25.- if BEV; 50% Bonus if gas
Wallis	VS	no policy	
Uri	UR	2007	33% Bonus if BEV
Zug	ZG	2005	50% Bonus if BEV
Zürich	ZH	2005	100% Bonus if BEV; 50% Bonus if HEV

Note: Highlighted in green are Cantons which implemented incentives for HEV. Highlighted in blue are Cantons which implemented incentives for BEV and in orange Cantons with incentives for BEV and cars operated with natural gas.

Table 3: Descriptive statistics about registration tax and tax rebates at the cantonal level. All figures based on data from 2005 – 2011 (CHF=2011 prices)

	Tax prior to policy				*Rebate*			
	Mean	**Min**	**Median**	**Max**	**Mean**	**Min**	**Median**	**Max**
AG	287	172	287	1,038	0	0	0	0
AI	483	191	487	950	0	0	0	0
AR	553	269	552	1,094	223	145	224	332
BE	624	299	623	1,050	0	0	0	0
BL	615	232	603	1,223	0	0	0	0
BS	428	132	429	1,355	0	0	0	0
FR	421	275	400	1,605	390	288	376	633
GE	409	158	282	3,803	111	94	105	273
GL	380	210	376	1,314	0	0	0	0
GR	564	298	554	1,760	301	199	301	484
JU	590	332	585	1,011	0	0	0	0
LU	375	212	366	1,507	0	0	0	0
NE	402	200	374	1,691	0	0	0	0
NW	339	153	322	1,299	270	160	250	505
OW	345	191	339	1,250	224	113	184	508
SG	488	214	485	910	398	262	390	615
SH	248	115	241	872	0	0	0	0
SO	373	202	355	1,466	0	0	0	0
SZ	363	198	356	1,399	0	0	0	0
TG	271	138	263	888	86	42	72	204
TI	516	202	460	3,043	182	109	176	421
UR	352	170	347	693	0	0	0	0
VD	551	237	515	2,025	186	119	177	338
VS	221	119	215	871	85	62	87	138
ZG	351	172	327	1,018	0	0	0	0
ZH	389	191	377	1,379	0	0	0	0

4. Methodology and model specification

A. The Difference-in-Difference Approach at municipality level

In this report we estimate the effect of registration tax schemes on the fuel economy and CO_2 emissions rates of new cars at the municipality level using the so-called "difference-in-difference" (DID) approach.[10] This approach requires identifying a situation that can be interpreted as a natural experiment, a "treatment," units that receive the treatment and units

[10] In the literature it is possible to find studies based on a structural model approach. This approach derives the equation to estimate directly from a utility function. In this report we decided to use a reduced model approach. However, in a companion study that we are using a structural model (Alberini et al., 2016). A working paper will be issued in spring 2016 (Alberini et al., 2015).

that do not receive the treatment and are thus regarded as "control" units. It is essential that observations be available from both the treated and the control units before *and* after the application of the treatment. This allows the researcher to disentangle the effect of the treatment from other factors that affect both treatment and control units to the same extent.

In our study, we consider the municipalities in cantons that have granted a rebate for fuel-efficient cars as "treatments", and municipalities in cantons without such policies as "controls". As shown in table 1, 15 cantons did not implement any particular ecological registration tax policy during the study period. Eleven cantons introduced in different years a policy measure to promote the adoption of energy efficient cars between 2005 and 2011. Therefore, the number of cantons (and municipalities) that belong to the treated group is changing over time. In addition, four out of these eleven cantons with a policy measure impose a penalty on fuel-inefficient or high-emitting cars.

We remind the reader that, as shown in table 1, the specifics of the registration tax and associated incentive for fuel efficient and clean cars vary across cantons. In some cantons the eligibility requirement to obtain this tax reduction is based on the level of CO_2 emissions, whereas in others it is based on the energy label of the car (or on a combination of energy label and CO_2 emissions). The penalties, when applicable, are based on the energy label or (in one canton) on the CO_2 emissions. Further, several cantons adopted an incentive for promoting alternative fuel types (see table 2).

The fact that cantons utilize different requirements for the tax reduction suggests that our units should be placed into one of four possible groups, namely i) the control group, which come from cantons that did not offer reductions to fuel-efficient or clean cars, ii) the treated group with the eligibility requirement based on the energy label, iii) the treated group with the eligibility requirement based on CO_2 emissions, and iv) the treated group with the eligibility requirement based on a combination of energy label and the CO_2 emissions. Two additional groups are used where v) the treated group come from cantons with a penalty based on the energy label and vi) the treated group come from cantons with a penalty based on the CO_2 emissions.

As we discuss below, in our empirical analysis we do a separate DID analysis for the five treated groups. This means that we run separate regressions (presented below) using samples comprised of i) and ii), then i) and iii), i) and iv), i) and v) and then finally i) and vi).

A number of options are available in terms of the outcome variable that we wish to study. For example, one may choose the share of fuel-efficient car registrations at the cantonal or municipal level or the registration figures for a specific make-model-year. It is also possible to select different units of observation, such as the canton or municipality in one year. It is not possible to work with household level choices because we do not have household level information. In this report, the unit of observation is either the municipality in each year, or the region in a year. We choose not to work with canton-level observations on car sales because they are potentially endogenous with the registration tax policies, which are imposed at the canton level.[11]

B. Statistical Models

We begin our empirical analysis by focusing on five possible outcome variables that may be affected by the tax registration policies. The first is the share of A-label cars out of all new car registrations. The second is the share of new cars that meet the 130 g/km threshold for CO_2 emissions, the third is the share of cars that meet this threshold *and* are A-label cars, the fourth is the share G-label cars, and the fifth the share of cars exceeding the 200 g/km threshold for CO_2 emissions.

Focusing on the share of A-label cars for the sake of expositional simplicity, we estimate the following regression equation:

$$\text{A share}_{it} = \alpha_i + \tau_t + \beta\, POL_{it} + X_{it}\delta + \varepsilon_{it} \tag{1}$$

where *i* denotes the municipality and *t* the year. Our units are thus municipalities, which we follow over 2005-2011, creating a panel (longitudinal) dataset. The right-hand side of equation (1) contains municipality-specific fixed effects, which allow us to control for unobserved heterogeneity, assuming that the latter is approximately constant over time. It also contains τ_t, a year-specific fixed effect, which is assumed constant across cantons and municipalities. Including time and municipality fixed effects allows us to distinguish the impact of a change in the registration tax *per se* from systematic differences across locales or country-wide effects (the economy, federal regulations, etc.) that affect treated and untreated units to the same extent. X_{it} is a set of time-varying covariates which includes income and number of residents in the municipality at time *t*.

[11] By endogeneity, we mean the possibility that the cantons might establish certain vehicle registration policies *because* of certain unobserved (for us) characteristics or trends in the vehicle stock or the registrations of new cars.

Variable POL_{it} is a dummy variable that indicates whether the municipality belongs to a canton that has adopted a reduced/increased registration tax for fuel-efficient/-inefficient or low/high emitting cars. The coefficient on this variable, β, is, provided that the assumptions of the DID are met, the so-called average effect of the treatment on the treated, namely the average effect of the policy at those locales that have adopted it. This coefficient is of key interest to us.

In our second approach, still in the case of efficient cars, we replace POL_{it} with $REBATE_{it}$, a continuous variable representing the level of tax reduction for fuel-efficient or continuous cars:

$$\text{A share}_{it} = \alpha_i + \tau_t + \beta\ REBATE_{it} + X_{it}\delta + \varepsilon_{it}. \quad (2)$$

REBATE is a numerical variable displaying the possible maximum rebate that can be achieved in a canton. When the policy of interest is based on the label, we calculated the highest possible registration tax in the canton for an A label car if the policy had not been implemented and then applied the bonus percentage to get the (hypothetically) maximum rebate in this canton.

When the eligibility for the rebate is based on the CO_2 emissions rate, we computed the hypothetically maximum rebate in a given canton following a similar procedure but focusing on cars that meet the CO_2 emissions threshold specified in the canton. This approach is adapted to the combination of the label and CO_2 emissions criteria to produce the relevant maximum rebate. We prefer to construct the maximum rebate in this way instead of using the average actual rebate to avoid possible endogeneity issues.[12] Likewise, if cantons apply a penalty, we use the maximum potential penalty. If cantons apply a penalty, we use the share of cars affected by the malus as dependent variable and the maximum potential penalty as the continuous policy variable in model specification (2).

[12] The average actual rebate depends on the number of registration which get a rebate which leads to an endogeneity problem.

C. Key Assumptions

The DID approach, and the associated equations (1) and (2), are appropriate if two key assumptions are met. The first is that assignment to the treatment group is exogenous, i.e., as good as random. This assumption is violated if, for example, there are unobserved characteristics of the units that affect both the outcome variables (i.e., the share of clean vehicles) *and* the adoption of the policy scheme.[13]

We take four steps to avoid this problem. First, our units are the municipalities, but the policy is established at the canton level, which, hopefully, individual municipalities are unlikely to affect (see also footnote 11). Second, we include municipality-specific effects, which mitigate this problem to the extent that any unobserved factors are reasonably constant over time. Third, we trim the sample, excluding municipalities that are poor matches for the treated ones in terms of basic characteristics likely to affect car demand (population, elevation, urban v. rural environment, and cultural characteristics of the residents). We describe our matching approach in more detail in section 4.D below. Fourth, we construct the rebate variable as described in section 4.B.

The second key assumption of the DID approach is that the trends in the outcome variable are similar for both the treatment and control groups. This means that the set of τ effects is the same for both control and treated units. If this assumption is violated, then one does not know if the effect of the policy can be safely attributed to the policy, or is due to something else.

In practice, it is possible to test this assumption only for the pre-policy period. We therefore estimate a variant of equation (1) where the sample is limited to pre-policy years, the *POL* variable is suppressed, and we enter interactions between the year dummies and a treatment group dummy. The common trends assumption is satisfied if we fail to reject the null hypothesis that the coefficients on the interactions are jointly equal to zero.

D. Matching

As mentioned, one concern is that the adoption of rebates to encourage the sales of fuel-efficient, "clean" cars is endogenous with the outcome variables. We further attempt to mitigate this problem using matching methods. In other words, we create samples of

[13] Such an unobserved variable could be the political orientation of the canton (the greener the more likely to implement a green policy and the higher the share of green cars).

municipalities that are more balanced with respect to key municipality and canton characteristics. Once each treated municipality is matched with one or more comparable but untreated municipalities, the treatment—namely, the adoption of the policy or the tax rebate amount—can be regarded as exogenous.

A variety of matching methods are available, such as methods that minimize a measure of "distance" between two units (Abadie and Imbens, 2006, 2008, 2011), methods based on the propensity scores (Dehejia and Wahba, 1999), and coarsened exact matching (Iacus et al., 2011). We choose coarsened exact matching because Iacus et al. (2011) compare various matching approaches using Monte Carlo simulations and conclude that CEM outperforms the others in terms of bias and variance of the average treatment effect (coefficient β in equations (1) and (2)), as well as execution time.

We first select a number of variables that describe municipalities, such as population, elevation, rural or urban classification, the year for which the data are available, and whether German is the primary language spoken in the municipality. CEM converts the continuous variable, population, into discrete intervals, and creates strata consisting of all possible combinations of values of these variables. The algorithm that implements this conversion seeks to select intervals that make the treated units and their matches among the controls balanced with respect to the matching variables.

Each stratum may contain treated and control municipalities, the latter serving as the matches for the former. Municipalities in strata with only control or only treatment units are discarded from the final usable sample, because they are unmatched. Municipalities in strata that contain both treated and control units are kept in the final usable sample, but weights are applied in the final regressions to account for the composition of the strata vis-à-vis that of the candidate units.

The weights are constructed as follows. To each matched unit in stratum s, CEM assigns the following weights:

$$w_i = \begin{cases} 1 \text{ if } i \in T^s \\ \dfrac{m_C}{m_T} \cdot \dfrac{m_s^T}{m_s^C} \text{ if } i \in C^s \end{cases} \tag{3}$$

where T^s denotes the treated units in stratum s, C^s denotes the control units in stratum s, m^C and m^T denotes the total number of control and treatment units, respectively, and m_s^T

and m_s^C denote the number of treated units in stratum s and the number of control units in stratum s, respectively. Unmatched units receive weight w_i equal to zero.

When we apply CEM in this report we deploy two possible sets of matching covariates. The first CEM exercise uses, year by year, residents, elevation, urban v. rural locale, and German as the primary language in the municipality. The second exercise drops language from the matching variables. Clearly, the first matching exercise is more restrictive than the second. For example, when the treatment is the adoption of rebates based on the A label, the first CEM finds a common support on 38% of the multivariate density of the strata, while the second CEM finds a common support on 50% of the multivariate density of the strata.

When the first CEM criteria is used, and the treatment is the adoption of a label-based rebate policy, we find matches for 1,569 of the treatment municipalities (with only 42 remaining unmatched). Of the controls, 7,001 serve as matches, and 1021 remain unmatched. When the treatment is a rebate based on CO_2 emissions rates, we find matches for 1,876 treated municipalities (407 go unmatched) and 2,114 controls (5,908 go unmatched[14]).

E. Alternate approach at the car level

An alternate approach to study the effects of vehicle registration fees linked with the vehicle's level of CO_2 emissions, fuel economy, or attainment of an A energy label is to form a panel dataset that tallies the market share for each make-model-trim-variant (summarized into the TARGA approval number[15]) in each region of Switzerland in each year,[16] and to run regressions relating them to the "normal" vehicle registration tax and any CO_2- or fuel economy-linked fee or rebate in place in the region in that year for this particular vehicle. We conduct our study at the regional level because the number of sales on municipality level are often very small.

Formally, we estimate the regression equation:

$$ln(share_{mit}) = \alpha_0 + \beta_1 \, REBATE_{mit} + \beta_2 \, PENALTY_{mit} + \theta_m + \gamma_{ist} + \varepsilon_{mit} \qquad (4)$$

[14] The reason for this high number of unmatched is that only one German speaking canton (AR) introduced a CO_2-based policy. The municipalities of this canton are rather small, and are located in a rural and mountainous region where only few non-treated matching municipalities are found.

[15] Using the TARGA approval number of car allows us to distinguish the cars in high detail, like engine size, horse power, body, weight, emissions, fuel consumption, size, etc.

[16] The region (also called district or Bezirk in German) is a geographic entity used the Statistics Switzerland. There are a total of 106 regions in Switzerland. Each region lies entirely within a single canton. In other words, no region straddles two or more cantons.

where *share* denotes the market share of model m (defined by its TARGA approval number) out of new car sales in region i and time t. *REBATE* is the discount applied by the canton to low emitters or vehicles with very good fuel economy, and *PENALTY* is the penalty applied to specified high emitters or highly fuel-inefficient cars. The car specific attributes and regional differences (mountainous, urban, rural, etc.) are capture by several fixed effects like trim θ_m, year, region-segment, segment-year and region-year fixed effects (γ_{ist}) where s stands for the segment (micro, compact, SUV, etc.) of a car. The region-segment for example is used to capture the preferences of certain type of car in a certain region (e.g. a SUV in mountainous regions or a micro car in a city), while the segment-year fixed effects shall capture the changing preferences of segments over the years (e.g, the rising demand for SUV in the last years). The coefficients β_1 and β_2 capture the effect of the policy on the market share of an average car affected by the policy. We use weights of the total number of new registrations per regions because the population size and therefore the car sales of the different region varies significantly.[17]

In a second approach, we use dummies for *REBATE* and *PENALTY* instead of continuous variables for the policy. Clearly, *REBATE* and *PENALTY* are equal to zero if the canton does not apply any special "green" fee system or if the system does not concern this particular vehicle.

Finally, we note that *t* ranges between max (2005, year the car was first approved for sale in Switzerland) and min (2011, year the TARGA number was "discontinued" and/or replaced by another). A particular vehicle can thus be present in our dataset for at most 7 years.

5. Data

The dataset used in this study is created by merging different datasets provided by the Federal Statics Office (FSO) and FEDRO. The merged dataset contains detailed information on all new passenger cars registered in Switzerland from 2005 to 2013. The main data source is the vehicle information system (MOFIS – Motofahrzeuginformationssystem) from FEDRO, which contains information about different car characteristics, the specific registration date and the zip code and canton of the municipality of the car owner. This dataset was merged with car homologation data (TARGA) by the type approval number and the transmissions

[17] A similar approach is also used by Chandra et al. (2010) where they analyze the effect of registration tax policies on HEV registrations.

code. The TARGA dataset gives us information about the CO_2 emissions, fuel consumption and other characteristics of the car. We added socio-demographic and geographical information at the municipality level, which we obtained from FSO and merged by the zip code at the car owner's residence.

We assigned the appropriate energy label to each vehicle using the federal laws in place at the time of the vehicle's registration. We computed the annual registration tax for each vehicle based on the cantonal laws in place at the time of the vehicle's registration. At the time of this writing, the full, merged dataset does not yet contain car prices. We hope to be able to append this information for the purpose of future analyses. Car and fuel prices do not generally vary across locales in Switzerland.

In sum, we have 2,422,199 new registered cars from 2005 to 2013. By "car" or "passenger car" we mean a light-duty vehicle with up to 9 passenger seats and weighing less than 3500 kg. In this report attention is restricted to cars in MOFIS dataset that could merged with TARGA information. Furthermore, we keep only observations such that the car owner lives in the same canton where his or her car is registered, and restrict our analysis to registrations before 2012 when the national CO_2 emissions scheme started. This leaves us with 1,765,590 observations, or roughly 91% of total new registrations between 2005 and 2011.[18]

A. General descriptive statistics

Descriptive statistics of our data are provided in tables 4, 5, and 6. Table 4 shows that over two-thirds of the new cars sold in Switzerland are gasoline cars, that about 31% has a diesel powertrain, and that hybrids account for less than 2% of all new car registrations. Our regressions are therefore based on gasoline and diesel cars only. Table 5 presents descriptive statistics of the dependent and independent variables considered in the empirical analysis. The maximum rebate in the cantons ranges from CHF 173 to CHF 633 and the maximum penalty from CHF 60 to CHF 1,902. The size of the municipalities is heterogeneous with a range from 7 to 376,990 residents with a median of 1,384 and an average of 3,552 residents. The average income per resident is CHF 31,144. Table 6 shows the trend over time of the three outcome variables considered in this study. The values reported in this table show that the share of A-label vehicles was 19% in 2005 and 24% by 2011. The share of cars emitting less than or just about 130 g CO_2/km was 4.3% in 2005 and 23% by 2011. the share of cars with A label and

[18] Detailed information about the data, merge process and descriptive statistics can be found in module1 of this report.

emitting less than or just about 130 g CO_2/km was 2.6% in 2005 and 16% by 2011. The share of G-label cars was 3.7% in 2005 and 2.7%by 2011. Finally, the share of cars emitting more than 200 g CO_2/km was 33.8% in 2005 and 7.4% by 2011. The discontinuity in the trend of the share of A-label and G-label cars is due to the biannual revision of the threshold to reach an A label.

Table 4: Share of fuel types (in percent in 2011)

	Gasoline	Diesel	HEV*	BEV	Rest
Share	66.99	30.77	1.75	0.12	0.37

*including range extender and plug-in hybrids

Table 5: Descriptive statistics of the dependent and independent variables in 2011

	Mean	Min	Median	Max
Maximum tax rebate	418	173	359	633
Maximum tax penalty	1,258	60	1,522	1,902
Number of residents per Municipality	3,552	12	1,384	376,990
Average income per resident	31,144	12,827	28,698	350,770
Share of cars with A label	23.77%	18.06%	24.07%	28.09%
Share of cars emitting ≤ 130 g CO_2/km	22.77%	14.51%	22.92%	27.68%
Share of cars with A label and emitting ≤ 130 g CO_2/km	15.83%	10.23%	15.98%	19.93%
Share of cars with G label	2.74%	1.40%	2.69%	5.67%
Share of cars emitting > 200 g CO_2/km	7.36%	4.64%	6.88%	13.17%

Table 6: Trends in the shares of vehicles with various characteristics

	2005	2006	2007	2008	2009	2010	2011
Share of cars with A label	19.30%	16.28%	14.54%	19.60%	25.08%	23.63%	23.77%
Share of cars emitting ≤ 130 g CO_2/km	4.31%	5.54%	6.34%	9.10%	14.06%	17.63%	22.77%
Share of cars with A label and emitting ≤ 130 g CO_2/km	2.59%	4.69%	6.16%	8.65%	13.53%	14.33%	15.83%
Share of cars with G label	3.72%	4.54%	4.37%	3.53%	3.08%	3.05%	2.74%
Share of cars emitting > 200 g CO_2/km	33.84%	33.71%	28.31%	20.86%	15.32%	9.97%	7.36%

B. Descriptive statistics at the cantonal level

In this subsection, we show some descriptive statistics to compare the cantons that introduced a policy with the cantons in the control group without any policy.

First, we compare the share of cars (potentially) affected by the policy in the treatment and control cantons one year before and one year after the implementation of the policy. We compute a difference in difference estimate of the effect of the treatment on a selected oucome variable in two possible ways.

$$\begin{aligned} DiD &= \frac{1}{n_T}\sum(y_2^T - y_1^T) - \frac{1}{n_C}\sum(y_2^C - y_1^C) \\ &= \overline{\Delta y^T} - \overline{\Delta y^C} \end{aligned} \tag{5}$$

where y is the outcome variable. The subscript 1 denotes the pre policy period and 2 denotes the post policy period, T denotes treatment cantons and C denotes control cantons.[19]

The results of these computations are displayed in tables 7 to 11. The highlighted numbers in the bottom right corner give us the calculated difference in difference. Results highlighted in green show a positive effect of the policy, i.e. the share of cars in cantons with a rebate policy increased compared to the control group. Results highlighted in red show the opposite (and counterintuitive) effect: we record a reduction in the shares of the cars in cantons with a rebate policy compared to the control group. The results show that in most cantons the policy increases the share of efficient or low emissions cars but there are also counterintuitive results.

These results should be interpreted with caution because the analysis does not control for other factors such as regional, socio-economic or other changes.

[19] Because the treatment cantons were observed individually, we are not able to take an average of the treatment cantons. Hence, a single treatment canton is always compared to the group of control cantons ($DID = \Delta y^T - \overline{\Delta y^C}$).

1. Cantons with label rebate policy

Table 7: DiD calculation – label rebate policy cantons vs. control cantons

Share of A cars

Canton Fribourg (FR)	2010	2011	Diff
control	24.04%	24.88%	0.84%
FR	25.04%	29.51%	4.48%
Diff	1.00%	4.64%	**3.64%**

Canton Thurgau (TG)	2010	2011	Diff
control	24.04%	24.88%	0.84%
TG	26.01%	25.64%	-0.37%
Diff	1.97%	0.76%	**-1.21%**

Canton Obwalden (OW)	2008	2009	Diff
control	18.85%	24.54%	5.70%
OW	17.19%	26.54%	9.35%
Diff	-1.66%	2.00%	**3.66%**

Canton Nidwalden (NW)	2008	2009	Diff
control	18.85%	24.54%	5.70%
NW	18.42%	29.84%	11.42%
Diff	-0.43%	5.29%	**5.72%**

2. Cantons with CO_2 rebate policy

Table 8: DiD calculation – CO_2 rebate policy cantons vs. control cantons

Share of cars emitting ≤120 g CO_2/km

Canton Geneva (GE)	2009	2010	Diff
control	8.95%	10.13%	1.18%
GE	11.12%	12.50%	1.38%
Diff	2.17%	2.37%	**0.20%**

Canton Graubünden (GR)	2010	2011	Diff
control	10.13%	12.41%	2.28%
GR	6.71%	8.27%	1.56%
Diff	-3.42%	-4.14%	**-0.72%**

Share of cars emitting ≤130 g CO_2/km

Canton Appenzell Ausserrhoden (AR)	2010	2011	Diff
control	17.35%	22.44%	5.10%
AR	15.66%	24.55%	8.88%
Diff	-1.68%	2.10%	**3.79%**

Share of cars emitting ≤140 g CO_2/km

Canton Graubünden (GR)	2008	2009	Diff
control	16.95%	24.32%	7.37%
GR	10.73%	16.18%	5.45%
Diff	-6.22%	-8.14%	**-1.92%**

Remark: Canton Waadt (VD) is not shown here because the policy was implemented in 2005 and hence we do not have before treatment observations.

3. Cantons with label and CO_2 rebate policy

Table 9: DiD calculation – Label and CO_2 rebate policy cantons vs. control cantons

Share of cars with A label and ≤130 g CO_2/km

Canton St. Gallen (SG)

	2008	2009	Diff
control	8.61%	13.18%	4.57%
SG	8.91%	18.15%	9.24%
Diff	0.30%	4.97%	**4.66%**

Canton Wallis (VS)

	2009	2010	Diff
control	13.18%	14.28%	1.10%
VS	11.60%	11.70%	0.09%
Diff	-1.58%	-2.59%	**-1.01%**

Share of cars with A label and ≤140 g CO_2/km

Canton Ticino (TI)

	2008	2009	Diff
control	12.62%	17.98%	5.36%
TI	14.79%	23.57%	8.78%
Diff	2.17%	5.58%	**3.41%**

4. Cantons with label penalty policy

Table 10: DiD calculation – Label penalty policy cantons vs. control cantons

Share of cars with G label

Canton Obwalden (OW)

	2008	2009	Diff
Control	3.66%	3.51%	-0.15%
OW	2.26%	3.16%	0.89%
Diff	-1.40%	-0.36%	**1.04%**

Share of cars with label D to G

Canton Fribourg (FR)

	2010	2011	Diff
Control	26.57%	25.12%	-1.45%
FR	20.31%	18.69%	-1.62%
Diff	-6.26%	-6.44%	**-0.17%**

Share of cars with F or G label

Canton Thurgau (TG)

	2010	2011	Diff
Control	5.86%	4.59%	-1.27%
TG	5.23%	4.19%	-1.04%
Diff	-0.63%	-0.40%	**0.24%**

Canton Ticino (TI)

	2008	2009	Diff
Control	7.06%	6.53%	-0.53%
TI	6.61%	5.37%	-1.24%
Diff	-0.44%	-1.15%	**-0.71%**

5. Cantons with CO_2 penalty policy

Table 11: DiD calculation – CO_2 penalty policy cantons vs. control cantons

Share of cars emitting >200 g/km

Canton Geneva (GE)

	2009	2010	Diff
Control	16.49%	10.52%	-5.97%
GE	16.82%	11.02%	-5.80%
Diff	0.33%	0.50%	**0.17%**

In a next step, we do not compare only the year before and after the implementation of the policy, but we show the trend of the different shares in graphs. In figures 1 to 3, we display the share of cars of selected types in each canton with a rebate policy versus the control cantons (left-hand side). The right-hand side graphs are similar but based on average CO_2 emissions. In figures 4 and 5, the share of high emissions or low fuel-economy cars in the treatment cantons are compared with those in the control cantons.

In some of the figures a small spike, i.e. an increase or reduction of the shares of cars affected by the policy can be observed. But overall there is no clear "break" discernible when the policy is introduced

Further statistics about the trend of registrations between the energy label categories or CO_2 groups within a canton can be found in figures 6 to 9 in Appendix 1.

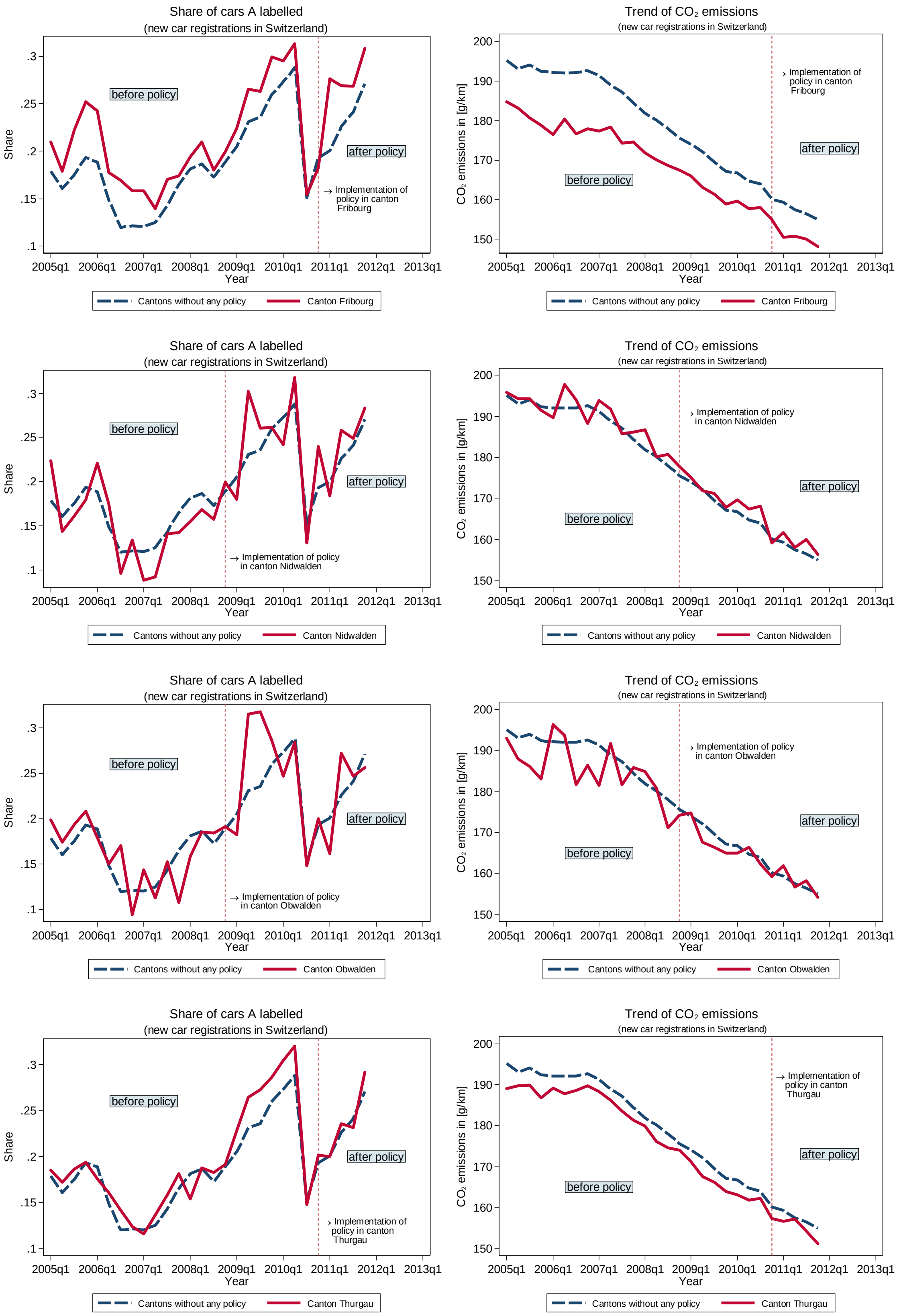

Figure 1: Share of A cars and average CO_2 emissions of cantons affected by label policies compared to control cantons over the years.

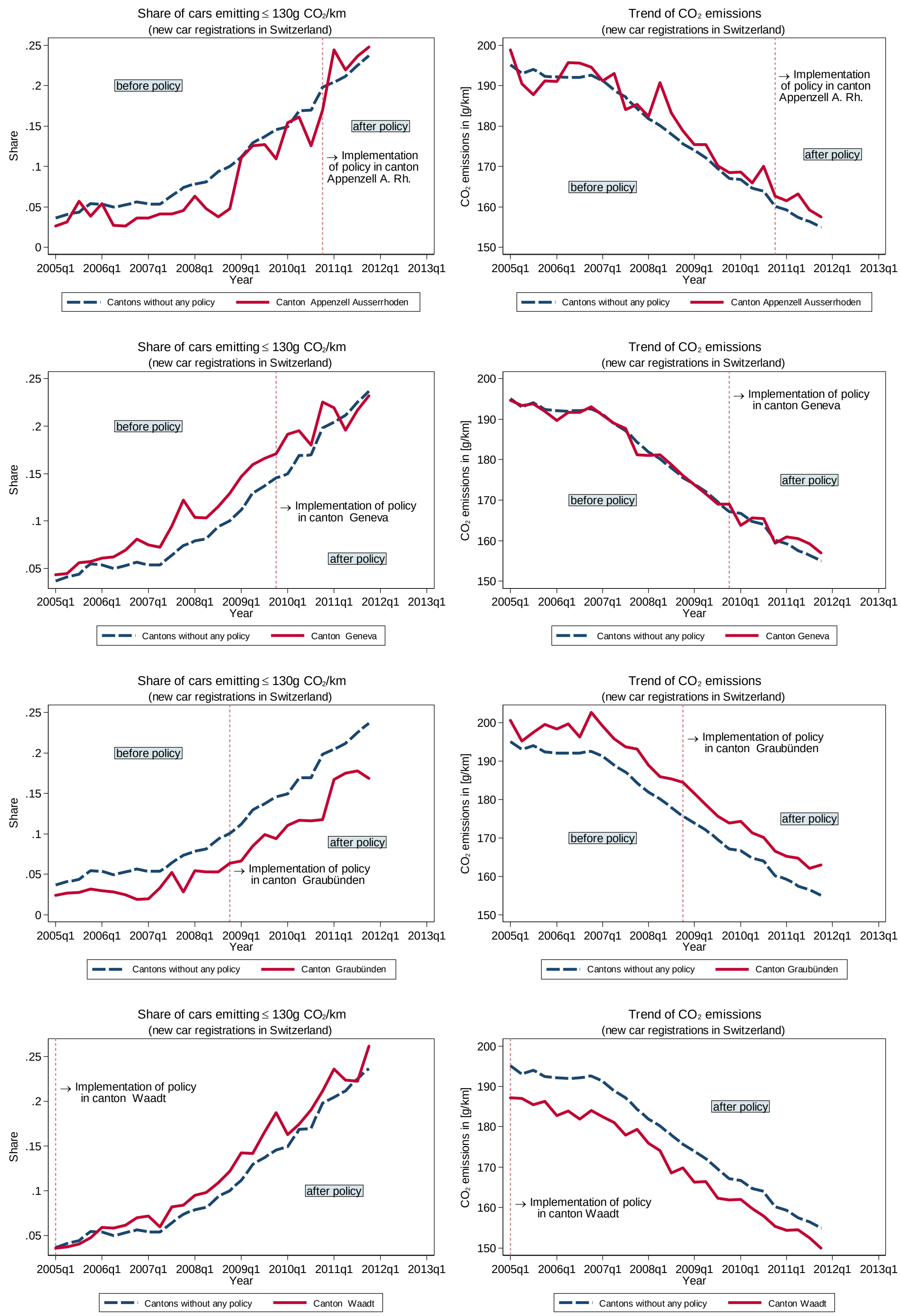

Figure 2: Share of cars emitting ≤130 g/km and average CO_2 emissions of cantons affected by CO_2 policies compared to control cantons over the years.

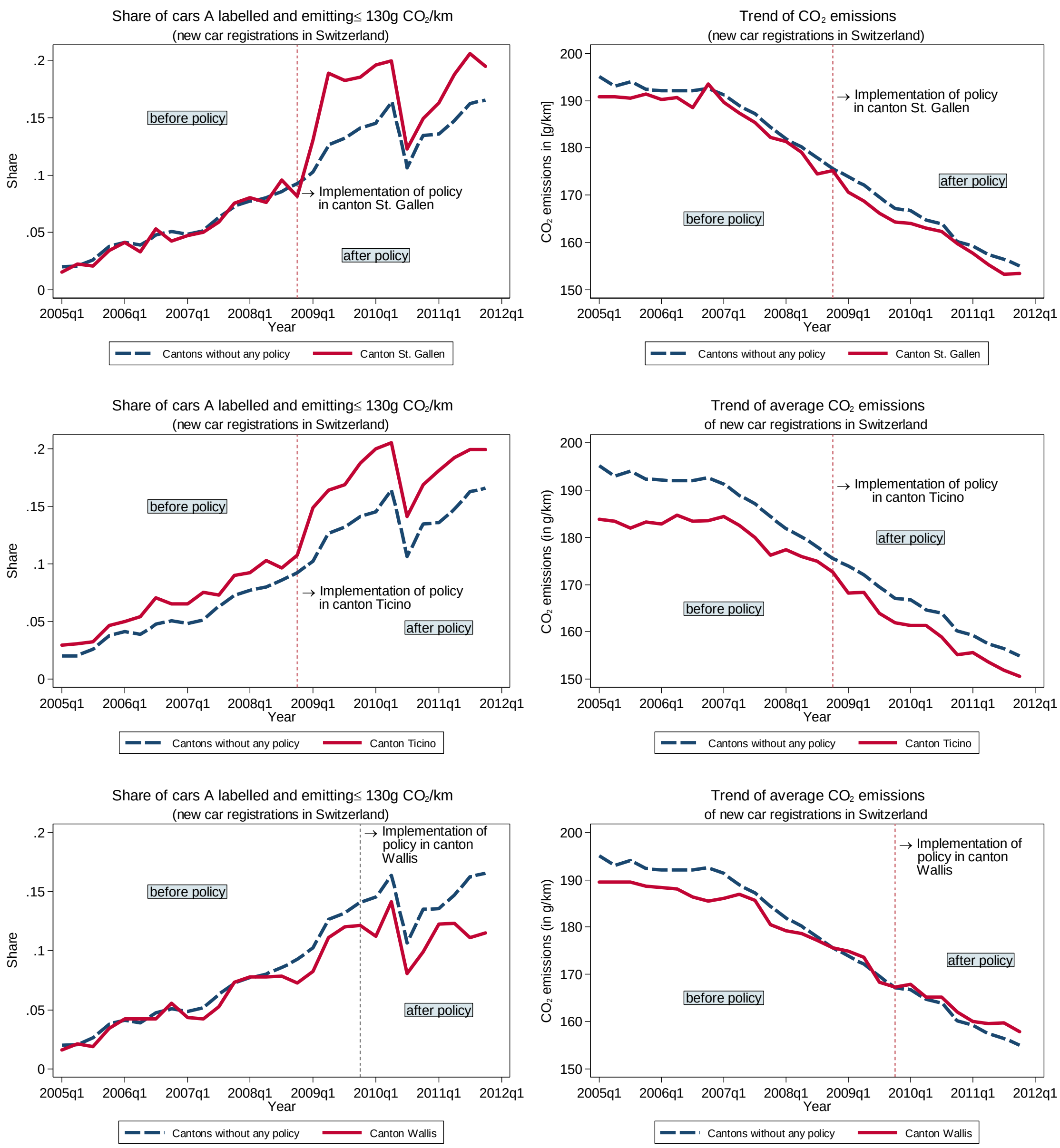

Figure 3: Share of A cars emitting ≤130 g CO_2/km and average CO_2 emissions of cantons affected by CO_2 and label policies compared to control cantons over the years.

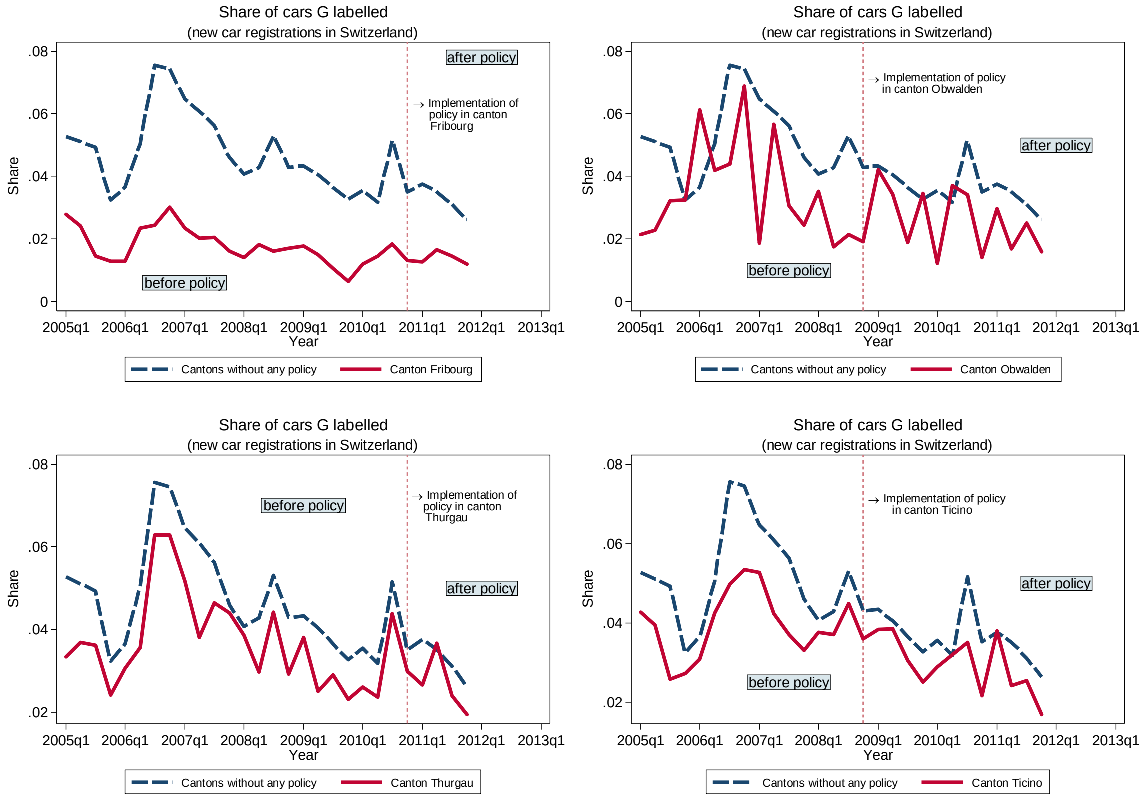

Figure 4: Share of G cars of cantons with a penalty system compared to control cantons over the years.

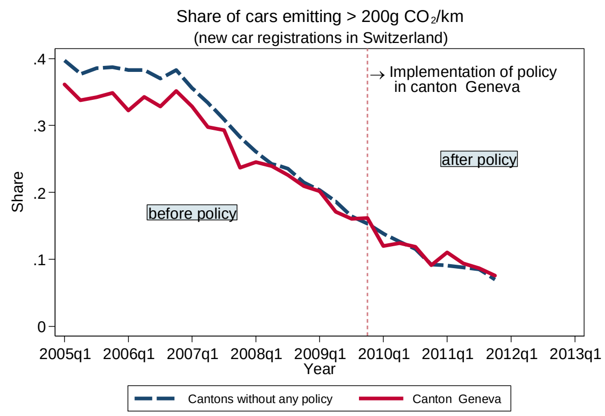

Figure 5: Share of cars emitting >200 g CO_2/km of cantons with a penalty system compared to control cantons over the years.

C. Impact on revenues

Before turning to our regressions, we calculate the impact of the incentives on the vehicle registration tax revenue of the different cantons. This impact is displayed in tables 12 and 13. Table 12 shows the absolute amount of revenue losses or gains due to the differentiated tax system while table 13 gives us the associated percentage changes. We make use of the annual passenger car fleet data to approximate the overall revenue changes.[20] While the cantons that introduced a penalty for inefficient or high emitting cars may even increase their tax revenues, in general cantons that offer a rebate only can lose tax revenues in the seven-figure range (i.e. by more than 10 percent on average). To keep in mind, that these are only approximate figures and as such they should be interpreted with caution.

[20] It will be still an approximation because we do not have the car characteristics of all cars. Hence, we are not able to calculate the registration taxes of these cars. A detailed description of the dataset with all car registrations can be found in module 1 of this project.

Table 12: Absolute effect of feebate policy on cantonal car registration tax revenue from 2005 – 2011 (CHF=2011 prices)*

	2005	2006	2007	2008	2009	2010	2011
AG	0	0	0	0	0	0	0
AI	0	0	0	0	0	0	0
AR	0	0	0	0	0	0	-260'891
BE	0	0	0	0	0	0	0
BL	0	0	0	0	0	0	0
BS	0	0	0	0	0	0	0
FR	0	0	0	0	0	0	-715'185
GE	0	0	0	0	0	613'124	1'246'189
GL	0	0	0	0	0	0	0
GR	0	0	0	0	-3'705'659	-4'541'054	-1'885'595
JU	0	0	0	0	0	0	0
LU	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0
NW	0	0	0	0	-627'619	-720'204	-824'999
OW	0	0	0	0	-392'652	-579'636	-732'051
SG	0	0	0	0	-1'893'629	-2'950'393	-4'023'262
SH	0	0	0	0	0	0	0
SO	0	0	0	0	0	0	0
SZ	0	0	0	0	0	0	0
TG	0	0	0	0	0	0	-187'878
TI	0	0	0	0	-164'288	-576'091	-1'014'612
UR	0	0	0	0	0	0	0
VD	-444'895	-576'939	-750'077	-1'035'206	-1'365'260	-1'838'169	-2'518'713
VS	0	0	0	0	0	-367'370	-483'553
ZG	0	0	0	0	0	0	0
ZH	0	0	0	0	0	0	0

*Note: These are only approximate figures and as such they should be interpreted with caution. The effects on the revenues were calculated from registration tax changes over the whole fleet (not only new registrations), but only for gasoline and diesel cars which account for more than 97% of all cars (see table 4), and only for the ones that we successfully merged across the MOFIS and TARGA datasets which range from 61% in 2005 to 81% in 2011 of all cars (see table 1 of module 1 of this project). Hence not all car registrations are considered and the figures presented are only approximations. The correct figures tend to be higher, i.e. the losses are smaller and the gains higher, because the most of the cars which could not be merged are old cars which do not profit from a rebate.

Table 13: Percentage effect of feebate policy on cantonal car registration tax revenue from 2005 – 2011*

	2005	2006	2007	2008	2009	2010	2011
AG	0%	0%	0%	0%	0%	0%	0%
AI	0%	0%	0%	0%	0%	0%	0%
AR	0%	0%	0%	0%	0%	0%	-1.99%
BE	0%	0%	0%	0%	0%	0%	0%
BL	0%	0%	0%	0%	0%	0%	0%
BS	0%	0%	0%	0%	0%	0%	0%
FR	0%	0%	0%	0%	0%	0%	-1.19%
GE	0%	0%	0%	0%	0%	0.89%	1.73%
GL	0%	0%	0%	0%	0%	0%	0%
GR	0%	0%	0%	0%	-8.44%	-9.63%	-3.80%
JU	0%	0%	0%	0%	0%	0%	0%
LU	0%	0%	0%	0%	0%	0%	0%
NE	0%	0%	0%	0%	0%	0%	0%
NW	0%	0%	0%	0%	-9.43%	-10.32%	-11.46%
OW	0%	0%	0%	0%	-7.51%	-10.18%	-12.16%
SG	0%	0%	0%	0%	-2.18%	-3.16%	-4.07%
SH	0%	0%	0%	0%	0%	0%	0%
SO	0%	0%	0%	0%	0%	0%	0%
SZ	0%	0%	0%	0%	0%	0%	0%
TG	0%	0%	0%	0%	0%	0%	-0.56%
TI	0%	0%	0%	0%	-0.21%	-0.68%	-1.14%
UR	0%	0%	0%	0%	0%	0%	0%
VD	-0.38%	-0.46%	-0.55%	-0.70%	-0.88%	-1.11%	-1.43%
VS	0%	0%	0%	0%	0%	-1.08%	-1.33%
ZG	0%	0%	0%	0%	0%	0%	0%
ZH	0%	0%	0%	0%	0%	0%	0%

*Note: These are only approximate figures and as such they should be interpreted with caution. The effects on the revenues were calculated from registration tax changes over the whole fleet (not only new registrations), but only for gasoline and diesel cars which account for more than 97% of all cars (see table 4), and only for the ones that we successfully merged across the MOFIS and TARGA datasets which range from 61% in 2005 to 81% in 2011 of all cars (see table 1 of module 1 of this project). Hence not all car registrations are considered and the figures presented are only approximations. The correct figures tend to be higher, i.e. the losses are smaller and the gains higher, because the most of the cars which could not be merged are old cars which do not profit from a rebate.

6. Empirical results

A. The Difference-in-Difference Approach

We remind the reader that in order to use the DID approach, we first need to verify the common trend assumption. For this reason, we apply the test of the common trend assumption of the outcome variable for the three bonus (CO_2, label, label and CO_2) and the two malus policy models (CO_2, label). For all these models we take as control groups

1) all municipalities in cantons without policy,
2) the municipalities in cantons without policy that are matches for municipalities in the treated cantons based on population, year, elevation, urban vs. rural environment, and German language and
3) the same as 2) but without controlling for German language.

The resulting F-statistics are displayed in table 14. Recall that our Null Hypothesis (H_0) is that trends in the outcome variables of the treatment and control groups are the same prior to the beginning of the policy. In table 14., we highlight the models in which H_0 is *not* rejected at the 5% significance level. This implies that the trends are the same prior to the policy. The table shows that in the case of the label & CO_2 bonus policy (share of cars with A label emitting ≤130 g CO_2/km) and the label malus policy (share of G labelled cars) the trends appear to be different even prior to the beginning of the policy. Moreover, in our preferred models based on the matching techniques, the common trend condition is not satisfied for the CO_2 malus policy (share of cars emitting more than 200 g CO_2/km). This means that a difference-in-differences study design cannot be applied in these cases. For this reason, we report the results for the DID model only for the label bonus policy (A label) and the CO_2 bonus policies (emitting ≤130 g CO_2/km).

Table 14: F statics of common trend tests

	(1)	(2)	(3)
	non weighted	matching with german dummy	matching without german dummy
Bonus			
A	1.744 (0.121)	2.786 (0.016)	1.590 (0.159)
$CO_2 \leq 130$g	0.668 (0.648)	1.326 (0.250)	0.781 (0.563)
A & CO_2	9.412 (0.000)	6.791 (0.000)	5.685 (0.000)
Malus			
G	2.382 (0.036)	2.456 (0.031)	2.456 (0.027)
$CO_2 \geq 200$g	0.730 (0.572)	4.266 (0.002)	2.741 (0.027)

p-values in parentheses
common trends prior to the policy are highlighted in green

Estimation results of model (1) and (2) are reported in tables 15 and 16. In table 15, the dependent variable in our regressions is the share of A-label cars out of all new car registrations in municipality *i* in year *t*. In table 16, the dependent variable is the share of cars with CO_2 emissions rates less than or equal to 130 g/km in municipality *i* in year *t*. The samples are constructed so that only control municipalities and municipalities in cantons that apply the specific type of policies being considered are included.

Each table (15 and 16) contains a total of 6 columns. Columns (1) and (2) use *POL* and *TAX*, respectively, as the key variable of interest. Columns (3) and (4) are similar, except that the sample exclude treated units that could not be matched with control units (and vice versa) based on population, year, elevation, urban v. rural environment, and German language. The estimation further applies the CEM weights. Columns (5) and (6) are similar to (3) and (4), but the CEM matching procedure is less restrictive because it does not include the German language dummy. We believe that the use of a matching procedure is important because it allows for a comparison between similar municipalities. We prefer the less restrictive matching procedure and consider the results reported in column 5 and 6 the most reliable.

Table 15 shows that the establishment of the rebate policies and the generosity of the policy, i.e. the level of the rebate, do increase the share of A-label cars sold in the "treated" municipality. The coefficients on these variables are positive and significant, but generally imply a small effect on the A-label shares. At the average maximum tax rebate available, the impact of the rebate is approximately 2 percentage points (1.96; see column (1)). The effect of establishing a rebate system with A-label eligibility is likewise estimated to be almost 2 percentage points (1.83; see column (2)). The effect is stronger –a little over 3 percentage points—when we apply the first CEM approach and the associated weights (columns (3) and (4)), and again about 2% when we apply the second CEM approach and its associated weights (columns (5) and (6)).

In table 16 we focus on the share of cars with CO_2 emissions rates of less than or equal to 130 g/km. We eliminate observations from Graubünden because of the changing eligibility criteria in this canton, which make it impossible to construct the dependent variable consistently over the years. The results are qualitatively similar to their counterparts in table 16, but less statistically significant. The effects of the policy (or the mean maximum tax rebate) range from 1.4 - 1.7 percentage point for the simplest, unweighted estimator to 2.6 – 4.4 percentage points when the first CEM approach is used.

Table 15: Regression Equations (1) and (2). Dependent Variable: share of A cars. Column (1, 2) do not use weights, (3-6) using weights from the CEM matching technique

	(1)	(2)	(3) [1)]	(4) [1]	(5) [2)]	(6) [2)]
Maximum rebate		0.0000397***		0.0000656***		0.0000444***
		(3.37)		(4.73)		(3.55)
Policy Dummy	0.0183**		0.0327***		0.0208**	
	(3.04)		(4.51)		(3.22)	
Income per resident	0.000299	0.000317	0.000457	0.000495	0.000264	0.000281
	(0.63)	(0.67)	(0.46)	(0.50)	(0.53)	(0.56)
Number of residents	0.00000466*	0.00000469*	0.0000420***	0.0000428***	0.0000190**	0.0000194**
	(2.42)	(2.43)	(4.44)	(4.51)	(2.97)	(3.03)
2006	-0.0294***	-0.0294***	-0.0120	-0.0121	-0.0285***	-0.0285***
	(-8.51)	(-8.51)	(-1.77)	(-1.78)	(-6.06)	(-6.06)
2007	-0.0413***	-0.0413***	-0.0352***	-0.0353***	-0.0401***	-0.0402***
	(-12.11)	(-12.12)	(-5.22)	(-5.23)	(-8.63)	(-8.64)
2008	0.00895*	0.00892*	0.00684	0.00675	0.00841	0.00835
	(2.51)	(2.51)	(0.90)	(0.89)	(1.73)	(1.72)
2009	0.0635***	0.0635***	0.0603***	0.0602***	0.0633***	0.0633***
	(17.15)	(17.13)	(8.20)	(8.18)	(12.45)	(12.43)
2010	0.0457***	0.0456***	0.0376***	0.0374***	0.0463***	0.0462***
	(12.20)	(12.18)	(5.34)	(5.31)	(8.98)	(8.96)
2011	0.0435***	0.0433***	0.0245***	0.0246***	0.0387***	0.0385***
	(11.15)	(11.22)	(3.34)	(3.38)	(6.92)	(6.94)
Constant	0.156***	0.155***	0.0713*	0.0683	0.124***	0.123***
	(10.30)	(10.23)	(1.97)	(1.89)	(5.83)	(5.75)
Observations	9633	9633	8570	8570	8927	8927
R^2	0.345	0.346	0.295	0.295	0.326	0.327
Change in percentage points	1.83%	1.96%	3.27%	3.23%	2.08%	2.19%

t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

1) Estimations (3) and (4) are weighted by the results of the applied coarsened exact matching technique. Each year the matching variables are number of residents, altitude, German speaking, rural/urban area in the treatment and control cantons.

2) Identical to 1) except that we do not include language among the matching variables.

Table 16: Regression Equations (1) and (2). Dependent Variable: share of cars emitting ≤130 g CO_2/km (excluding canton Graubünden, GR), Column (1, 2) do not use weights, (3-6) using weights from the CEM matching technique

	(1)	(2)	(3)	(4)	(5)	(6)
Maximum rebate		0.0000563*		0.000147***		0.0000598*
		(2.36)		(3.71)		(2.44)
Policy Dummy	0.0139*		0.0259**		0.0153*	
	(1.97)		(2.66)		(2.10)	
Income per resident	0.0000201	0.00000884	0.000249	0.000185	-0.0000127	-0.0000242
	(0.04)	(0.02)	(0.37)	(0.28)	(-0.03)	(-0.05)
Number of residents	-0.00000128	-0.00000130	0.00000651	0.000000638	-0.00000612*	-0.00000606*
	(-1.50)	(-1.52)	(0.66)	(0.07)	(-2.04)	(-2.02)
2006	0.0161***	0.0162***	0.0283***	0.0291***	0.0162***	0.0163***
	(7.29)	(7.36)	(4.84)	(5.01)	(6.77)	(6.84)
2007	0.0226***	0.0222***	0.0317***	0.0297***	0.0224***	0.0220***
	(9.32)	(9.16)	(5.10)	(4.78)	(8.77)	(8.60)
2008	0.0529***	0.0526***	0.0584***	0.0565***	0.0533***	0.0529***
	(20.26)	(20.11)	(9.67)	(9.35)	(18.45)	(18.31)
2009	0.0991***	0.0988***	0.0958***	0.0942***	0.0987***	0.0983***
	(35.42)	(35.27)	(14.75)	(14.52)	(32.49)	(32.36)
2010	0.130***	0.129***	0.130***	0.126***	0.129***	0.128***
	(42.74)	(42.13)	(17.61)	(16.44)	(38.29)	(37.73)
2011	0.183***	0.182***	0.178***	0.171***	0.184***	0.183***
	(60.75)	(58.74)	(22.76)	(19.46)	(54.09)	(52.45)
Constant	0.0492**	0.0499**	0.0271	0.0383	0.0665***	0.0670***
	(3.16)	(3.19)	(0.93)	(1.32)	(3.68)	(3.69)
Observations	10305	10305	3990	3990	9946	9946
R^2	0.553	0.553	0.506	0.507	0.553	0.553
Change in percentage points	1.39%	1.68%	2.59%	4.39%	1.53%	1.78%

t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

B. Alternate Approach

In this approach we no longer examine the effect of the rebate or penalty policies on the shares of cars which meet certain requirements. Instead, we examine the effect of the policy on the share of cars of a specified make, model, trim and variant (captured into a TARGA approval number). The shares are computed out of all new car sales. We try to identify the change of the market share of a certain type of car in a region because of the different cantonal policies. We fit four different models where we changed the interactions between segment, regional and time fixed effects. The fixed effects and interactions we used are:

1. TARGA FE (fixed effects on make-model-trim)
2. TARGA FE, Region FE and Year FE
3. TARGA FE and Region*Year FE
4. TARGA FE, Region*Segment FE and Segment*Year FE

Further, in alternate runs, we use a) continuous variables (rebate and penalty), and b) dummy variables (bonus and malus) for the policy variables for each of the above mentioned models. This leads us to a total of eight different models. The results are displayed in table 17.

A positive coefficient on the rebate or bonus variable means that a rebate leads to a higher market share for a car that receives a rebate, and a negative coefficient on the penalty or malus variables tells us that the share of a car decreases because of the penalty. As shown in table 17, the estimated coefficients in model 1a) and 1b) have the correct sign and are large. The fit of the regression (R^2) is also lower in these models than in 2a) to 4b).Most likely this is because the policy variables capture not only the effect of the policy but potentially also segment, time and regional effects. Hence, we prefer models 2a) to 4b). While the penalty coefficients in these models are not significant, all of the other policy variables get significant coefficients with the correct sign. Our dependent variable is the log of the share of a particular car, so e.g. the coefficient of 0.0161 can be interpreted as a 1.6% increase in the share of a car that receives a rebate of CHF 100. An average rebate of around CHF 225 would lead to an increase of the share of 3.6% (=1.6%*225/100). The results vary slightly depending on the model used but are all within a close range. They are also similar to the results found in previous literature mentioned in section 2 (e.g. Klier and Linn, 2015).

We remind the reader that this model and analysis is not suited for estimating cross fee effects – the change in the share of one vehicle as the fee on another vehicle is changed. A structural model is needed to establish such cross effects. We do not take up the structural model in this project.

Table 17: Estimation results of alternate approach on car level

	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
rebate (100 CHF)	0.0670***		0.0161***		0.0226***		0.0163***	
	(21.06)		(5.54)		(7.13)		(5.52)	
penalty (100 CHF)	-0.0601***		-0.00258		-0.00320		-0.00690	
	(-19.21)		(-0.92)		(-1.09)		(-1.66)	
bonus		0.0938***		0.0404***		0.0528***		0.0220*
		(9.04)		(4.30)		(5.10)		(2.30)
malus		-0.460***		-0.0429*		-0.0474*		-0.0921***
		(-23.15)		(-2.35)		(-2.45)		(-4.05)
TARGA FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	No	No	Yes	Yes	No	No	No	No
Year FE	No	No	Yes	Yes	No	No	No	No
Region*Year FE	No	No	No	No	Yes	Yes	No	No
Region*Segment FE	No	No	No	No	No	No	Yes	Yes
Segment*Year FE	No	No	No	No	No	No	Yes	Yes
R^2	0.412	0.412	0.584	0.584	0.585	0.585	0.587	0.587
N	628539	628539	628539	628539	628539	628539	589902	589902

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

7. Conclusion

We have exploited variation across cantons and over time in the cantonal car registration tax incentives from 2005 to 2011 to see if rebate or penalty policies had an effect on the registrations of fuel-efficient and clean cars. Our study design follows the format of a natural experiment where the treatment is the rebate policy, and we have control and treatment units. We have data at the municipal level before and after the adoption of the cantonal rebate policy (if any).

In our first and main approach, we find that the cantonal rebate policies attain an increase in the share of A-label cars by about 2 percentage points (if we consider an average share of A-label cars of approximately 20% this is a 10% increase of A-label cars) and a comparable increase in the share of cars less than or just about 130 g CO_2/km. To put things in perspective, we perform a simple exercise to obtain a rough estimate of the cost of reducing CO_2 emissions by one ton. We use the results of our econometric estimations of the policy impact on the share of A labelled cars from column (5) in Table 15 and assume an average Swiss canton that applies only a bonus (without malus) policy. The cost of the policy for the canton is represented by the loss of tax revenues. Of course, we are aware that correct estimation of the abatement cost requires information on the individual driving behavior and the mileage of each car. Unfortunately, our dataset does not contain these information, and so we can only calculate the cost effectiveness of the policies under simplifying assumptions.

We consider an average Swiss canton in the year 2008, when no canton, except Canton Vaud (VD), had a policy in place yet. We assume that this average canton registers around 9000 cars per year and adopts a (pure) 50% rebate policy for cars emitting maximum 130 g CO_2/km. The share of new cars complying with this threshold was around nine percent in 2008. Holding the total number of new cars registered constant, the policy increases the number of cars emitting maximum 130 g CO_2/km from 800 to 961. The change is thus 161 units, which means that the registrations of cars emitting more than 130 g CO_2/km decline by the same amount. Since treated cars have an average CO_2 emissions rate of 117.4 g/km in 2008 and non-treated vehicle have an average CO_2 emissions rate of 184.3 g/km, assuming that cars are driven 13,800 km per year the resulting decline in CO_2 emissions is 1,784 tons over the assumed lifetime of 12 years.[21] – less than 1% of the emissions of the total fleet.

[21] Back of the envelop calculation: (184.3 g/km – 117.4 g/km)*13,800 km * 161 units * 12 years / 10^6 = = 1,784 t CO_2

Considering the revenue losses of the canton, we calculate a cost effectiveness of 248 Swiss Francs per ton of CO_2 mitigated. We need to point out that we made very strong assumptions to calculate these figures. The actual costs per ton of CO_2 saved is likely to be much higher. For example, we do not know what kind of car a customer would have bought if he did not get a bonus for the low-emitting car.[22] A potential rebound effect, which reduces the CO_2 emissions saved because of a different driving behavior, is not consider in our calculation either. Further, the higher the share of cars receiving a rebate, the higher the number of free riders, which rises the abatement costs substantially. Obviously, the abatement cost would be much lower or even zero or positive if a canton introduced a combined system with bonus and malus that reduces the impact on the cantonal tax revenues.

We also examine an alternate outcome variable—namely the market share for a specified make-model-trim in any given region in a year—finding that the rebates have a statistically significant effect on the market share, while the penalties do not have a significant effect.

Clearly a rebate policy implies disbursements or at least a loss of revenue. Unless this can be made up for by setting up a fee (malus) system within a proper feebate program, the savings in CO_2 emissions will come at a high cost for the canton.

An additional concern is that when the rebate system is introduced, the rebate is given to anyone who purchases a qualifying car. From our results that only show small effects of the policy incentives, we assume that most drivers who bought a fuel-efficient or low-emitting vehicle would have bought this vehicle even without the incentive. This raises the cost per ton of CO_2 mitigated. However, with the model applied in this report, it is not possible to estimate a potential free riding effect in detail.

In order to improve the impact of the policy, we recommend implementing a bonus system for low-emitting cars based on strict CO_2 emissions thresholds accompanied with a high malus for high-emitting cars. The bonus should be granted only for new registrations in the first one to three years, and the malus should be imposed on both new and used cars. Furthermore, it is important to raise the awareness of the policy and to communicate it clearly and effectively, so that customers take the registration tax into consideration while buying a new car.

[22] By considering varying assumptions of rebates and control groups the cost per ton of CO_2 saved can increase to more than CHF 1,500.

References

Abadie, Alberto and Guido W. Imbens (2006) “Large-Sample Properties of Matching Estimators for Average Treatment Effects,” Econometrica, 74(1), 235-267.

Abadie, Alberto and Guido W. Imbens (2008) “On the Failure of the Bootstrap for Matching Estimator,” Econometrica, 76(6), 1537-1557.

Abadie, Alberto and Guido W. Imbens (2011) “Bias-Corrected Matching Estimators for Average Treatment Effects,” Journal of Business and Economic Statistics, 29(1), 1-11.

Adamou, Adamos, Sofronis Clerides and Theodoros Zachariadis (2014). Welfare implications of car feebates: A simulation analysis. Economic Journal, 124, F420-F443.

Alberini, Anna, Markus Bareit and Massimo Filippini (2015). The Effect of Registration Taxes on New Car Registrations: Evidence from Switzerland. Center for Energy and Economics, CEPE, ETH Zurich, Mimeo.

Alberini, Anna, Markus Bareit and Massimo Filippini (2016). “What is the Effect of Fuel Efficiency Information on Car Prices? Evidence from Switzerland.” Energy Journal (forthcoming).

Anderson, Soren T., Ian W. Parry, James Sallee and Carolyn Fischer (2011), “Automobile Fuel Economy Standards: Impacts, Efficiency, and Alternatives,” Review of Environmental Economics and Policy, 5(1), 89-108.

Asa (2007). Rabattmodell für die kantonale Motorfahrzeugsteuer zur Förderung energie- und umwelteffizienter Personenwagen - Empfehlung der Vereinigung der Strassenverkehrsämter der Schweiz (asa). Association of the Swiss road traffic licensing departements, July 2007. Available at: http://www.asa.ch/media/archive1/Shop/Broschueren/Gratis/asa_Rabattmodell_de.pdf

BAFU (1999). Bundesgesetz über die Reduktion der CO2-Emissionen (CO2-Gesetz) vom 8. Oktober 1999 (Stand am 1. Mai 2012). Federal Office fort he Environment FOEN, Bern, 1999. Available at: http://www.bafu.admin.ch/klima/00493/00494/index.html?lang=de&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1acy4Zn4Z2qZpnO2Yuq2Z6gpJCGfYF,fWym162epYbg2c_JjKbNoKSn6A--

BAFU (2014a). Kyoto Protocol: Switzerland fulfils its commitment for 2008-2012. Federal Office for the Environment FOEN, Bern, 2014. Available at: http://www.bafu.admin.ch/dokumentation/medieninformation/00962/index.html?lang=en&msg-id=52619

BAFU (2014b). Swiss climate policy at a glance. Federal Office for the Environment FOEN, Bern, 2014. Available at: http://www.bafu.admin.ch/publikationen/publikation/01757/index.html?lang=en&download=NHzLpZig7t,lnp6I0NTU042l2Z6ln1ad1IZn4Z2qZpnO2Yuq2Z6gpJCHdn95fWym162dpYbUzd,Gpd6emK2Oz9aGodetmqaN19XI2IdvoaCVZ,s-.pdf

BAFU (2014c). Entwicklung der Treibhausgasemissionen seit 1990. Excel-File, Federal Office for the Environment FOEN, Bern, 2014. Available at: http://www.bafu.admin.ch/klima/09570/09574/index.html?lang=de&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1acy4Zn4Z2qZpnO2Yuq2Z6gpJCHdn95g2ym162epYbg2c_JjKbNoKSn6A--

Beresteanu, Arie and Shanjun Li (2011). Gasoline prices, government support, and the demand for hybrid vehicles in the United States. International Economic Review, 52, 161-182.

BFE (2009). Schweizer Autos sind immer noch zu durstig. Press release of 7.5.2009, Bundesamt für Energie, Bern. Available at: http://www.bfe.admin.ch/energie/00588/00589/00644/index.html?lang=de&msg-id=26779

BFE (2011). CO2-Zielwerte für Personenwagen gelten ab Mitte 2012. Press release of 16.12.2011, Bundesamt für Energie, Bern. Available at: http://www.news.admin.ch/message/index.html?lang=de&msg-id=42730

BFE (2013). 17. Berichterstattung im Rahmen der Energieverordnung über die Absenkung des spezifischen Treibstoff-Normverbrauchs von Personenwagen 2012. Erstellt von auto-schweiz im Auftrag vom Eidg. Departement für Umwelt, Verkehr, Energie und Kommunikation (UVEK), Bern. Available at: http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_695528591.pdf&endung=17. Berichterstattung im Rahmen der Energieverordnung über die Absenkung des spezifischen Treibstoff-Normverbrauchs von Personenwagen 2012

Chandra, Ambarish, Sumeet Gulati and Milind Kandlikar (2010). Green drivers or free riders? An analysis of tax rebates for hybrid vehicles. Journal of Environmental Economics and Management, 2010, 60, 78-93

Cicone, Alice (2014). Is it all about CO_2 emissions? The environmental effects of a tax reform for new vehicles in Norway. Working Paper, University of Oslo.

De Haan, Peter, Michel Müller, Anja Peters and Andrea Hause (2007a). Lenkungsabgaben zur Senkung des CO2-Ausstosses beim Neuwagenkauf. On behalf of Swiss Federal Office of Energy, Bern, 31.12.2007. Available at: http://www.bfe.admin.ch/forschungewg/02544/02807/02808/index.html?lang=en&dossier_id=02984

De Haan, Peter, Anja Peters and Roland W. Scholz (2007b). Reducing energy consumption in road transport through hybrid vehicles: Investigation of rebound effects, and possible effects of tax rebates. Journal of Cleaner Production 15, 1076-1084.

De Haan, Peter (2009a). CO2-Emissionen der PW-Neuzulassungen der Schweiz: Orientierung an der EU – Schlussbericht. On behalf of Swiss Federal Office of Energy, Bern, 11.05.2009, Available at: http://www.bfe.admin.ch/php/modules/enet/streamfile.php?file=000000010193.pdf&name=000000290055

De Haan, Peter (2009b).Übernahme des EU-Ziels 130 g CO2/km: Abschätzung Abgabenverläufe 2012-2020 – Schlussbericht. On behalf of Swiss Federal Office of Energy, Bern, 14.12.2009 Available at: http://www.bfe.admin.ch/php/includes/container/enet/flex_enet_anzeige.php?lang=en&publication=10252&height=400&width=600

De Haan, Peter (2009c). Umsetzung der 130 g CO2/km-Strategie für die Schweiz: CO2-Reduktionseffekte 2012-2020 – Schlussbericht. On behalf of Federal Office for the Environment, Bern, 18.05.2009. Available at: http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_40080965.pdf&endung=Umsetzung der 130 g CO2/km-Strategie für die Schweiz: CO2-Reduktionseffekte 2012-2020 – Schlussbericht

Dehejia, Rajeev H. and Sadek Wahba (1999), Causal Effects in Nonexperimental Studies: Reevaluating the Evaluation of Training Programs. Journal of the American Statistical Association, 94, p. 1053-1062.

D'Haultfoeuille Xavier, Pauline Givord and Xavier Boutin (2014). The Environmental Effect of Green Taxation: The Case of the French Bonus/Malus. Economic Journal 124, F444-F480.

Diamond, David (2009). The impact of government incentives for hybrid-electric vehicles: Evidence from US states. Energy Policy, 2009, 37, 972 – 983.

Gallagher, Kelly S. and Eric Muehlegger (2011). Giving green to get green? Incentives and consumer adoption of hybrid vehicle technology. Journal of Environmental Economics and Management 61 (2011), p. 1-15.

Hammer, Stephan and Markus Maibach (1999). Finanzielle Anreize zur Förderung energieeffizienter Personenwagen. On behalf of: Swiss Federal Office of Energy, Bern, 01.12.1999.

Hammer, Stephan; Markus Maibach and Peter Marti (2001). Instrumente zur Absenkung des spezifischen Treibstoffverbrauchs von Personenwagen. On behalf of Swiss Federal Office of Energy, Bern, Infras (Zürich); Metron (Brugg), 2001.

Heckman, James J., Hidehiko Ichimura, and Petra Todd (1998), Matching as an Econometric Evaluation Estimator. Review of Economic Studies, 65, 261-294.

Huse, Christian and Claudio Lucinda (2014). The market impact and the cost of environmental policy_ Evidence from the Swedish green car rebate. Economic Journal, 124, F393-F419.

Iacus, Stefano M., Gary King and Giuseppe Porro (2011), "Causal Inference without Balance Checking: Coarsened Exact Matching," Political Analysis.

ICCT (2013). European Vehicle Market Statistic – Pocketbook. The International Council of Clean Transportation (ICCT), 2013.

Iten, Rolf and Katharina Sammer (2005) Massnahmen zur Absenkung des Flottenverbrauchs. Abschätzung der Wirkung. On behalf of Swiss Federal Office of Energy, Bern, 01.09.2005 Available at: http://www.bfe.admin.ch/php/modules/enet/streamfile.php?file=000000010431.pdf&name=000000250211

Klier, Thomas and Joshua Linn (2015). Using Taxes to Reduce Carbon Dioxide Emissions Rates of New Passenger Vehicles: Evidence from France, Germany, and Sweden. American Economic Journal: Economic Policy 2015, 7, 212-242.

Ott, Walter; Jürg M. Grütter; Mario Keller; René Zbinden and Peter de Haan (2002). CO2-Reduktion durch Beeinflussung der Treibstoffpreise. On behalf of Swiss Federal Office of Energy, Bern, 30.11.2002 Available at: http://www.bfe.admin.ch/php/includes/container/enet/flex_enet_anzeige.php?lang=en&publication=10426&height=400&width=600

Maibach, Markus (2000). Verminderung des Treibstoffverbrauchs: Instrumentenevaluation. On behalf of Swiss Federal Office of Energy, Bern, 01.12.2000, Available at: http://www.bfe.admin.ch/php/includes/container/enet/flex_enet_anzeige.php?lang=de&publication=6940&height=400&width=600

Maibach, Markus; Silvia Banfi; Christoph Schreyer; Mario Keller and Bettina Baumgartner (1998). Kosten-Wirksamkeit von Umweltschutzmassnahmen im Verkehr.

Forschungsauftgrag Nr. 41/96. On behalf of the Swiss Association of Transportation Engineers and Experts SVI, Zürich. 01.05.2000.

Ryan, Lisa, Susana Ferreira and Frank Convery (2009). The impact of fiscal and other measures on new passenger car sales and CO2 emissions intensity: Evidence from Europe. Energy Economics 31 (2009), p. 365-374.

Wüstenhagen Rolf and Katharina Sammer (2007). Wirksamkeit umweltpolitischer Anreize zum Kauf energieeffizienter Fahrzeuge: Eine empirische Analyse Schweizer Automobilkunden, Zeitschrift für angewandte Umweltforschung (ZAU), Jg. 18, Heft 1, S. 61-78.

Zimmermannova, Jarmila (2012). Ex-post analysis of impacts of the car registration fee in the Czech Republic. Transportation Research Part A: Policy and Practice, 2012, 46, 1458 – 1464.

Appendix 1: Trend of energy labels and CO_2 groups within control and treatment cantons

A1.1 Cantons of control group

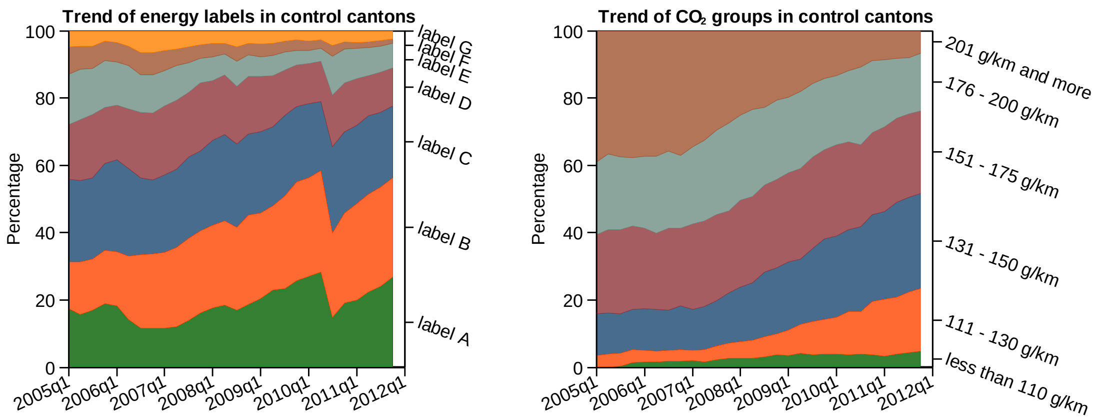

Figure 6: Trend of CO_2 groups and energy labels in cantons without policy

A1.2 Cantons with label policy

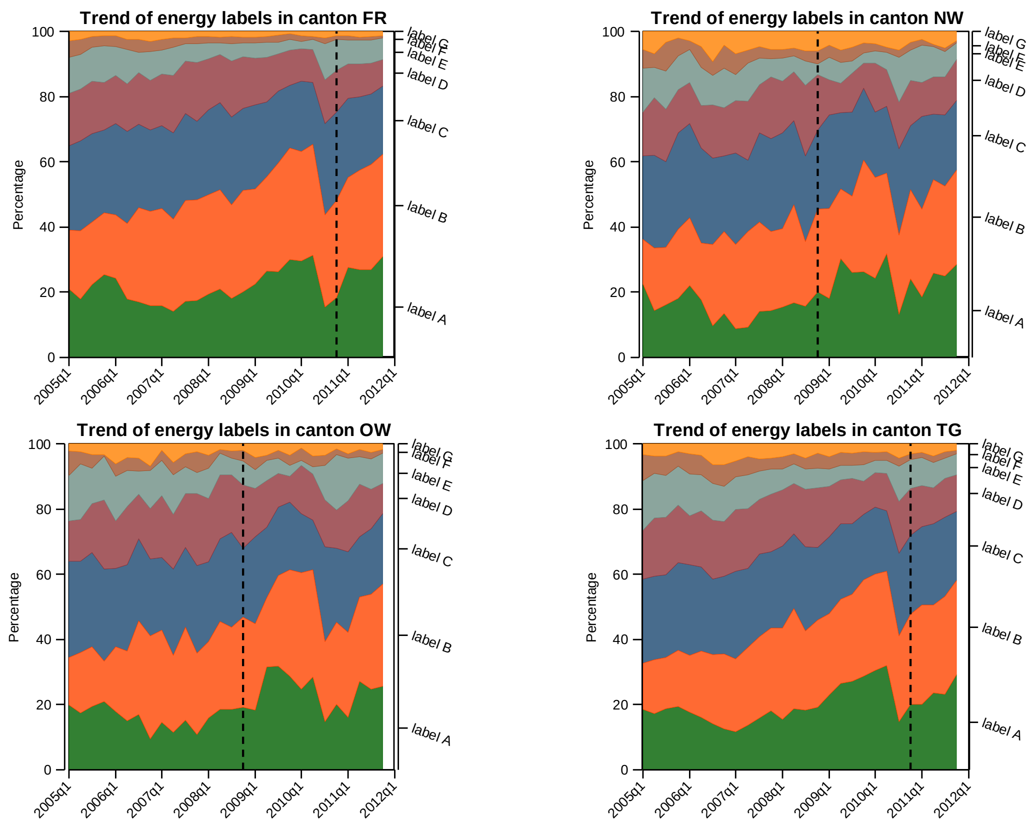

Figure 7: Trend of energy labels in Cantons with label policy

A1.3 Cantons with CO2 policy

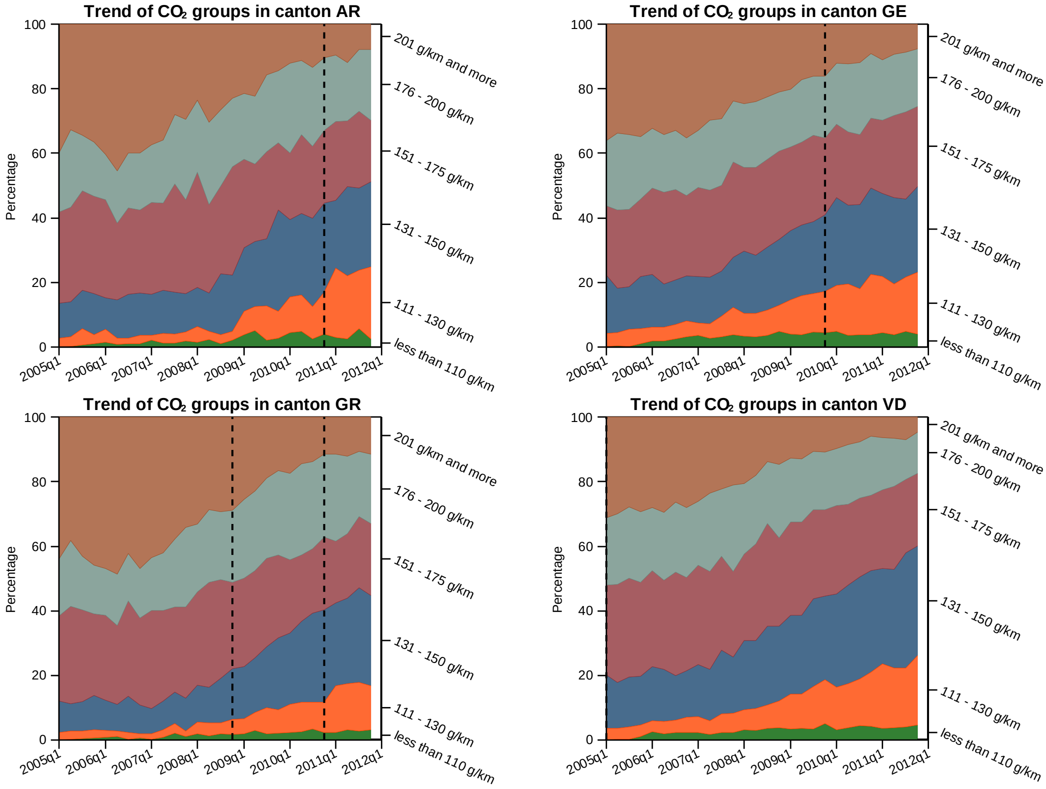

Figure 8: Trend of CO_2 groups in Cantons with CO_2 policy

A 1.4 Cantons with CO2 and label policy

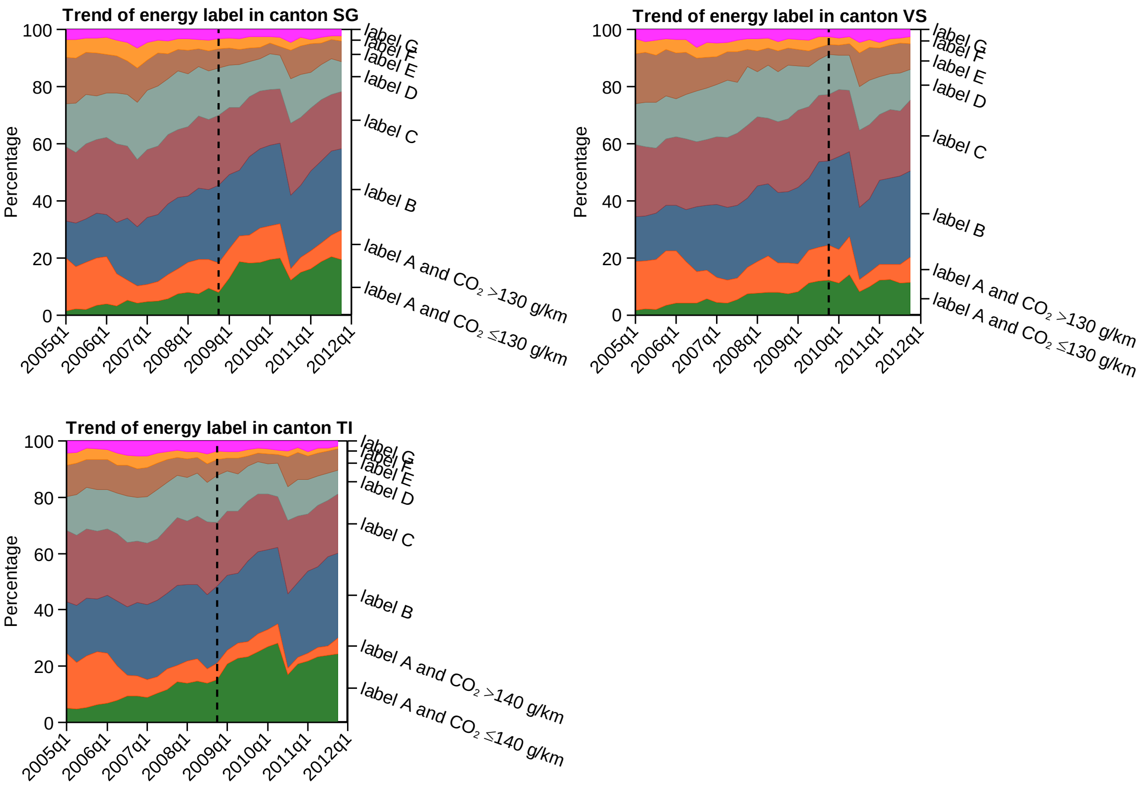

Figure 9: Trend of energy labels in Cantons with CO_2 and label policy

Appendix 2: Adoption of Hybrid electric vehicles

The goal of this appendix is to evaluate if rebates on the Cantonal vehicle registration taxes for HEV have an effect on its registrations in Switzerland. Table 2 gives an overview of the cantons that implemented incentives for vehicles run by alternative fuel types during our observation period from 2005 – 2011. It can be seen that 10 cantons introduced vehicle registration tax rebates for HEV.

Looking at new passenger vehicle registration data from 2005 to 2011 as described in module 1, we find a clear increasing trend in HEV registrations. The number of HEVs sold increased by 385% from 2005 to 2011. Despite of this substantial increase the market share of HEV was only 1.76% of new car registrations in 2011 (see figure 10 and 11 and table 19). This small amount of observations hinders our difference in differences (DID) approach at the municipality level as described above. We could, of course, aggregate hybrid sales to the cantonal level, but this leads to a potential endogeneity problem.

As discussed above, the DID approach is only appropriate if two key assumptions are met. The first is that assignment to the treatment group is exogenous, i.e., as good as random. This assumption is violated if, for example, there are unobserved characteristics of the units that affect both the outcome variables (i.e., the number or share of hybrid vehicles) *and* the adoption of the policy scheme. Above, we looked at the effect of the policies on gasoline and diesel cars, we estimated our model at the municipality level and included municipality-specific fixed effects which mitigated this problem to the extent that any unobserved factors are reasonably constant over time. Because of the small number of registered HEVs this approach cannot be applied here.

The second key assumption of the DID approach is that the trends in the outcome variable are similar for both the treatment and control groups. This means that the time effects have to be the same for both control and treated units. If this assumption is violated, then one does not know if the effect of the policy can be safely attributed to the policy, or is due to something else. We can test this assumption by applying the following model on observations in the pre-policy period:

$$\text{HEV share}_{it} = \alpha_i + \tau_t + \beta \; treatment_i * year_t + X_{it}\delta + \varepsilon_{it} \qquad (1)$$

where *i* denotes the canton and *t* the year. The right-hand side of equation (1) contains canton-specific fixed effects, which allow us to control for unobserved heterogeneity, assuming that the latter is approximately constant over time. It also contains τ_t, a year-specific fixed effect, which is assumed constant across cantons. $treatment_i * years_t$ are interactions between the year dummies and a treatment group dummy. X_{it} is a set of time-varying covariates such as income and number of residents in the canton at time t. The common trends assumption is satisfied if we fail to reject the null hypothesis that the coefficients on the interactions are jointly equal to zero. Applying this test to our data results in an F-statistic of 3.59 (p-value 0.003) which leads to a rejection of the null hypothesis. The cantons with and without HEV-friendly registration fees appear to have diverging trends even before these policies were implemented, and the DID approach cannot be applied in this context.[23] For this reason, we restrict our analyses to descriptive statistics of figures and trends in the sales of HEVs in Switzerland.

Descriptive Statistics

In 2005 only 4 different car models of 3 different makes were on the market and 1,293 new HEVs were registered. In 2011 already 4,979 HEV cars consisting of 22 models and 14 makes were registered in Switzerland (see table 18). Table 19 displays the number of registrations of different make-models trims. It can be seen that Toyota Prius was clearly the market leader from 2005 to 2010 and was replaced from its pole position by Toyota Auris and Honda Jazz in 2011.

The map in figure 12 shows the share of new HEV registrations in the different cantons. As expected the share of HEVs is higher in cantons with more urban areas or higher population density per square kilometer as in Basel-Stadt (BS), Geneva (GE) or Zurich, compared to the mountainous and more rural cantons like Wallis (VS), Graubünden (GR) or Uri (UR). The trends in the HEV shares per canton is displayed in table 20. The cantons which offer incentives on HEV registration are highlighted in gray to distinguish them from the cantons without such policy. By comparing the trends of these treated and non-treated cantons we do not discover any substantial discrepancies. In order to compare the trends better, figure 14 displays the trends in the HEV shares in cantons which introduced an incentive for HEV after 2005 and the cantons without a policy on a quarterly basis. These graphs show no clear increase of the shares in HEV registrations in treated cantons compared to the so-called control cantons without policy which leads to the tentative conclusion that the policies did not influence the registrations of HEV significantly. We caution the reader,

[23] The trend of share of new HEV registration of treated and non-treated cantons over the whole observation period from 2005 -2011 can be seen in figure 16.

however, that this cannot be clearly confirmed without better data and a proper econometrical analysis. As mentioned, this analysis is unfortunately not feasible due insufficient sales volumes and the violation of the common trend assumption before policy introduction.

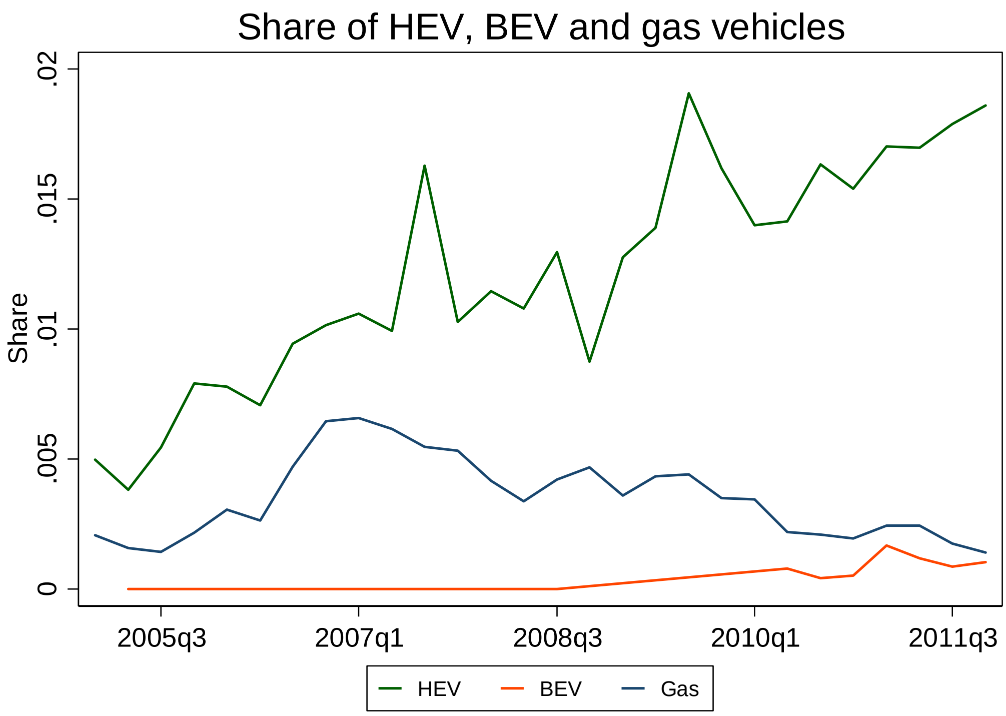

Figure 10: Trend of shares of alternative fuel types

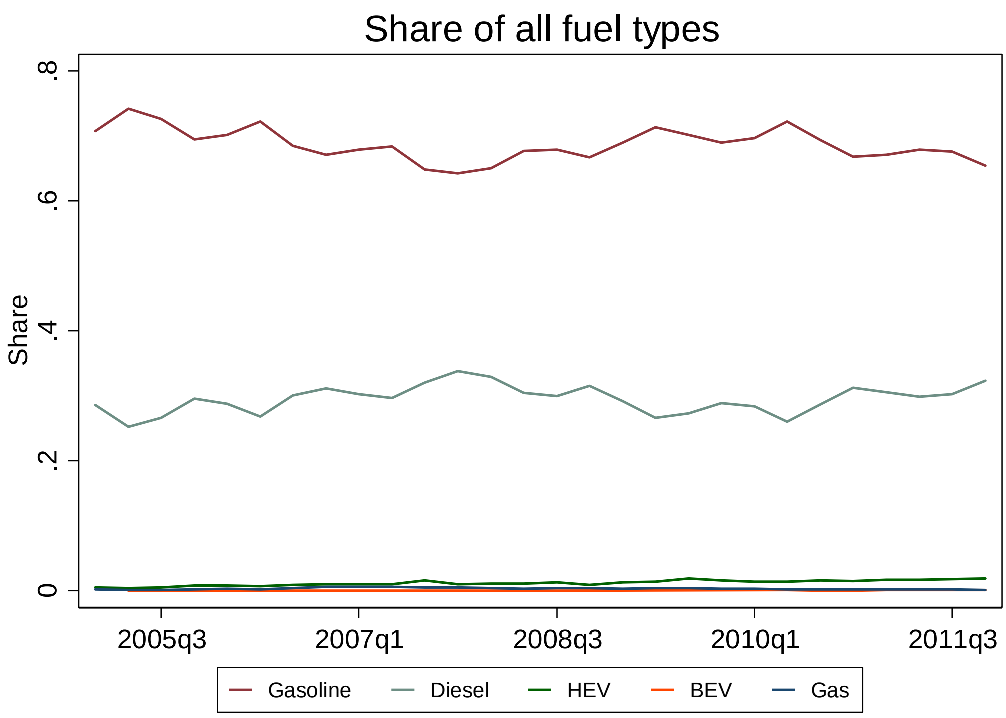

Figure 11: Market share of different fuel types

Table 18: Number of HEV makes and models per year

	2005	2006	2007	2008	2009	2010	2011
Makes	3	4	3	3	4	7	14
Models	4	5	5	5	7	12	22
HEV total	1,293	2,089	3,006	2,883	3,761	3,979	4,979

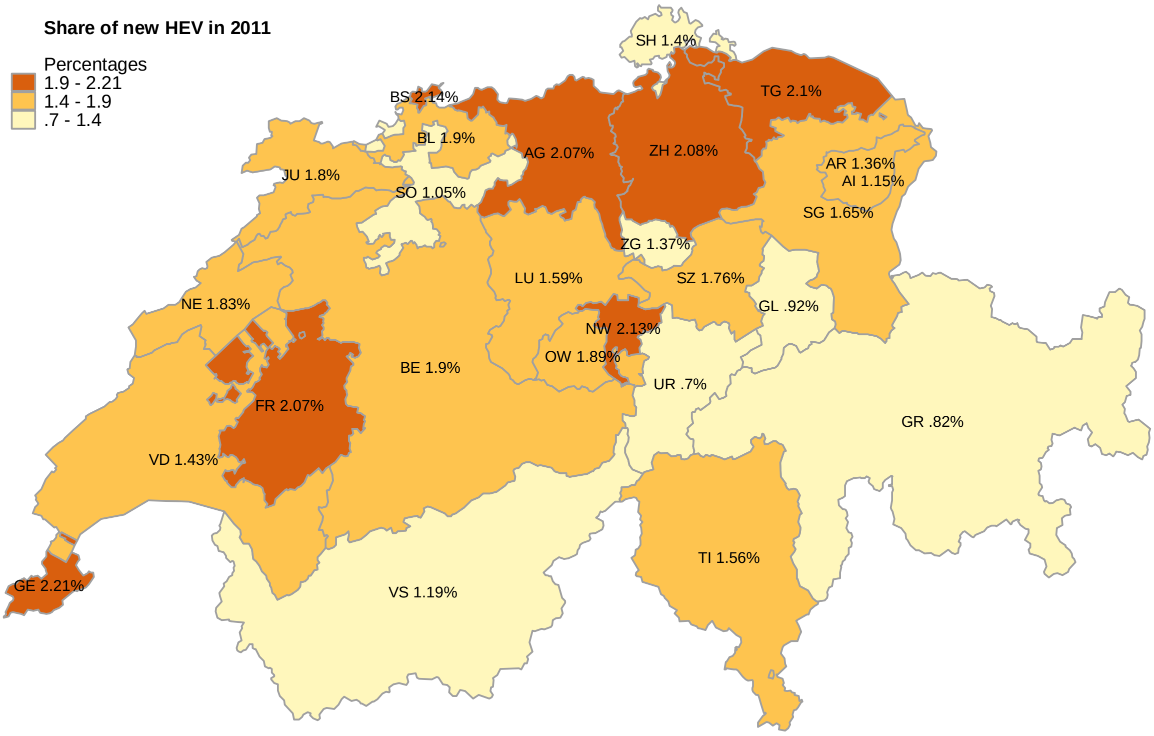

Figure 12: Map with share of new HEV registrations per canton

Table 19: Registration of HEV models over the years

Make-Model-Trim	2005	2006	2007	2008	2009	2010	2011
AUDI Q5 HYBRID	0	0	0	0	0	0	36
BMW ACTIVEHYBRID 7	0	0	0	0	0	19	1
BMW ACTIVEHYBRID 7 L	0	0	0	0	0	0	1
BMW ACTIVEHYBRID X6	0	0	0	0	0	29	6
CADILLAC ESCALADE HYBRID	0	0	0	0	0	0	2
CHEVROLET VOLT	0	0	0	0	0	0	22
CITROEN DS5 2.0 HDI HY	0	0	0	0	0	0	7
HONDA CIVIC HYBRID	0	93	411	358	85	36	17
HONDA CIVIC IMA	59	18	0	0	0	0	0
HONDA CR-Z	0	0	0	0	0	390	266
HONDA INSIGHT	1	0	0	0	1,037	490	203
HONDA JAZZ HYBRID	0	0	0	0	0	0	1,349
INFINITI M35H	0	0	0	0	0	0	6
LEXUS CT200H	0	0	0	0	0	0	526
LEXUS GS450H	0	55	83	63	28	23	24
LEXUS LS600H	0	0	21	54	7	11	5
LEXUS LS600H L	0	0	12	26	5	4	4
LEXUS RX400H	238	775	717	645	220	3	0
LEXUS RX450H	0	0	0	0	482	660	286
MERCEDES-BENZ S 400 HYBREC	0	0	0	0	14	20	1
MERCEDES-BENZ S 400 HYBRID	0	0	0	0	40	26	4
OPEL AMPERA	0	0	0	0	0	0	15
PEUGEOT 3008 HYBRID4	0	0	0	0	0	0	6
PORSCHE CAYENNE S HYBRID	0	0	0	0	0	79	57
PORSCHE PANAMERA S HYBRID	0	0	0	0	0	0	2
TOYOTA AURIS HSD	0	0	0	0	0	710	1,356
TOYOTA PRIUS	995	1,148	1,762	1,737	1,843	1,433	747
TOYOTA PRIUS PHV	0	0	0	0	0	1	2
VW TOUAREG 3.0HYBRID	0	0	0	0	0	45	28
Total number of HEV	1,293	2,089	3,006	2,883	3,761	3,979	4,979
Market share	0.54%	0.85%	1.16%	1.10%	1.54%	1.49%	1.76%

Table 20: Policies and share of HEV on cantonal level

Canton	Rebate	2005	2006	2007	2008	2009	2010	2011
AG		0.56%	1.01%	1.38%	1.20%	1.83%	1.90%	2.07%
AI		0.00%	0.00%	0.21%	0.93%	1.30%	0.60%	1.15%
AR	50%	0.34%	0.70%	0.57%	1.01%	0.92%	0.75%	1.36%
BE		0.51%	0.74%	1.03%	1.12%	1.40%	1.44%	1.90%
BL	50%[1)]	0.67%	0.97%	1.56%	1.02%	2.03%	1.52%	1.90%
BS		0.90%	0.85%	1.29%	0.84%	1.38%	1.32%	2.14%
FR	30%	0.49%	0.62%	0.78%	0.80%	1.19%	1.25%	2.07%
GE		0.71%	1.01%	1.26%	1.35%	2.42%	2.01%	2.21%
GL		0.56%	0.47%	0.71%	0.46%	1.31%	0.57%	0.92%
GR		0.34%	0.70%	0.86%	0.79%	0.87%	0.74%	0.82%
JU	50%	0.13%	0.38%	0.57%	0.59%	1.06%	1.19%	1.80%
LU	41.20[2)]	0.59%	0.83%	1.21%	1.14%	1.79%	1.49%	1.59%
NE		0.31%	0.56%	0.75%	0.74%	1.68%	1.22%	1.83%
NW	50%	0.26%	1.41%	1.94%	1.23%	1.54%	2.23%	2.13%
OW	50%	0.81%	0.76%	1.39%	0.82%	2.95%	1.58%	1.89%
SG		0.60%	0.77%	1.09%	1.01%	1.45%	1.32%	1.65%
SH		1.36%	1.02%	1.81%	1.12%	1.56%	2.12%	1.40%
SO		0.50%	0.68%	0.99%	0.69%	1.37%	1.14%	1.05%
SZ	50%	0.75%	1.39%	1.53%	1.42%	1.93%	1.53%	1.76%
TG		0.57%	0.86%	1.35%	1.06%	1.44%	1.41%	2.10%
TI	50%	0.08%	0.34%	0.53%	0.71%	1.12%	1.17%	1.56%
UR		0.25%	0.37%	0.38%	0.98%	0.81%	0.66%	0.70%
VD		0.44%	0.82%	0.97%	1.03%	1.38%	1.21%	1.43%
VS		0.32%	0.61%	0.87%	0.77%	1.00%	1.10%	1.19%
ZG		0.77%	1.17%	1.38%	1.41%	1.44%	1.70%	1.37%
ZH	50%	0.73%	1.11%	1.61%	1.47%	1.75%	1.95%	2.08%
CH		0.54%	0.85%	1.16%	1.10%	1.54%	1.49%	1.76%

Note: Light gray highlighted are the cantons which implemented a rebate for HEV. Dark gray highlighted are the years when the policy was in place.

[1)] In Canton Basel-Landschaft HEV car need to have an A label and reach EURO4 to get a 50% rebate.

[2)] In Canton Lucerne the tax for every HEV is CHF 41.20

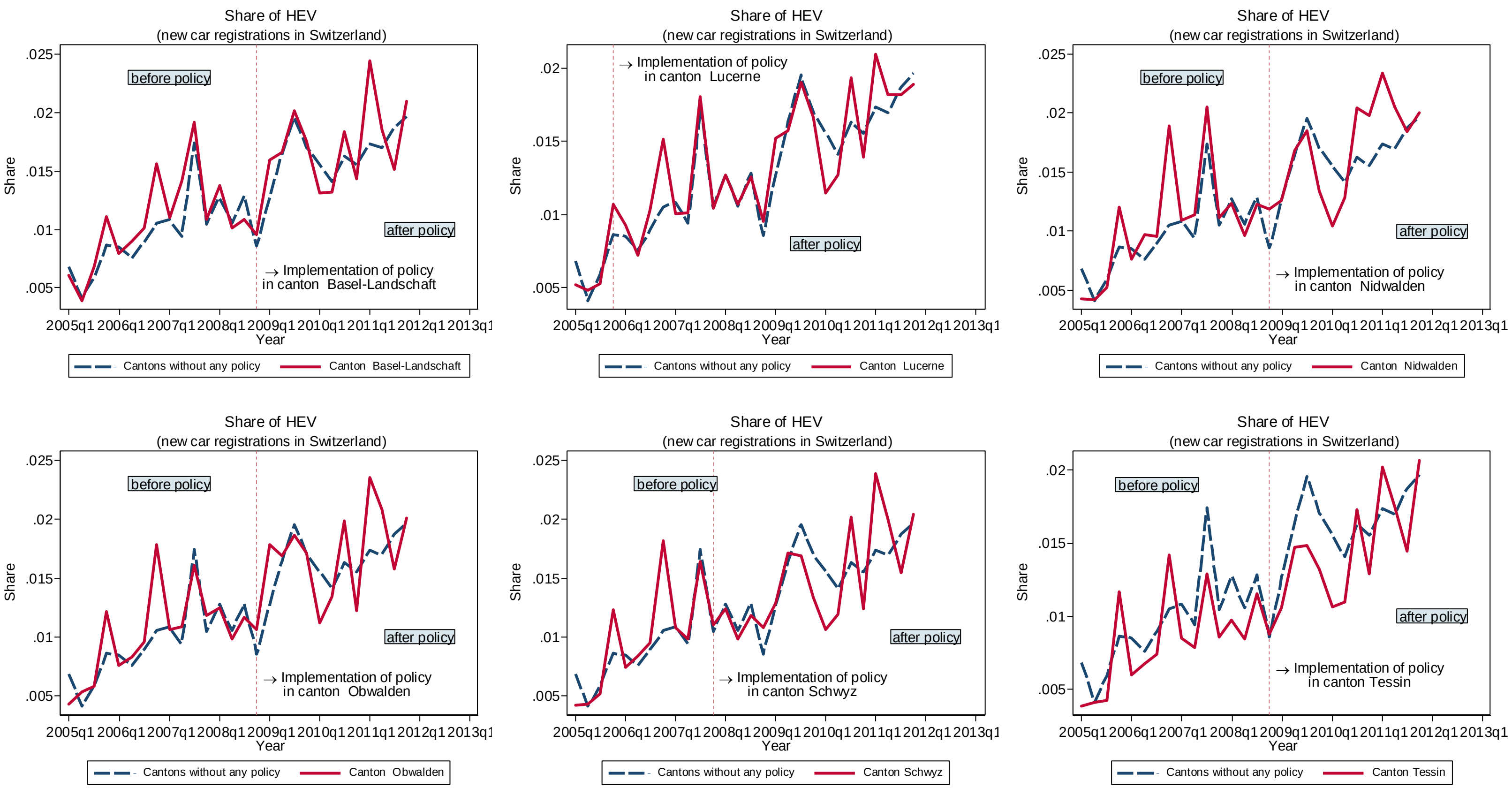

Figure 13: Adoption of HEV in cantons which introduced rebates for HEV after 2005 compared to cantons without policy

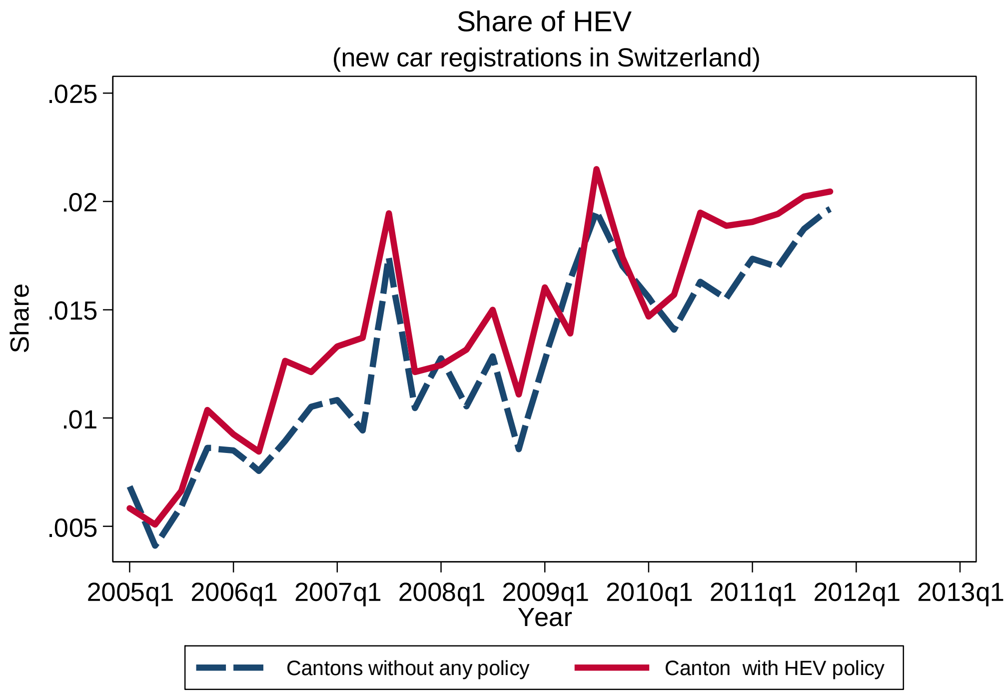

Figure 14: Trend of share of HEV registrations of treatment and control canton

Module 3:

The Effect of CO_2 Emissions Standards for New Passenger Cars:
Evidence from Switzerland

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ETH Zurich

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1. Introduction

The Swiss Federal Office for the Environment (FOEN) and the Swiss Federal Roads Office (FEDRO) commissioned the Center for Energy Policy and Economics of ETH Zurich (CEPE) to conduct a study with the title “Economic analysis of policy measures to reduce CO_2 emissions of passenger cars in Switzerland”, in order to assess the impact of the different policy measures in the Swiss passenger car sector. The study shall help the federal government assess the existing policies and use these experiences for potential further policy incentives for CO_2 emissions mitigation.

This study is comprised of three modules. The first described in detail the composition of the Swiss passenger car fleet from 2005 to 2012 and made regional comparisons of the car fleet by displaying different car characteristics on a map of Switzerland. In module 2, the impact of different cantonal vehicle registration taxes on the new car registrations and on the survival rate of used cars was analyzed.

This report on module 3 is the third and last part of the study and attempts to evaluate the effects of the national CO_2 emissions standards for new passenger cars in Switzerland. The CO_2 emissions standards were introduced in July 2012 with the final target of reaching an average CO_2 emissions rate of 130 g/km of newly registered cars in Switzerland by 2015. From 2012 to 2014 there was a phase-in period where only a certain percentage of the fleet was required to reach the target. As mentioned in the proposal of this project, the analysis in this report is only a first attempt to evaluate the impact of this policy. Because of the short time period since the policy introduction, the fact that we only have data up to 2014 (when the policy is still in the phase-in period), and other data inadequacies, we are limited in our ability to assess the total impact of the policy. The results in this report should, therefore, be interpreted with caution.

The remainder of this report is organized as follows. In the next section, we will describe the CO_2 emissions standards that have been in place in Switzerland since July 2012. In section 3 possible empirical models are described to evaluate the impact of the policy. Section 4 presents the data and section 5 the estimation results. In section 6 we compare the Swiss policy with that in the European Union (EU). Section 7 concludes and discusses potential further research.

2. Institutional background

As described in the other reports from this project (module 1 and 2), personal motorized transport accounts for a large share of the CO_2 emissions in Switzerland. In its previous CO_2 Act[1], Switzerland stipulated that it would seek to reduce heating fuels by 15 percent and motor fuels by eight percent with respect to their 1990 levels (BAFU, 1999), but it (barely) failed to meet the prescribed reductions in CO_2 emissions for heating fuels, and failed badly with motor fuels (BAFU, 2014).

In order to reach the target for motor fuels, a voluntary agreement between the Federal Department of the Environment, Transport, Energy and Communications (DETEC) and the association of Swiss car importers (auto-schweiz) was established in 2002 with the goal of reducing CO_2 emissions rates and improving the fuel economy of vehicles by 2008. These efforts failed to produce results and the agreement is generally regarded as a failure (BFE, 2009). It was thus replaced by mandatory CO_2 emissions standards, similar to those adopted in the European Union (EU), which oblige car importers to reduce the sales-weighted average CO_2 emissions of their new cars to 130 grams per kilometer by 2015. This new program was introduced in Switzerland in July 2012 (BFE, 2011). The most important features of these new emissions standards are explained below. For a more detailed description we refer to the website of the Swiss Federal Office of Energy (SFOE).[2]

<u>Goal</u>

The goal is to reduce the average CO_2 emissions rates of newly registered passenger cars (hereafter cars) in Switzerland to 130 grams of CO_2 per kilometer by 2015.

<u>Target groups</u>

The target groups are importers of new cars and cars that have not been registered abroad for more than six months. Each importer gets an individual target for his car fleet which is based on the fleets average curb weight. Importers have the opportunity to bundle with other importers to pool their fleets and receive a joint emissions target.

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1 Bundesgesetz über die Reduktion der CO2-Emissionen (CO2-Gesetz) vom 8. Oktober 1999 (Stand am 1. Mai 2012), Art. 2 Abs. 2. (Ausserkraft seit 31. Dezember 2012), SR 641.71.

2 http://www.bfe.admin.ch/themen/00507/05318/index.html?lang=en

Private or small importers who import fewer than 50 cars per year do not receive an average target for their fleet. These importers get a separate target for each car.[3]

Car makes that are manufactured only in small numbers can apply for a special target in the European Union.[4] The Swiss importers can apply for these special targets, too.

Calculation of importer specific target (limit value curve)

Each importer receives yearly an individual emissions limit according to the average curb weight of the imported and sold car fleet. The individual targets are calculated according to a limit value curve. Importers of heavier cars are allowed higher emissions than importers of lighter cars.

The individual target for large-scale importers is calculated using the following formula (equation (1)) for each importer (BAFU 2015):

$$\text{Permissible specific CO}_2\text{ emissions} = 130 + a \times \left(M_{i,t} - M_{t-2}\right) \frac{g\,CO_2}{km} \qquad (1)$$

where a is equal to 0.0457. $M_{i,t}$ is the average curb weight of the importer's passenger cars registered for the first time in the reference year i in kilogram (kg). M_{t-2} is the average curb weight of the passenger cars registered for the first time in Switzerland in the penultimate calendar year before the reference year in kilograms. The values for M_{t-2} are:

- 1453 kg in 2010 (valid for 2012)
- 1465 kg in 2011 (valid for 2013)
- 1493 kg in 2012 (valid for 2014)

Example: An importer has a fleet with an average curb weight of 1600 kg in 2013. His average emissions rate limit for 2013 will be 130+0.0457*(1600-1465) = 136.17 g CO_2/km.

Phase-in of requirements

The policy was implemented in July 2012 and the target is phased in between 2012 and 2015 to reach 130 grams CO_2 per kilometer in 2015. During the phase-in period only a certain

3 These so-called small importers will not be considered in our analysis as will be explained in section 4.
4 See http://ec.europa.eu/clima/policies/transport/vehicles/cars/index_en.htm

percentage of the importers car fleet is required to comply with the target. These are the cars with the lowest emissions of the fleet.

Phase-in period:

- 2012: 65%
- 2013: 75%
- 2014: 80%
- 2015: 100%

In other words, in 2012 35 percent of the car fleet did not have to comply with the target.

Multi-metering of low emitting cars (super credits)

Cars with emissions rates below 50 g CO_2/km get so-called super credits as they will be counted multiple times:

- In 2012: 3.5 times;
- In 2013: 3.5 times;
- In 2014: 2.5 times.

Example: An importer which imports 50 cars with 200 g CO_2/km and 20 electrical vehicles with zero emissions in 2013 will have a fleet with average CO_2 emissions of (50 cars * 200 g/km + 20 cars * 0 g/km * 3.5 super credits) / (50 cars + 20 cars * 3.5) = 83.33 g/km.[5] The purpose of this provision is to incentivize imports of very low-emissions cars.

Incentive scheme

The importers have an incentive to comply their target because there will be a penalty payment for excess emissions. The exceedance is calculated as the average emissions of the importer's fleet minus the specific target. A penalty must be paid for each gram per kilometer times the number of cars imported. The penalty is:

- CHF 7.50 for the first gram,
- CHF 22.50 for the second gram,
- CHF 37.50 for the third gram, and

[5] Without super credits the average CO_2 emissions would be (50*200+0)/(50+20)=142.86 g/km.

- CHF 142.50 for the fourth and any further gram.

Example: If an importer's 2500 cars fleet exceeds the target by 5 g CO_2/km the penalty will be: 2500 cars * (7.50 + 22.50 +37.50 + 142.50 * 2) = 881,250 CHF (= 352.50 CHF per car)

3. Methodology and model specification

The purpose of this report is to assess the effect of the corporate average CO_2 emissions standards in place in Switzerland starting July 2012 on new car sales and the associated CO_2 emissions.

We will use extensive descriptive statistics to show the trends in car registrations and CO_2 emissions over time, and econometric analysis to estimate the impact of the policy implementation on trend of CO_2 emissions.

As shown in figure 1, there was a monotonic decrease of the CO_2 emissions already before the implementation of the new standards. This may be due to different reasons, such as technological improvement and/or the emissions standards implemented in the EU, which oblige car manufacturer to reduce the emissions of the cars sold in the EU. In our analysis we try to find out if the Swiss standards program has led to an additional decrease in CO_2 emissions rates, while accounting for existing trends.

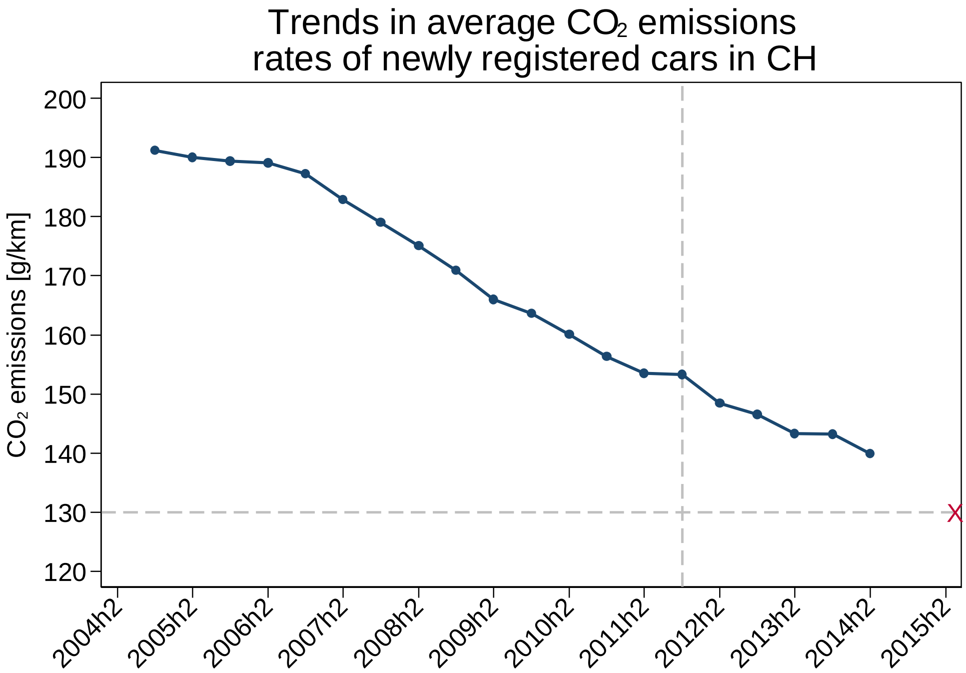

Figure 1: Trend of average CO_2 emissions and average target

The ideal approach for such an assessment would be a “difference-in-difference” study, which requires a treatment group (i.e., cars or importers affected by the standards), a control group (otherwise comparable cars or importers that are not covered by the standards), and observations on both groups before and after the implementation of the policy. Unfortunately, it is not possible to identify control units here, since the policy applies to all cars and importers sold in Switzerland. We initially considered, but eventually ruled out, selecting a neighboring country as the control group, because all neighboring countries belong to the European Union, and the European Union has had corporate average emissions standards in place even before Switzerland.[6]

Other study designs (like matching approaches or regression discontinuity designs) cannot be applied here either, and the only option that is available to us is to compare units before and after the implementation of the policy.

The next challenge is the choice of outcome variable, namely the dependent variable in our statistical models. Since the policy regulates the average CO_2 emissions for each importer, the ideal outcome variable would be the average CO_2 emissions at the importer level. Unfortunately, we do not know which importers import which cars, and that forces us to assume that each importer deals only one make. We therefore examine the average CO_2 emissions rate of all cars by any given make.

We have a longitudinal (panel) dataset documenting the sales of new vehicles for each make in each month from January 2005 to December 2014. The effect of the policy is identified from our data only because we assume an additive, linear trend in the average CO_2

[6] Indeed, the Swiss program is modeled after the EU program. The European Union implemented almost identical standards as those of Switzerland about six months before the Swiss program started. For all practical purposes, this makes a neighboring country a treated group, rather than a control group.

emissions rate common to all makes, and because we have multiple observations before and after the policy starts.[7]

Our basic statistical model is the regression equation:

$$y_{it} = \alpha_i + \beta \cdot t + \delta \cdot \mathrm{D_t} + \varepsilon_{\mathrm{it}} \quad (2)$$

where i denotes the car make and t=1, 2, … the month and year since January 2005. In subsequent runs, we restrict the sample to 2010 – 2014 (two and a half years before and two and a half years after the policy) in hopes of making the pre and post-policy periods as similar as possible. As outcome variable y, we use average CO_2 emissions by make. The right-hand side of equation (2) contains make-specific fixed effects (α_i) which allow us to control for unobserved effects at the make level assuming that these are approximately constant over time. These fixed effects capture the fact that certain makes sell systematically more than others.

The key coefficient of interest in equation (2) is δ, the coefficient on the policy dummy D, which takes on a value of 1 when the policy is in place (starting in July 2012) and zero otherwise. Coefficient δ captures the vertical shift (if any) in emissions rates due to the introduction of the standards. We wish to emphasize that since we don't have a control group, identification of this coefficient requires the assumption that the emissions rates are declining at a constant annual rate for all makes. More flexible models, such as models with individual-year fixed effects or make-by-year fixed effects, do not allow us to disentangle the effect of the policy.

We further consider two variants on basic regression (2). The first adds an interaction term between the time trend t and the policy dummy, plus a dummy for May-June 2012 to capture abnormal sales patterns due to the importers' anticipation of the policy:

$$y_{it} = \alpha_i + \beta \cdot t + \delta \cdot \mathrm{D_t} + \theta \cdot (\mathrm{D_t} \times t) + \gamma \cdot MayJune2012 + \varepsilon_{\mathrm{it}}. \quad (3)$$

We reason that since the policy was announced already at the end of 2011, the importers may have had time to adjust and may have imported and sold more highly emitting cars in the months just before July 2012. This would be followed by a sharp decline in July 2012. To avoid biasing the results of our regressions, we re-run equations (2)-(3) after including a

7 Our study is thus similar to that by Ciccone (2014), who examined the environmental effects of a tax reform for new vehicles in Norway, where the tax reform was likewise implemented at the national level.

dummy for May-June 2012, when the incentive to import and sell quickly highly polluting vehicles would be the strongest.

Equations (2) and (3) can be re-run by restricting the sample to specific groups of years. For example, we run equation (2) separately for the pre-policy (2005 – 2011) and post-policy periods (2013 – 2014), making sure that the policy dummy is omitted, to check if there is evidence of changing versus constant trends. We likewise re-run both equations with observations from 2010 to 2014, namely two years before and two years after the policy was put in place, in hopes of reducing the effect of other external factors and making economic and other transportation regulations as similar as possible.

4. Data

The dataset used in this study is created by merging different datasets provided by the Federal Statics Office (FSO) and the Federal Roads Office (FEDRO). Detailed information about merge process can be found in the first module of this project. The merged dataset contains detailed information on all new passenger cars registered in Switzerland from 2005 to 2014. The main data source is the vehicle information system (MOFIS – Motorfahrzeug-informationssystem) from FEDRO, which contains information about different car characteristics, the specific registration date and the zip code and canton of the municipality of the car owner. This dataset was merged with car homologation data (TARGA) by the type approval number and the transmissions code.[8] The TARGA dataset contains more information about car characteristics like the CO_2 emissions, fuel consumption and others.

In sum, we have 2,939,379 new registered cars from 2005 to 2014. By "car" or "passenger car" we mean a light-duty vehicle with up to 9 passenger seats and weighing less than 3,500 kg. In this report attention is restricted to cars in the MOFIS dataset that were successfully merged with TARGA information and where correct CO_2 emissions are declared. If a car is imported directly from abroad, for example from a private person, it does not have a type approval number and, hence, it cannot be merged with the TARGA dataset.[9] Only very few MOFIS observations cannot be merged with the TARGA data because of missing or

8 We used all available type approval numbers including the ones of parallel importers starting with "1X…".

9 The number of direct imports increases especially if the Euro depreciates to the Swiss Franc because cars in Euro countries get relatively cheaper. Such depreciation took place in 2011. This mainly explains the lower percentage of valid cars for our sample in table 1.

wrong type approval number or because of missing or unidentifiable one-digit transmissions code.[10] This leaves us with a total of 2,822,037 cars (96% of the whole sample; see table 1).

Table 1: Number of cars in the sample and used in our analysis

Year	all	valid*	% valid
2005	266,278	258,799	97.19%
2006	269,141	264,275	98.19%
2007	283,258	279,167	98.56%
2008	287,410	282,815	98.40%
2009	266,057	261,635	98.34%
2010	296,025	286,017	96.62%
2011	326,946	302,396	92.49%
2012	332,673	306,083	92.01%
2013	308,486	292,670	94.87%
2014	303,105	288,180	95.08%

* successfully merged with TARGA information

The dataset contains specific information on car characteristics and the date when the car was first registered. We use this information to examine the composition of new car sales. However, there is an important drawback to the analysis in this report. The CO_2 emissions standards apply to importers of new cars. Importers are not restricted to one make. Importers get a specific target depending on the average weight of all cars they import and even have the option to cooperate with other importers and bundle their respective fleet. Our dataset does not have information about which importer imported a car. We do not know which importers bundle their fleets either. Hence, we are not able to calculate the specific targets for the importers and analyze their strategic behaviors.

Due to this lack of information, we are forced assume that each make is imported by an individual importer and there are no co-operations. With this assumption, we reduce our analysis to the make level. The make level is a good approximation for the importer, but if importers act strategically in pooling car fleets with other importers, target compliance will be underestimated in this study.

[10] Detailed information about the data, merge process and descriptive statistics can be found in the first module of this project. The creation of the final data set took several months of intense work.

Further, we will restrict our analysis to makes with at least 50 new registrations per year. As described in section 2 only these importers (makes, respectively) receive a specific target for their fleet. Smaller importers have a target for each individual car. Another reason for this restriction is that we were often unable to merge individual imports with the TARGA information because of missing type approval number.

We calculated the specific emissions targets per make and the average emissions of the fleet which has to comply with the target (e.g. 2012 65%) following the rules issued by the SFOE.[11]

A. General descriptive statistics

The first discussions about the emissions standards with the goal to reduce the average CO_2 emissions to 130 g/km by 2015 took place in 2009. This 130 g/km target is equivalent to a gasoline consumption rate of 5.6 liters per 100 km (l/100 km) or a diesel consumption rate of around 4.9 l/100 km. In table 2, we see that in 2009 the average CO_2 emissions rate was 168 g/km. The 2015 target represents reductions of 22.6% compared with the 2009 fleet average. Table 2 and figure 2 show that the CO_2 emissions decreased constantly during our study period. Since 2005 emissions have decreased by 49 g CO_2/km or 25.8% which is an annual decrease rate of 2.9%.[12] The average curb weight stayed more or less constant over time while the average engine size fell and the average power increased.

[11] http://www.bfe.admin.ch/themen/00507/05318/05600/index.html?lang=de, visited last on 18.03.2015.
[12] This lends support to the linear time trend in equations (2) and (3).

Table 2: Descriptive statistic of registrations and car characteristics over time

Year	Registrations	CO_2	Fuel consumption	Curb weight	Engine size	Power	CO_2 per unit of weight
		[g/km]	[l/100km]	[kg]	[ccm]	[kW]	[CO_2/kg]
2005	258,799	190.7	7.8	1479	1990	103.8	129.8
2006	264,275	189.3	7.7	1491	1998	107.5	127.7
2007	279,167	185.1	7.5	1502	1980	109.0	124.1
2008	282,815	177.1	7.2	1472	1917	106.6	121.2
2009	261,635	168.4	6.9	1450	1850	105.7	117.1
2010	286,017	161.8	6.7	1448	1812	106.4	112.8
2011	302,396	154.9	6.4	1460	1783	107.8	107.2
2012	306,083	151.0	6.2	1485	1806	110.7	102.9
2013	292,670	144.9	6.0	1490	1794	112.7	98.2
2014	288,180	141.5	5.8	1503	1796	116.6	95.1

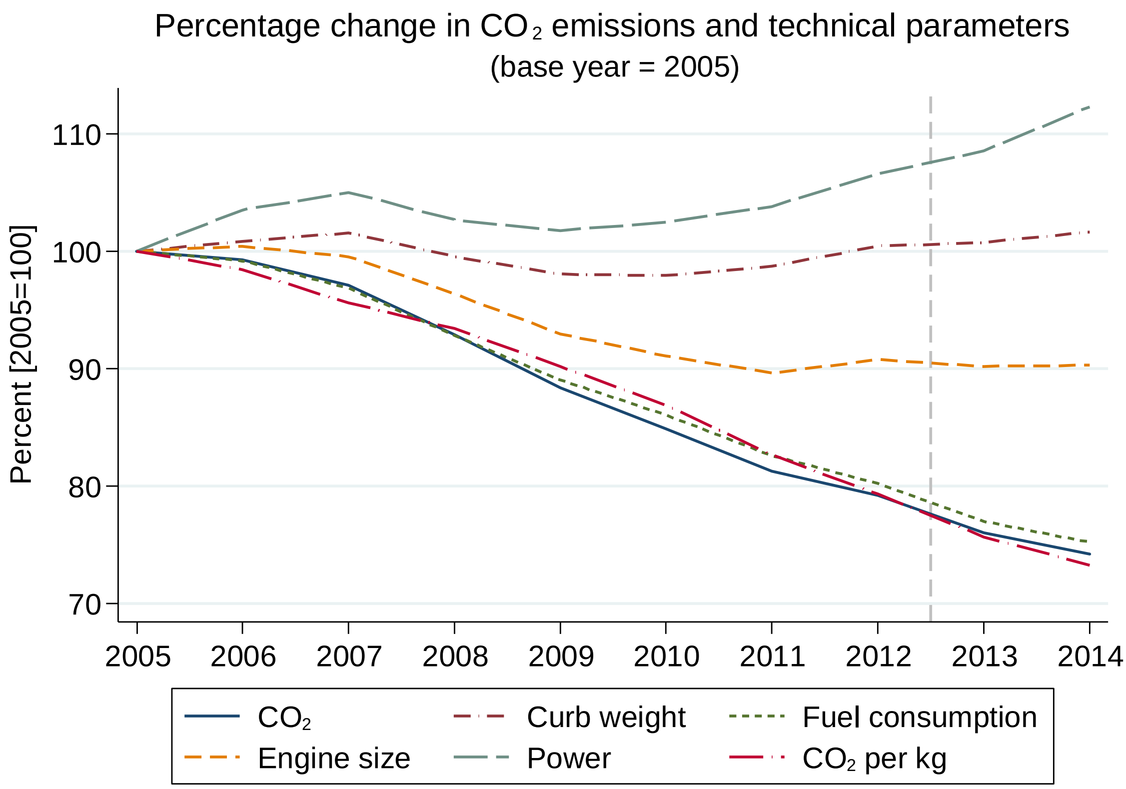

Figure 2: Percentage change in CO_2 emissions and technical parameters of newly registered cars in CH

In figures 3 and 4 the trends in the average CO_2 emissions are displayed separately for diesel and gasoline cars, and are then compared to the trend in the average curb weight (figure

3) and average engine size (figure 4), respectively. It can be clearly seen that gasoline cars are on average lighter and have a smaller engine. The CO_2 emissions of gasoline cars were higher than the emissions of diesel cars in 2005 and decreased faster and by a higher amount until 2014. The curb weight of gasoline cars decreased until 2010 and increased again afterwards. The average curb weight of diesel cars decreased from 2007 to 2010 and increased again afterwards. All in all, the average curb weight of gasoline cars is in 2014 on a lower level than 2005, while the weight of diesel cars increased substantially from 2005 to 2014. As shown in figure 4, the average engine size of gasoline cars decreased heavily from 2006 to 2011 and stayed almost constant thereafter while the average engine size of diesel cars first increased from 2005 to 2007, decreased again until 2010 and stayed constant thereafter.

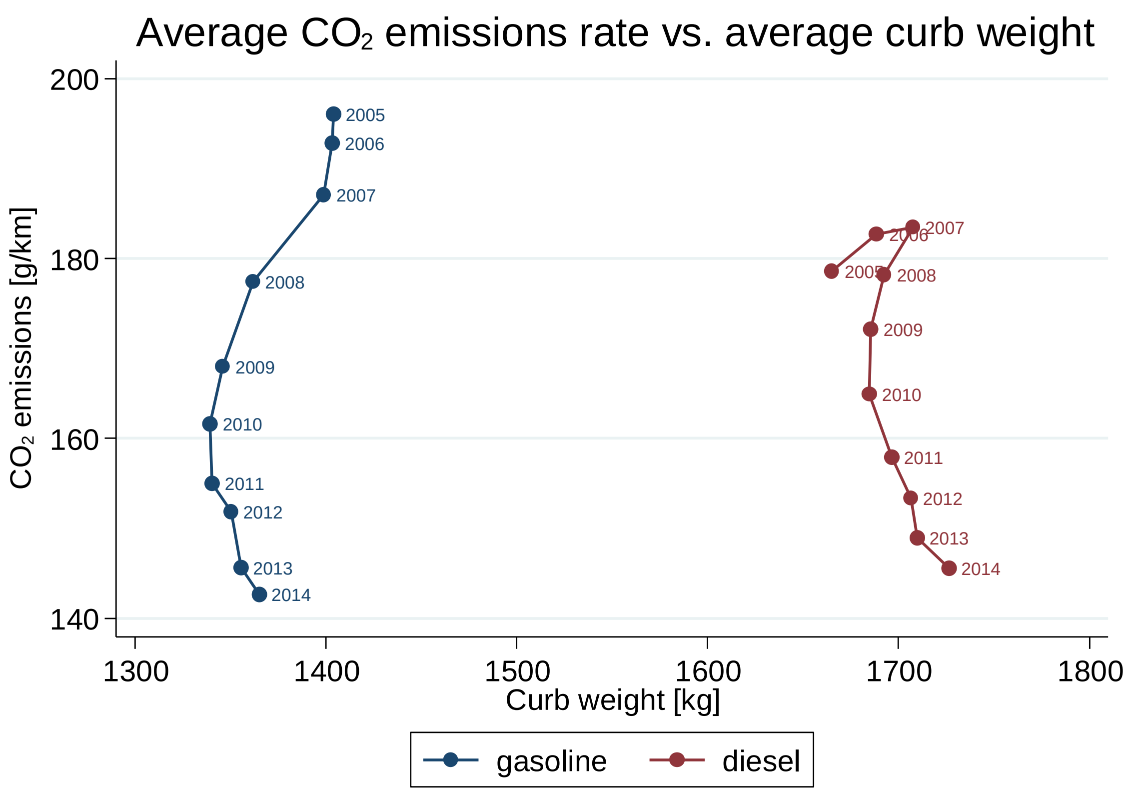

Figure 3: Trend in CO_2 emissions compared to curb weight

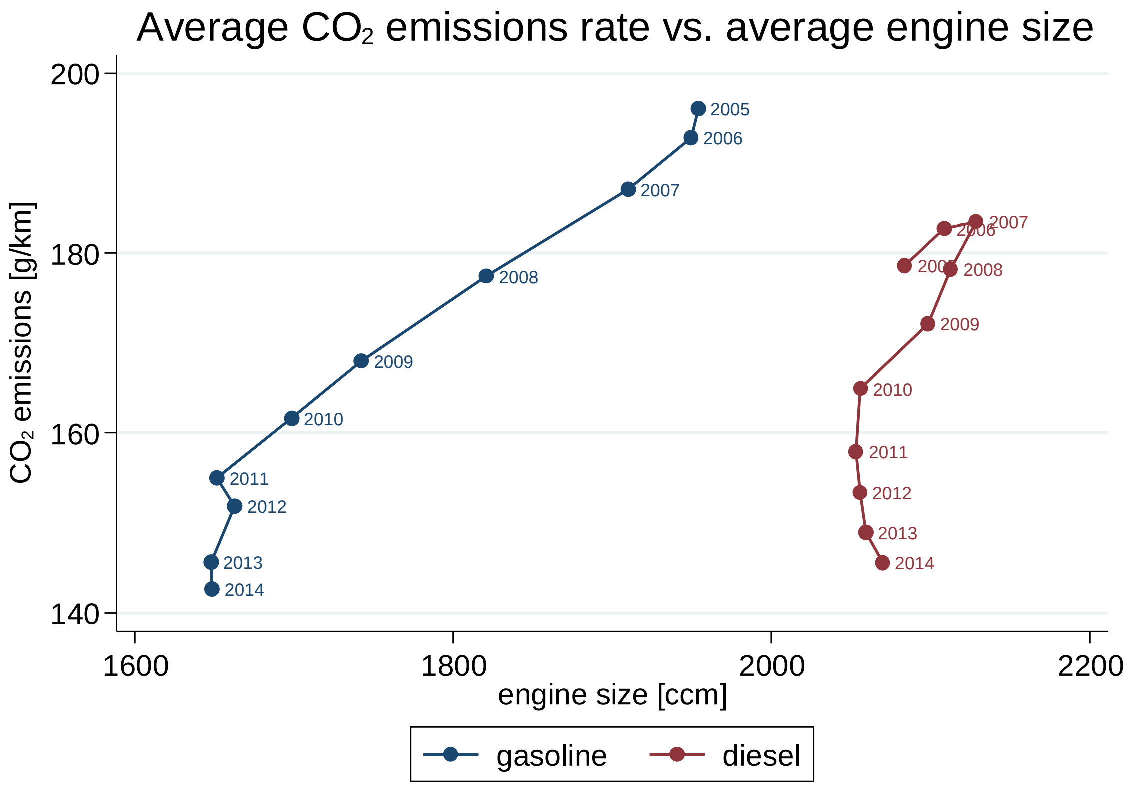

Figure 4: Trend in CO_2 emissions compared to engine size

The distribution of CO_2 emissions and engine size groups are displayed in figures 5 and 6. Figure 5 shows that 1) over time the distribution of CO_2 emissions rates has shifted towards lower values and 2) the distribution of CO_2 emissions rate is bimodal, due to the difference between gasoline and diesel cars. Figure 6 shows that the number of cars emitting 130 g CO_2/km or less increased 10 times from 2005 to 2014 and the number of cars emitting more than 200 g CO_2/km decreased especially in the years from 2005 to 2011 and kept its level after that. For more general descriptive statistics about the trend of different car characteristics, CO_2 emissions, energy label and so forth, we refer to yearly published statistics mandated by SFOE (see e.g. BFE, 2015) .

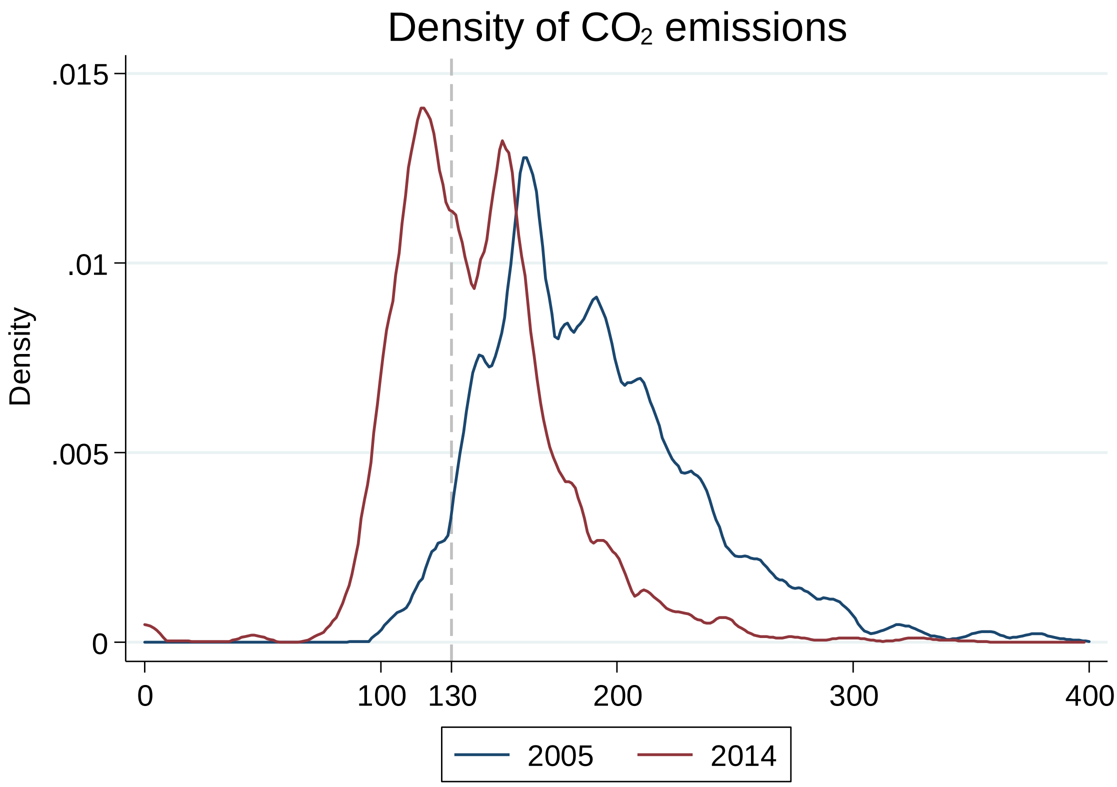

Figure 5: Comparison of the density of CO_2 emissions in the year 2005 and 2014

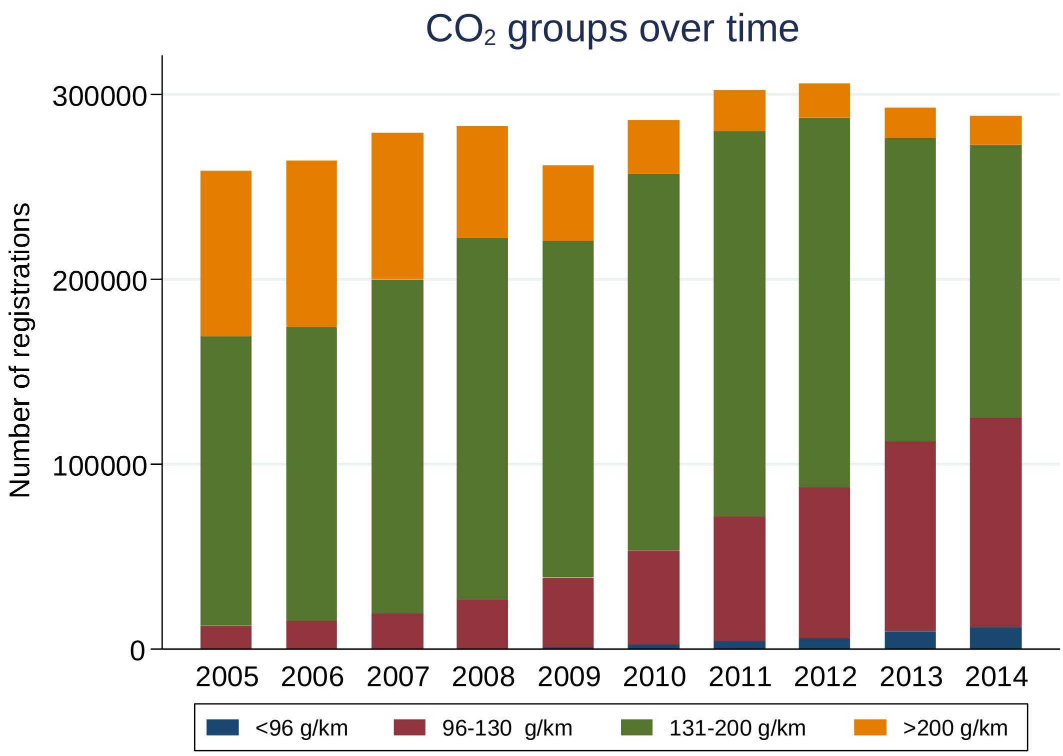

Figure 6: Number of registrations per CO_2 group over time

B. Descriptive statistics at the make level

As discussed previously, our analysis is at the make level due to a lack of information about the different importers. In this subsection and Appendix A, we present descriptive statistics for makes with at least 50 registrations per year.

Figure 7 shows the trend in the average CO_2 emissions of the eleven makes with the most registrations from 2005 to 2014 and the trend in the average CO_2 emissions of all cars registered during the study period. The figure suggests that there is considerable variation in the average CO_2 emissions per make. While some makes, such as Renault and Toyota, have averages already below 130 g CO_2/km, others are still far above the average target of 130 g CO_2/km. One reason for this discrepancy is the difference in the average weight across the different makes. As described in section 2 of this report, the specific target per importer (in our case the make) depends on the average weight of each fleet and during the phase-in period only the average emissions of part of the fleet need to comply with the target. The actual target compliance for the eleven makes with the most registered cars in 2014 is displayed in figure 8.[13] It can be seen that most makes fulfill the target if only the 80% most efficient cars of the fleet are considered, as is allowed in the phase-in stage. The figure shows also that there is a substantial gap between the average emissions of 80% of the fleet and the total fleet which implies that for most makes strong efforts are needed to decrease the average emissions of the total fleet to the specific target level by 2015.

The target compliance for all makes with at least 50 registrations per year are shown in table 3. Figure 9 displays the target compliance in 2014 graphically.[14] More information on the fleet composition of each make in the years 2012 to 2014 is displayed in Appendix A. Table 3 and figure 9 show that there are still several makes that do not reach their specific average emissions target. Using the mechanism explained in section 2, we calculate a total penalty of 67.5 Million CHF over all makes with at least 50 registered new cars. This is a much higher number than the 130,000 CHF that the importers with at least 50 registered new cars actually had to pay in 2014 according to the SFOE.[15] This illustrates clearly that strategic bundling between importers lowers the penalties tremendously. If we pool all of the car makes in our dataset into a single group, the 80 percent least emitting cars have an average CO_2

[13] The graphs for the years 2012 and 2013 can be found in Appendix A.
[14] The graphs for the years 2012 and 2013 can be found in Appendix A.
[15] See http://www.news.admin.ch/NSBSubscriber/message/attachments/39826.pdf

emissions rate of 126 g/km (considering super credits) in 2014 and consequently over fulfill the target of 130 g/km without paying any penalty. Figure 10 shows the trends in CO_2 emissions for all registered cars, for the 80% most efficient cars (as per the phase-in criteria of 2014), and for the 20 % inefficient cars of the fleet. The trend of the 80% most efficient cars shows that the 130 g CO_2/km target is reached by the end of 2014 while the average CO_2 emissions of the whole fleet are still well above the target line of 130 g CO_2/km. The same graphs with the phase in criteria of 2012 and 2013, respectively, can be found in Appendix A.

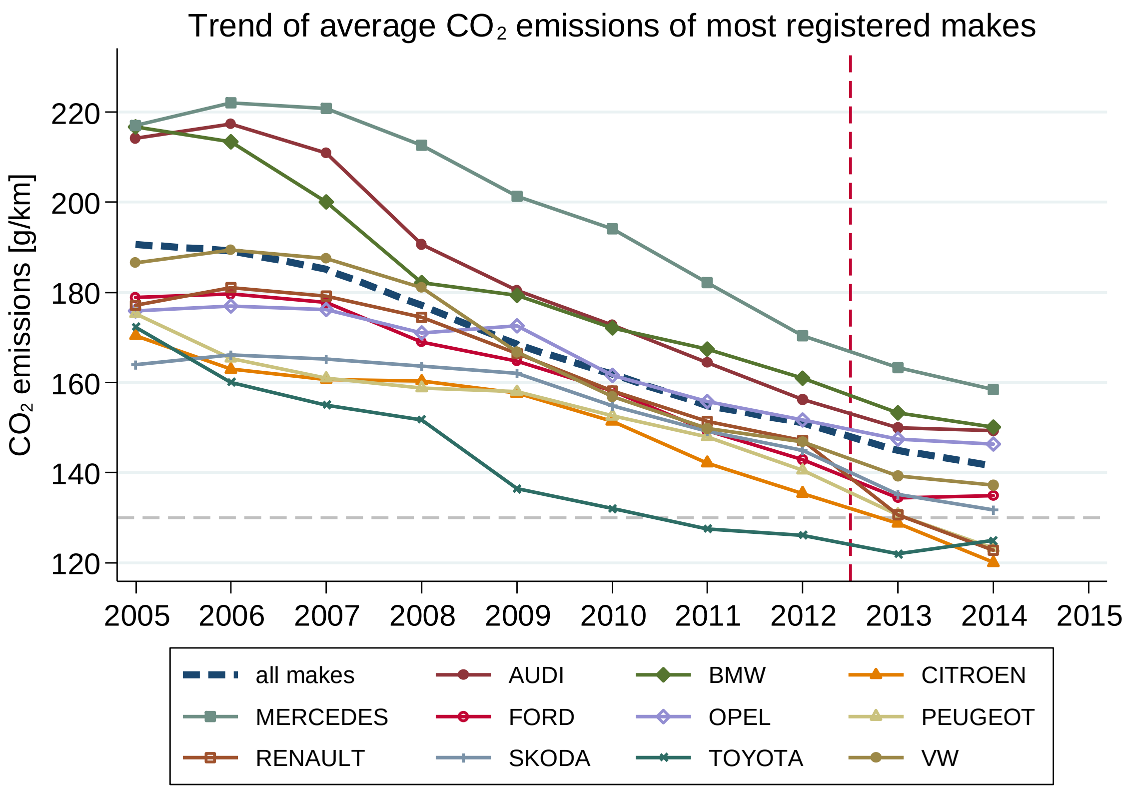

Figure 7: Trend of CO_2 emissions of the top 11 most registered makes

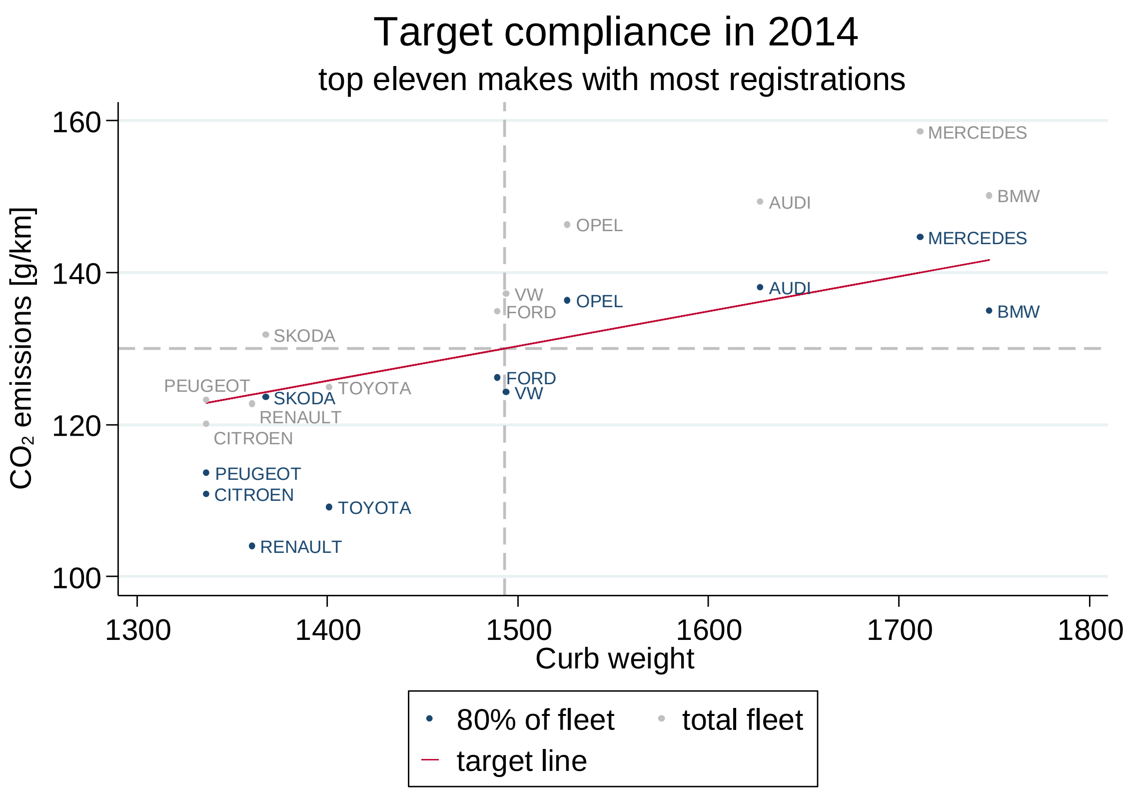

Figure 8: Average CO_2 emissions of total fleet and 80 % of the fleet compared to specific fleet target in 2014

Table 3: Average CO_2 emissions and yearly targets of makes with at least 50 registrations per year (all figures in g/km)[16]

Make	2012			2013			2014		
	CO_2	65%	Target	CO_2	75%	Target	CO_2	80%	Target
Alfa Romeo	142.8	130.3	125.5	138.3	131.1	123.8	137.3	130.4	121.9
Alpina	-	-	-	-	-	-	181.7	176.4	225.0*
Aston Martin	337.9	313.3	320.0*	312.5	293.9	318.0*	323.2	317.4	313.0*
Audi	155.4	138.6	138.9	149.9	137.2	136.8	149.3	138.0	136.1
Bentley	287.7	248.8	175.8	295.7	276.7	176.2	297.1	281.9	175.6
BMW	156.5	139.7	142.5	153.3	138.2	141.6	150.2	135.0	141.6
Cadillac	-	-	-	255.0	233.2	157.6	228.9	216.2	150.7
Chevrolet	160.8	119.0	133.4	163.7	132.0	134.7	170.2	135.3	133.1
Citroen	134.7	117.3	128.1	128.8	116.9	126.3	120.0	110.8	122.9
Dacia	149.9	136.8	122.4	140.5	127.9	120.8	138.1	126.8	119.5
Ferrari	331.6	305.4	303.0*	338.6	323.7	303.0*	300.1	284.7	303.0*
Fiat	136.6	119.6	120.9	130.1	117.8	118.7	127.8	116.0	118.1
Ford	138.9	123.7	126.9	134.4	122.8	129.9	134.9	126.2	129.8
Honda	142.2	121.7	127.9	140.2	126.8	128.4	134.2	123.1	127.1
Hyundai	145.4	129.3	130.2	146.6	134.2	131.0	143.5	133.0	128.7
Infiniti	-	-	-	249.2	233.6	157.6	196.0	171.1	152.1
Jaguar	194.4	161.4	178.0*	208.4	194.8	178.0*	208.7	196.3	178.0*
Jeep	220.2	203.3	163.6	216.6	200.6	166.0	198.8	183.6	162.2
Kia	143.1	123.1	128.9	141.7	127.9	130.1	146.8	136.5	128.9
Lamborghini	-	-	-	-	-	-	336.9	326.3	138.3
Lancia	156.8	120.3	134.2	168.8	149.5	140.6	179.9	167.0	145.8
Land Rover	197.4	176.9	178.0*	207.0	189.7	178.0*	199.2	182.1	178.0*
Lexus	130.2	114.4	151.7	138.6	121.2	151.1	123.6	113.4	147.4
Lotus	-	-	-	216.2	209.9	280.0*	213.7	208.1	280.0*
Maserati	-	-	-	289.3	268.8	154.7	242.0	227.9	153.1
Mazda	145.2	133.5	127.9	141.7	133.5	129.4	135.8	129.5	129.4
Mercedes	167.7	147.3	145.0	163.3	146.5	142.4	158.5	144.6	140.0
Mini	142.2	129.6	123.4	145.1	135.6	123.2	138.2	129.5	121.9
Mitsubishi	144.6	112.1	127.1	139.7	112.0	126.2	133.0	101.3	129.4
Nissan	156.5	129.9	128.0	153.8	128.6	128.1	132.9	116.1	126.5
Opel	150.5	128.9	134.8	147.4	134.4	132.7	146.3	136.3	131.5
Peugeot	136.0	117.8	129.4	130.7	118.6	125.5	123.2	113.7	122.9
Porsche	222.2	202.4	151.3	220.3	209.0	146.7	212.1	202.3	147.2
Renault	143.7	119.3	127.1	130.6	104.4	126.3	122.8	104.1	123.9
Seat	141.8	128.2	129.3	135.8	125.2	127.2	133.1	125.4	127.2
Skoda	141.6	129.8	126.4	135.1	124.5	125.3	131.8	123.6	124.3
Smart	96.9	71.9	102.3	94.6	67.1	102.1	92.7	74.7	101.5
Ssangyong	190.2	180.8	180.0*	185.4	175.6	180.0*	184.8	178.1	180.0*

16 Missing values are caused by the fact that there were less than 50 imports of this make in this specific year. Makes with less than 50 imports are not considered in our analysis.

Table 3 (continued)

Make	2012			2013			2014		
	CO_2	65%	Target	CO_2	75%	Target	CO_2	80%	Target
Subaru	161.3	148.3	164.6*	161.3	150.3	164.6*	163.8	151.9	164.6*
Suzuki	139.6	128.5	118.5	139.8	131.5	123.1*	134.7	127.7	123.1*
Tesla	-	-	-	0.0	0.0	162.3	0.0	0.0	161.0
Toyota	123.2	99.1	124.8	121.9	104.5	125.3	124.9	109.1	125.8
Volvo	158.0	134.1	140.2	158.2	133.9	139.9	153.3	135.7	139.1
VW	143.4	126.9	129.7	139.3	125.6	129.9	137.2	124.2	130.0

* Special target negotiated with European Union (see http://ec.europa.eu/clima/policies/transport/vehicles/cars/index_en.htm)

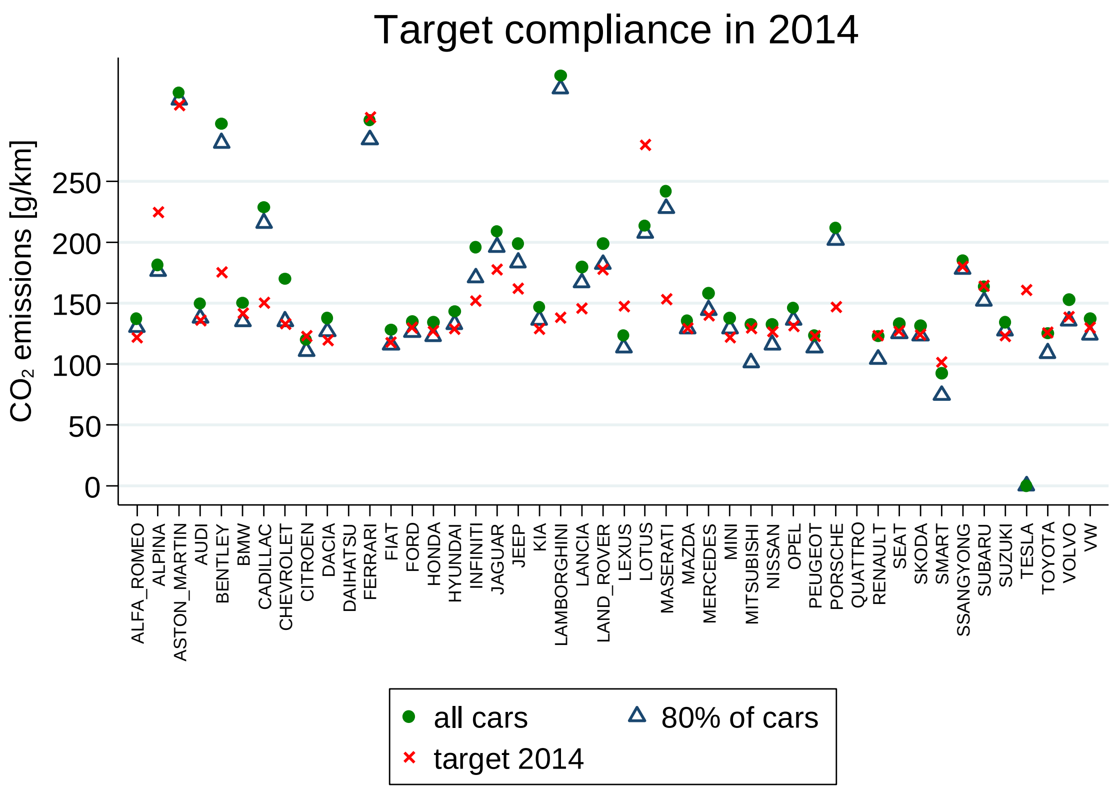

Figure 9: Target compliance of all makes with at least 50 registrations in 2014

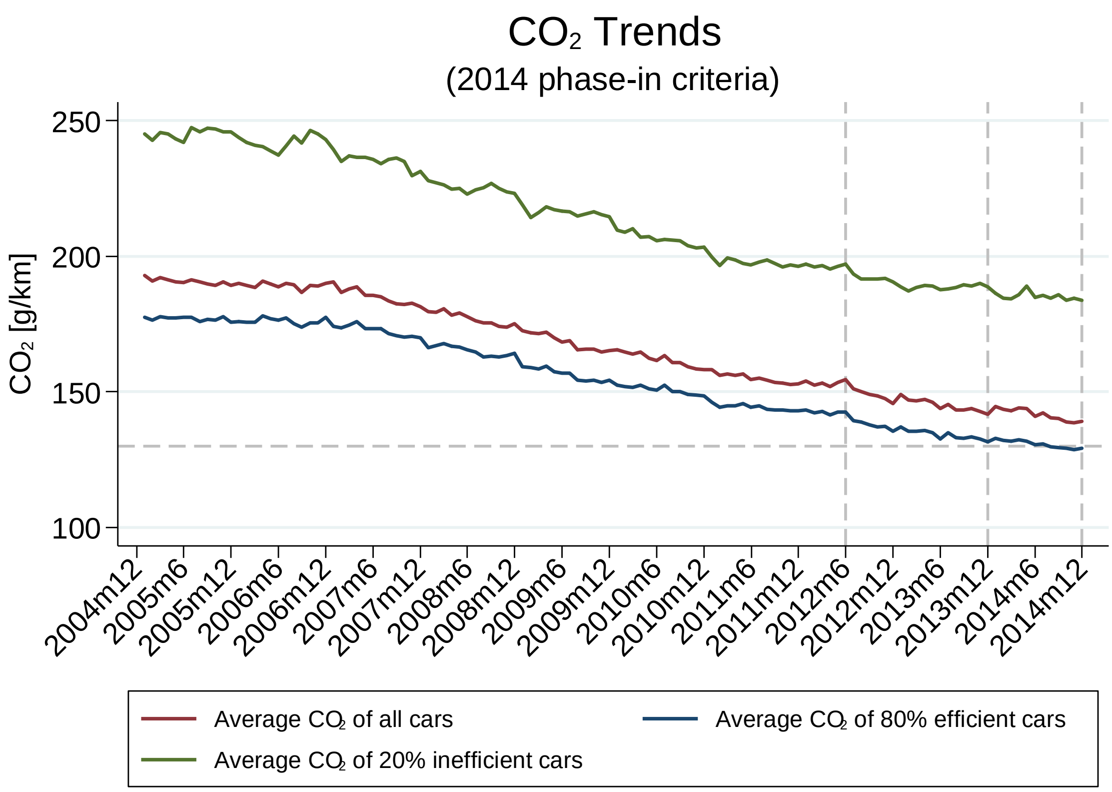

Figure 10: Trend of average CO_2 emissions of total fleet and 2014 phase-in criteria

5. Empirical results

Estimation results from the first model (equation (2)) are reported in the first column of table 4a. In column (2) we add the May-June 2012 dummy. Column (3) reports the results from a model where we add an interaction between the policy dummy and the time trend, and column (4) further includes the May-June 2012 dummy (equation (3)).

The dependent variable in all models is the average CO_2 emissions per kilometer of all newly registered cars of make *i* in month *t*. The make fixed effects are included in all specifications but omitted from the table. The regressions are weighted by the number of registrations per make in each month.[17]

The results from these regressions are striking. Column (1) of table 4a, for example, shows that even prior to the policy, CO_2 emissions were declining—at a rate of about half a gram per km per month, or about 6 grams per year. The coefficient on the policy dummy is

[17] If we are not weighting the regressions, 1) average CO_2 emissions of makes which are sold rarely as e.g. Ferrari would be counted equally as the average emissions of makes which are sold multiple times more, e.g. VW and 2) we would have the problem of heteroscedasticity .

negative, which is intuitively correct, implying a downward shift in the CO_2 emissions rates. But at only 0.87 g/km, the coefficient is very small and only weakly significant at the 5 percent level. Adding the May-June 2012 dummy, as we do in column (2), makes the effect of the policy even smaller and insignificant at the conventional levels.

Columns 3 and 4 confirm the existence of the trend prior to the beginning of the policy. The coefficients on the policy dummy are much larger (in absolute value) than those in columns (1) and (2), indicating a downward shift by more than 14 grams per km. The coefficient on the interaction between the trend and the policy dummy is positive, indicating that the time trend in average CO_2 emissions rate becomes slightly flatter in the periods after July 2012. Finally, there is evidence that in the two months prior to the beginning of the policy the CO_2 emissions rates increased slightly—by 1.6 to 1.9 grams per km, depending on the specification—presumably while auto importers were seeking to deplete inventories of higher emitting cars.

In table 4b we run the same models as in table 4a, but the sample is restricted to a narrow window around the introduction of the policy in hopes of keeping all major economic and regulatory circumstances approximately constant. The results are similar but the effect of the policy is stronger in three out of four specifications, which is consistent with the main findings from table 4a.

If we run separate regressions before and after implementation of the emissions standards (see table 5), we get results that support those in table 4a and 4b. The estimated coefficient of the time trend before policy implementation gives us a steeper slope than the estimated coefficient of the time trend after policy implementation. The difference is around 0.16 which is comparable to the coefficient of the interaction between policy dummy and time trend which is 0.13 (see table 4a). The change of the intercept from before to after policy is 16.3 which is comparable to the coefficient of the policy dummy of 14.3 in table 4a. This result is also displayed graphically in figure 11.

Table 4a: Regression results, average CO_2 emissions of a makes total fleet as outcome variable (2005 – 2014)

	(1)	(2)	(3)	(4)
Time trend	-0.509^{***}	-0.512^{***}	-0.514^{***}	-0.517^{***}
	(-80.15)	(-78.53)	(-79.27)	(-77.69)
Policy dummy	-0.872^{*}	-0.651	-14.35^{***}	-14.46^{***}
	(-2.00)	(-1.47)	(-4.22)	(-4.25)
Policy*Time trend			0.130^{***}	0.134^{***}
			(3.99)	(4.09)
Dummy May/June 2012		1.643		1.874^{*}
		(1.74)		(1.98)
Constant	197.5^{***}	197.6^{***}	197.8^{***}	197.9^{***}
	(509.58)	(502.96)	(501.02)	(493.88)
Observations	6224	6224	6224	6224
R^2	0.926	0.926	0.926	0.926

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4b: Regression results, average CO_2 emissions of a makes total fleet as outcome variable (only 2010 – 2014)

	(1)	(2)	(3)	(4)
Time trend	-0.434^{***}	-0.449^{***}	-0.496^{***}	-0.544^{***}
	(-27.98)	(-27.72)	(-24.45)	(-26.17)
Policy dummy	-1.731^{***}	-1.157^{*}	-13.18^{***}	-16.59^{***}
	(-3.51)	(-2.24)	(-4.48)	(-5.60)
Policy*Time trend			0.126^{***}	0.174^{***}
			(4.03)	(5.53)
Dummy May/June 2012		1.864^{**}		3.266^{***}
		(2.82)		(4.81)
Constant	191.0^{***}	192.0^{***}	195.7^{***}	199.1^{***}
	(157.16)	(152.75)	(124.40)	(123.64)
Observations	3103	3103	3103	3103
R^2	0.927	0.928	0.928	0.929

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Regression results of robustness check with average CO_2 emissions as output variable

	(1)	(2)
	Before 2012	After 2012
Time trend	-0.514***	-0.347***
	(-72.36)	(-14.48)
Constant	197.2***	180.9***
	(522.35)	(69.45)
Observations	4392	1207
R^2	0.935	0.955

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

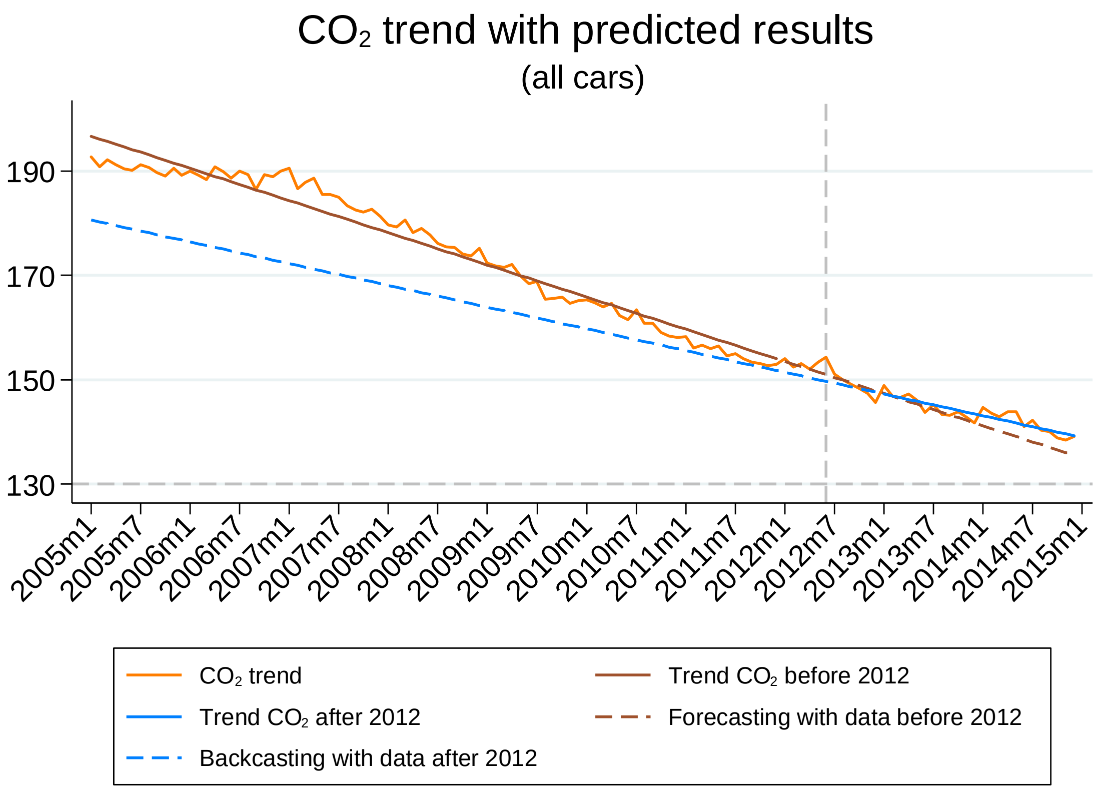

Figure 11: Illustration of robustness check results

Note: Figure 11 displays the average CO_2 emissions rate and the regressions lines based on the results in table 5. The solid lines are the regression lines based on the pre-2012 and after-2012 samples. The dashed lines are the predictions for after 2012 using the pre-2012 regression, and the "backcast" for years before 2012 using the after-2012 regressions. It can be clearly seen that the slope flattened after the policy implementation.

A possible explanation for the fact that the reduction in average CO_2 emissions rates appears to slow down slightly is the design of the phase-in criteria from 2012 to 2014. For example, in 2014 only the 80% most efficient cars of each importer's fleet need to comply with the target. Consequently the 20% most inefficient cars of each importer's fleet do not need to reach the target. Assuming a higher profit margin for bigger and luxury cars compared to smaller cars, importers will have an incentive to use the phase-in criteria to import very heavy and luxury cars. With the higher profit margin of these cars they can compensate margin losses of the rest of the fleet. A further incentive to import heavy cars, since they do not yet have to comply with the target, is created by the way the importers' specific targets are computed. As explained in section 2, an importer's specific target depends on the average curb weight of its total fleet. Therefore, heavy and inefficient cars escape the target *and* increase the average weight, which in turn means that the computed target will be a higher CO_2 emissions rate and will be easier to achieve. These 20 % high emitting cars of the importer's fleet can drive up the average CO_2 emissions.

We re-run all equations for the efficient car fleet defined by the phase-in criteria and the inefficient car fleet (100% minus phase-in criteria of 65%, 75% and 80%, respectively) separately.[18] The regression results of the 2014 phase-in criteria and the corresponding robustness check are shown in table 6 and 7. The results for the criteria of 2012 and 2013 are reported in Appendix B.

Table 6 refers to the 80% cleanest cars, and displays qualitatively similar results to those in table 4a. It is noteworthy that the effect of the policy in column (1) is stronger than its counterpart in table 4a, and that the slowdown in the trend after the policy starts is less pronounced than in table 4a.

Table 7 focuses on the 20% "dirtiest" cars. In table 7, we can see that in column (1 and 2) the coefficient on the policy dummy is positive, suggesting that the policy may have made the "dirtiest" cars even dirtier. These results are also supported by the results of the robustness check in table 8 and figure 12.[19] Possible explanations include:

- Holding the CO_2 emissions reductions constant, the importers can import more low-emissions cars than before and more high-emissions cars than before, but do so just in the right proportion so that they still attain the target.

[18] To construct the sample, we identify the 35% highest emitting cars of each make in each year, the 25% highest emitting cars of each make in each year, and the 20% highest emitting cars of each make in each year.
[19] The results of the phase-in criteria in 2012 and 2013 are shown in Appendix B.

- Swiss car buyers demand heavier cars which makes it more difficult for the importers to reach the target.
- The technological improvement slightly decelerated.

Table 6: Regression results with average CO_2 emissions of 80% most efficient cars per make and year

	(1)	(2)	(3)	(4)
Time trend	-0.473^{***}	-0.473^{***}	-0.477^{***}	-0.478^{***}
	(-79.88)	(-77.53)	(-78.68)	(-76.31)
Policy dummy	-1.843^{***}	-1.790^{***}	-13.35^{***}	-13.39^{***}
	(-4.79)	(-4.53)	(-4.57)	(-4.58)
Policy*Time trend			0.111^{***}	0.112^{***}
			(3.93)	(3.97)
Dummy May/June 2012		0.403		0.596
		(0.51)		(0.75)
Constant	183.8^{***}	183.8^{***}	184.0^{***}	184.0^{***}
	(500.31)	(493.56)	(490.85)	(483.50)
Observations	5424	5424	5424	5424
R^2	0.928	0.928	0.928	0.928

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: Regression results with average CO_2 emissions of 20% most inefficient cars per make and year

	(1)	(2)	(3)	(4)
Time trend	-0.633^{***}	-0.638^{***}	-0.646^{***}	-0.652^{***}
	(-65.84)	(-64.45)	(-65.96)	(-64.70)
Policy dummy	1.727^{*}	2.083^{**}	-35.17^{***}	-35.36^{***}
	(2.53)	(2.99)	(-7.44)	(-7.48)
Policy*Time trend			0.357^{***}	0.363^{***}
			(7.80)	(7.93)
Dummy May/June 2012		2.517		3.145^{*}
		(1.67)		(2.09)
Constant	251.2^{***}	251.3^{***}	251.8^{***}	251.9^{***}
	(450.15)	(444.19)	(443.36)	(436.96)
Observations	5273	5273	5273	5273
R^2	0.906	0.906	0.908	0.908

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: Regression results of robustness check with 2014 phase-in criteria

	(1)	(2)	(3)	(4)
	Before 2012 (80% efficient cars)	After 2012 (80% efficient cars)	Before 2012 (20% inefficient cars)	After 2012 (20% inefficient cars)
Time trend	-0.475***	-0.312***	-0.647***	-0.196***
	(-71.17)	(-15.95)	(-60.99)	(-7.02)
Constant	183.4***	166.2***	251.1***	208.0***
	(504.20)	(78.35)	(484.68)	(68.49)
Observations	3896	1036	3785	1005
R^2	0.937	0.965	0.927	0.959

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

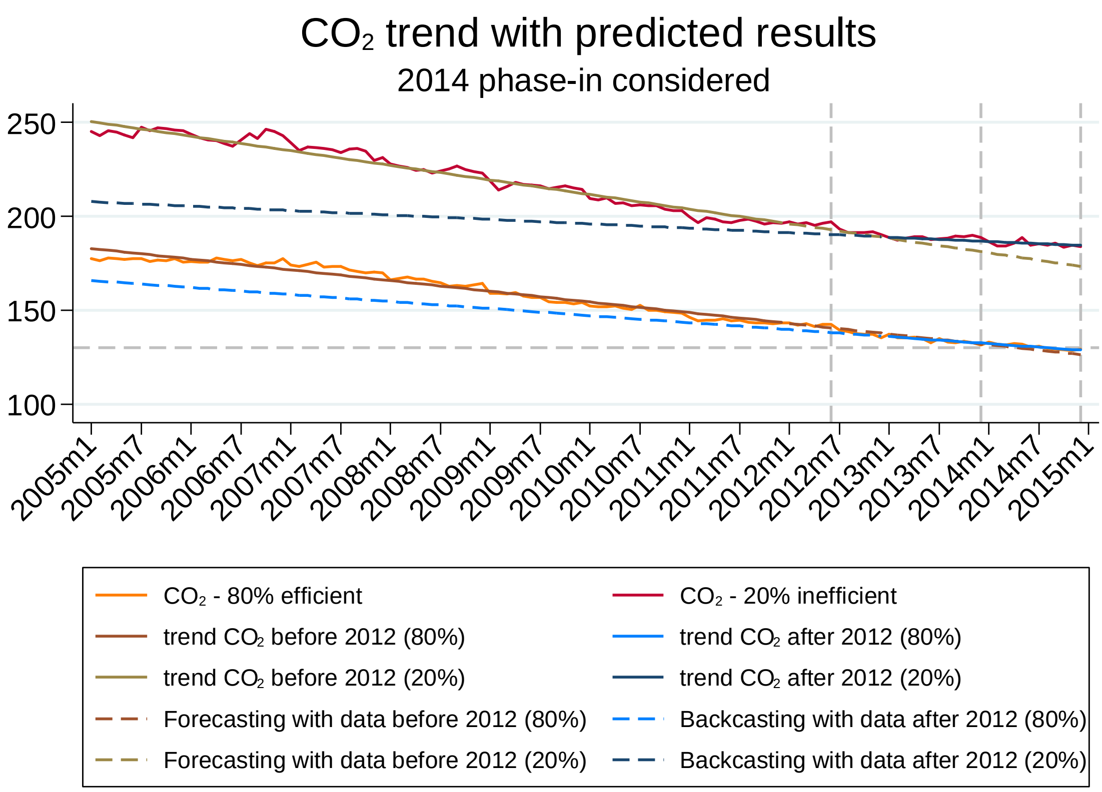

Figure 12: Illustration of robustness check results with 2014 phase-in criteria

6. Comparison of Swiss policy impact with the impact in the EU

The Swiss CO_2 emissions standards were adapted from the EU CO_2 emissions standards and are almost identical to them. The biggest difference is that in the EU the target is at the manufacturer level, and so the manufacturers or a pool of manufacturers get a specific fleet target for all cars sold in the EU. In Switzerland the policy obliges the importers because there is no commercial car manufacturing in Switzerland, and the target has to be fulfilled within Switzerland. Hence, there is no opportunity to compensate between countries like in the EU. The target is in both cases 130 g/km average CO_2 emissions. As can be seen in figure 13, Switzerland started at a much higher level of average emissions which implies that target will be more difficult to reach. But the graph also shows that EU’s fleet decreased below the 130 g CO_2/km target already in 2013 while Switzerland, as discussed above, reaches the target only due to the phase-in criteria and will need strong efforts to reach the target of the total fleet by 2015. However, the gray bars show that the difference between the Swiss average CO_2 emissions and the EU average CO_2 emissions decreased over time and it can be expected that this gap shrinks even more in 2015, when the average CO_2 emissions of the total fleet need to fulfill the target. If we look at the country level, we can see in figure 14 that in the EU not all countries fulfilled the target in 2013, but, as mentioned above, manufacturers have a EU-wide and not country-wide target.

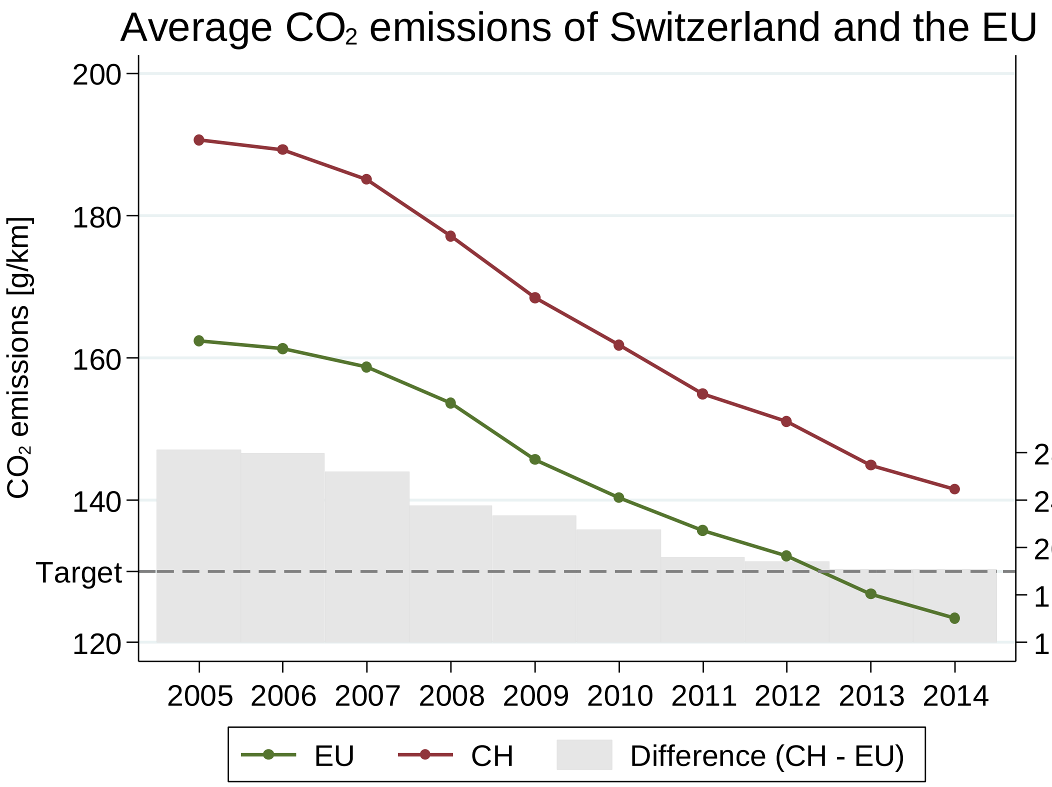

Figure 13: Average CO_2 emissions of Switzerland and the EU (Source: FEDRO, European Environment Agency)

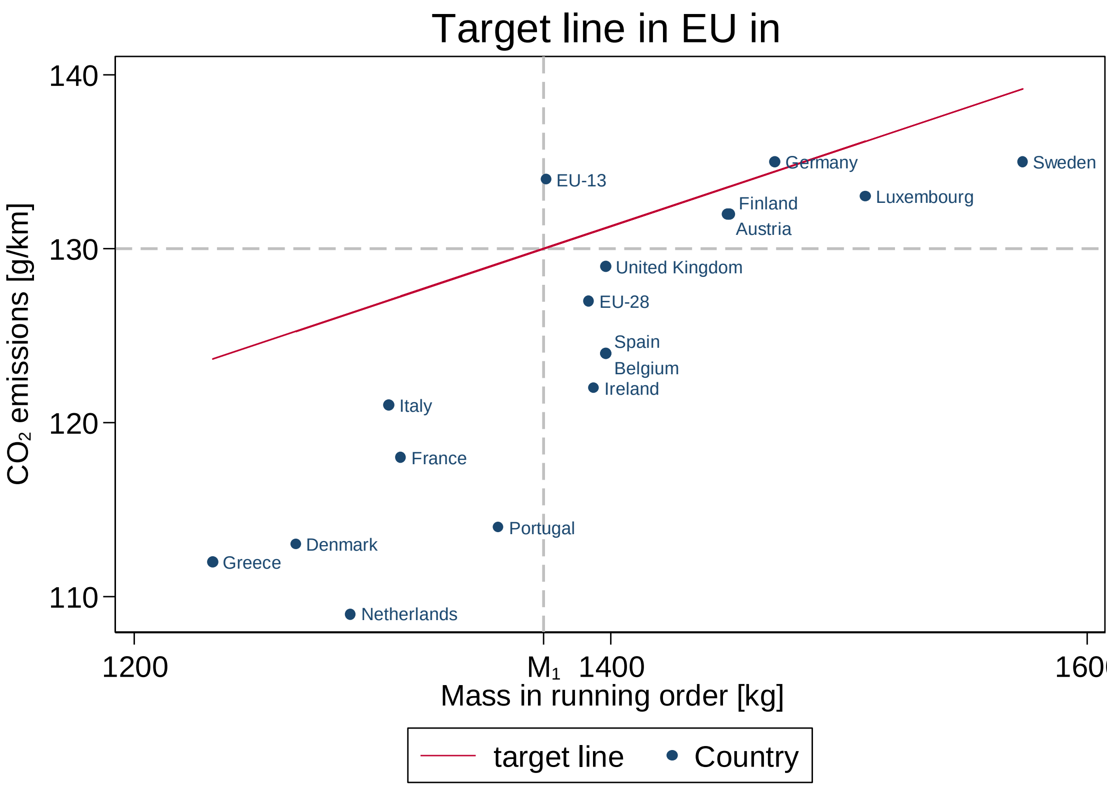

Figure 14: Hypothetical target compliance of EU member states in 2013 (Source: ICCT Pocketbook 2014)

EU manufacturers have an incentive to put a lot of effort in research and development to reduce CO_2 emissions even though they are already below the target of 130 g/km because they are already looking ahead at the 2021 target of 95 g/km. Of course there are also other reasons for the low CO_2 emissions in Europe such as a lower purchasing power (e.g. Greece or Portugal)[20] or stringent national policies in different countries (e.g. Denmark or the Netherlands)[21]. By contrast, Swiss importers first need to reach the 2015 target which is difficult because they started from a much higher emissions level. Nonetheless they can still take advantage of the EU manufacturers' technological improvements and may act strategically during the phase-in period. In theory, they had the possibility to import a car fleet that reaches exactly the annual target although more efficient cars would already be on the market. In 2015, when the average of the total fleet needs to comply with the target, the Swiss importers can benefit from the improvements by the EU manufacturers. The efficient cars are on the market to reach the target. The much more difficult task will be to convince the customer to buy them.

A recently published report of the European Commission evaluated the effect of the CO_2 emissions standards on the average CO_2 emissions of new passenger cars in the EU (Gibson et al., 2015). The authors of this report use a statistical model similar to ours. Their study period ranges from 2001 to 2013. They use a policy dummy for the time after the adoption of the law, which was in 2009, although the phase-in period with potential penalties for target failures started only in 2012. The dependent variable in their regressions is the annual average CO_2 emissions in each Member State. Their regression model includes country fixed effects to capture the time-invariant characteristics of each Member State. They estimate a policy effect of -3.5 g CO_2/km per year. Due to potential other effects as GDP growth or country specific policies in the mobility sector, which they do not control for in their model, the authors effectively assign only two thirds of the reduction of 3.5 g CO_2/km to the EU CO_2 emissions standards.

Their results are different from ours for the case of Switzerland, and need to be interpreted with caution. On the one hand, country specific policies might have had a higher effect than the authors stated. Many Member States implemented very stringent registration tax policies in their countries. In order to mention just one example, Kok (2015) estimated that the Dutch average CO_2 emissions would be 13 g/km higher without the CO_2-based tax

[20] http://ec.europa.eu/eurostat/web/purchasing-power-parities/overview
[21] http://www.acea.be/industry-topics/tag/category/co2-taxation

incentives in 2013. Due to these salient tax incentives, The Netherlands has moved from the 12th position before the tax changes in 2007 to become Europe's number one in terms of the lowest average CO_2 emissions of passenger cars (Kok, 2015). Besides that, the main reason that explains the diverging results is probably the different time periods used. While we used data from 2005 to 2014, Gibson et al. (2015) used data from 2001 to 2013. From 2001 to 2007 the reduction of average CO_2 emissions was very low and increased thereafter (Gibson et al., 2015). In 2007, the discussion of a mandatory target in the EU started and the law was finally implemented in 2009. Although the phase-in period with penalties did not apply until 2012, manufacturers started improving the efficiency of their car fleets in prior years. Car imports into Switzerland were influenced by this change by the European car manufacturers, which brought about a reduction in average CO_2 emissionsrates in Switzerland—at a faster rate. Accordingly, in our empirical model with a study period from 2005 to 2014, we can assume that part of the effect of the EU policy is already captured in the time trend before the implementation of the Swiss policy and our estimated results show the effect of the Swiss policy itself.

7. Conclusions

This study is the third and final module of a project with the title "Economic analysis of policy measures to reduce CO_2 emissions of passenger cars in Switzerland" which CEPE conducted for FOEN and FEDRO. We made a first attempt to evaluate the impact of the CO_2 emissions standards introduced in July 2012 in Switzerland. Through the emissions standards, every importer gets a specific CO_2 emissions target depending on the average weight of its fleet. A phase-in period where only a certain percentage of the fleet needs to comply to the target takes place from 2012 to 2014. In 2015 the average target is 130 g CO_2/km.

Although the policies targets the importers of new passenger cars, our units are the car makes. The lack of information on the importer forced us to assume that each make was imported separately by an individual importer. This is a very stringent assumption which leads to an underestimation of the target compliance because if importers bundle different makes strategically the target will be easier to fulfill. Other important study limitations are the fact that we only have data up to 2014 (when the policy is still in the phase-in period) and that we do not have a "control" group. As a consequence, the results of this study should be interpreted with caution.

Descriptive statistics show that average CO_2 emissions of the total fleet decrease monotonically but that much effort is still needed to achieve the target of 130 g CO_2/km. However, if we look only at the average CO_2 emissions of the fleet that needs to be considered during the phase-in period, we see that on average the targets are more or less reached at the make level in the years 2012 to 2014.

Our regression analysis results show a slight deceleration in the decrease in average CO_2 emissions rates. By splitting the car fleet of each make into two groups where the first contains the proportion of the new car sales that must comply with the target and the second group the rest, we see further evidence that the decrease in the average emissions rate slowed down but less so in the first group than in the second group. An interpretation can be that importers act strategically and only try to meet exactly, but not exceed, the specific target, assuming that cars with larger engines and hence higher emissions rates give higher profit margins to the importer.

When interpreting the results, we remind the reader that we are forced to ignore other factors that may affect the fleet, such as economic growth or recession or other policies, like the Cantonal vehicle registration taxes. We have attempted to circumvent this problem by running additional regressions for 2010 to 2014 in hopes that most circumstances are approximately constant over this period.

As mentioned above our study period ranges only until 2014 when the policy is still in the phase-in period and importers do not need to achieve the average target with their entire fleet. Hence, it is not possible to estimate the full effect of the policy and how Switzerland is doing compared to the European Union. A more rigorous analysis of the effect of the policy on CO_2 emissions rates would require the registration data of 2015 (the year when the full fleet needs to meet the target), and knowing exactly which importers carry which makes and enter in agreement with other importers. As a concluding remark, we note that here we examine emissions rates “on paper,” i.e., as per the manufacturers’ tests following the New European Driving Cycle (NEDC) protocol. On-road emissions rates may be very different from the “per-specs” emissions rates.

References

BAFU (1999). Bundesgesetz über die Reduktion der CO2-Emissionen (CO2-Gesetz) vom 8. Oktober 1999 (Stand am 1. Mai 2012). Federal Office for the Environment FOEN, Bern, 1999. Available at: http://www.bafu.admin.ch/klima/00493/00494/index.html?lang=de&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1acy4Zn4Z2qZpnO2Yuq2Z6gpJCGfYF,fWym162epYbg2c_JjKbNoKSn6A--

BAFU (2014). Swiss climate policy at a glance. Federal Office for the Environment FOEN, Bern, 2014. Available at: http://www.bafu.admin.ch/publikationen/publikation/01757/index.html?lang=en&download=NHzLpZig7t,lnp6I0NTU042l2Z6ln1ad1IZn4Z2qZpnO2Yuq2Z6gpJCHdn95fWym162dpYbUzd,Gpd6emK2Oz9aGodetmqaN19XI2IdvoaCVZ,s-.pdf

BAFU (2015). Ordinance for the Reduction of CO2 Emissions of 30 November 2012 (Status as of 1 January 2015), Annex 5. Federal Office for the Environment FOEN, Bern, 2015. Available at: https://www.admin.ch/opc/en/classified-compilation/20120090/index.html

BFE (2009). Schweizer Autos sind immer noch zu durstig. Press release of 7.5.2009, Bundesamt für Energie, Bern. Available at: http://www.bfe.admin.ch/energie/00588/00589/00644/index.html?lang=de&msg-id=26779

BFE (2011). CO2-Zielwerte für Personenwagen gelten ab Mitte 2012. Press release of 16.12.2011, Bundesamt für Energie, Bern. Available at: http://www.news.admin.ch/message/index.html?lang=de&msg-id=42730

BFE (2015). Energieverbrauch und Energieeffizienz der neuen Personenwagen 2014 – 19. Berichterstattung im Rahmen der Energieverordnung. Bundesamt für Energie, Bern. Available at: http://www.bfe.admin.ch/energieetikette/00886/index.html?lang=de&dossier_id=00959

Ciccone, Alice (2014). Is It All about CO2 Emissions? The Environmental Effects of a Tax Reform for New Vehicles in Norway. Memorandum, Department of Economics, University of Oslo.

Gibson, Gena, Sujith Kollamthodi, Felix Kirsch, Elisabeth Windisch, Charlotte Brannigan, Ben White, Eugenia Bonifazi, Outi Korkeala and Ian Skinner (2015). Evaluation of Regulation 443/2009 and 510/2011 on the reduction of CO2 emissions from light-duty vehicles. On behalf of the European Commission, Brussels. Available at: http://ec.europa.eu/clima/policies/transport/vehicles/docs/evaluation_ldv_co2_regs_en.pdf

Kok, Robert (2015). Six years of CO_2-based tax incentives for new passenger cars in The Netherlands: Impacts on purchasing behavior trends and CO_2 effectiveness. Transportation Research Part A 77 (2015), p. 137 – 153. Rotterdam (NL).

Appendix A

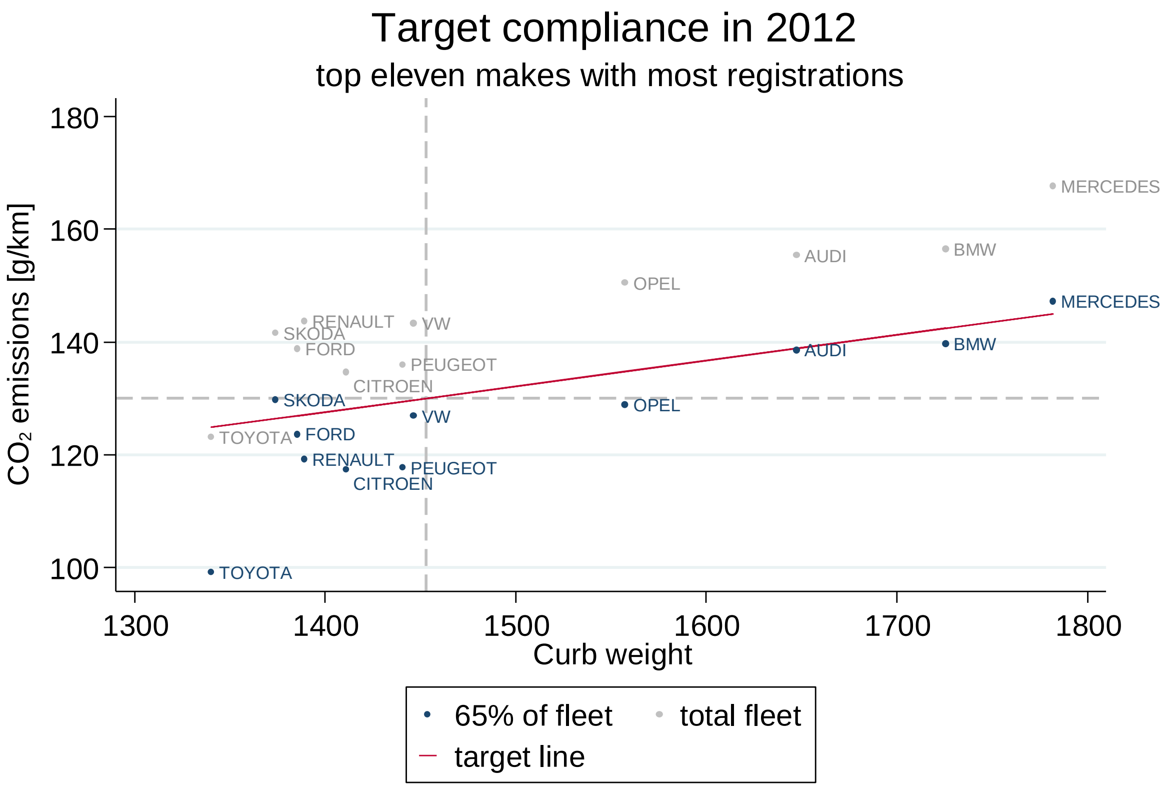

Figure 15: Average CO_2 emissions of total fleet and 65% of the fleet compared to specific fleet target in 2012

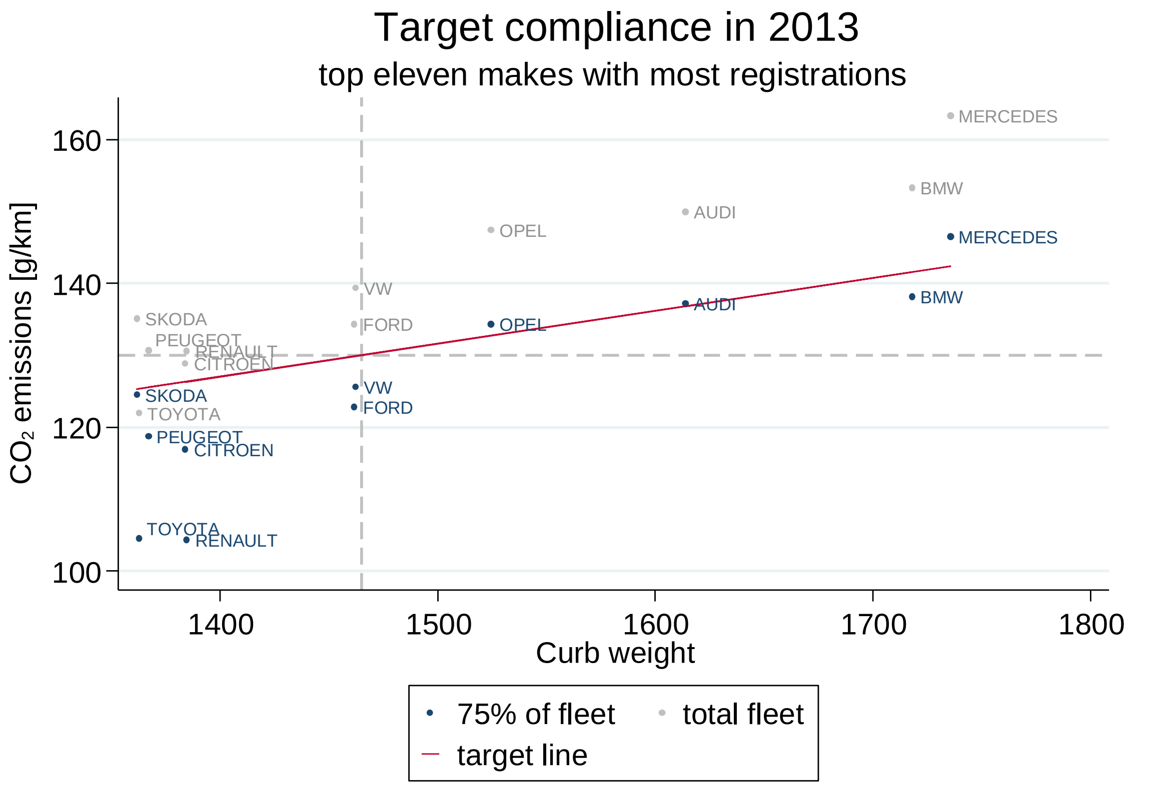

Figure 16: Average CO_2 emissions of total fleet and 75% of the fleet compared to specific fleet target in 2013

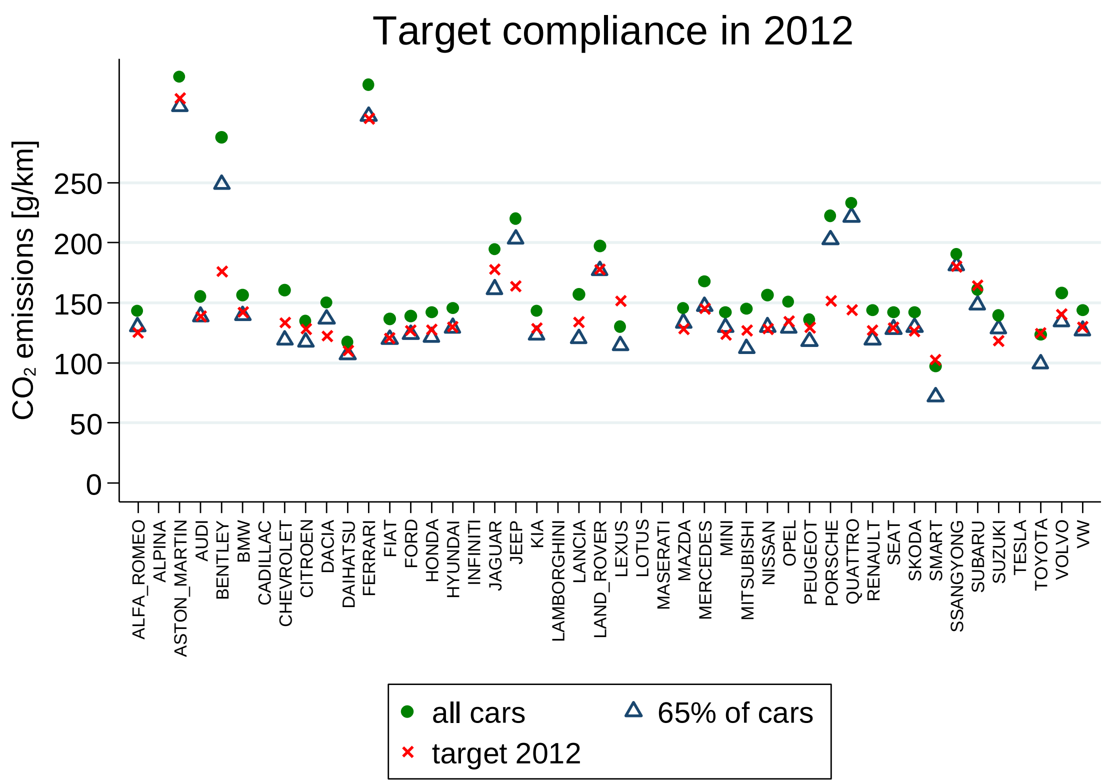

Figure 17: Target compliance of all makes with at least 50 registrations in 2012

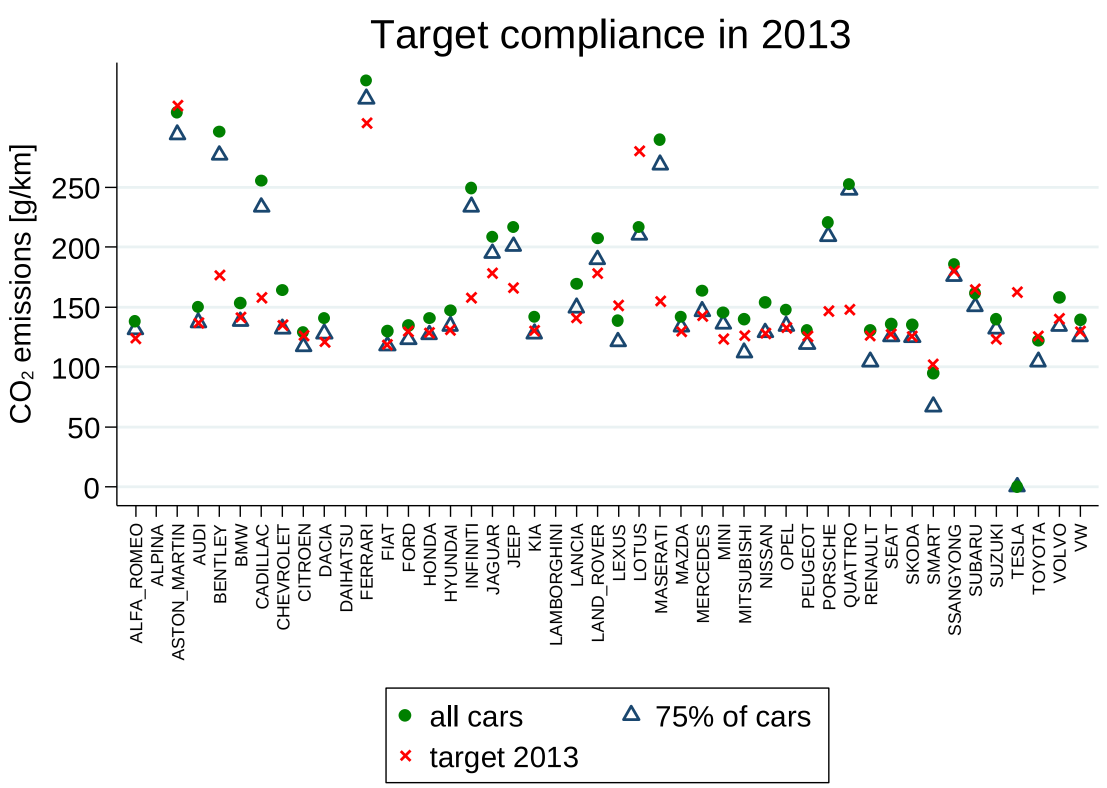

Figure 18: Target compliance of all makes with at least 50 registrations in 2013

Table 9: Make statistic 2012 (CO_2 emissions in g/km and weight in kilogram)

Make	Registra-tions	Avg. CO_2	min CO_2	Avg. CO_2 (65%)	max CO_2	Avg. weight	min weight	max weight
Alfa Romeo	1102	143	98	130	210	1355	1155	1730
Aston Martin	89	338	116	313	388	1793	1063	2065
Audi	9556	155	99	139	277	1647	1115	2515
Bentley	78	288	246	249	396	2454	2370	2760
BMW	9157	157	99	140	325	1726	1320	2380
Chevrolet	1807	161	27	119	355	1528	939	2058
Citroen	4976	135	0	117	284	1411	910	2290
Dacia	2354	150	104	137	185	1287	1050	1469
Daihatsu	351	118	104	107	181	1024	840	1330
Ferrari	116	332	270	305	415	1772	1455	1955
Fiat	4606	137	90	120	262	1253	935	2583
Ford	7965	139	87	124	244	1386	940	2348
Honda	2257	142	96	122	213	1407	1123	1876
Hyundai	3935	145	93	129	231	1457	997	2345
Jaguar	164	194	139	161	292	1945	1719	2062
Jeep	947	220	172	203	329	2188	1645	2499
Kia	2402	143	94	123	209	1429	950	2287
Lancia	451	157	97	120	252	1544	1040	2330
Land Rover	1561	197	129	177	348	2161	1715	2810
Lexus	493	130	94	114	379	1927	1485	2495
Mazda	3177	145	110	133	243	1407	1035	1940
Mercedes	6958	168	0	147	397	1782	1245	3000
Mini	2035	142	99	130	184	1308	1145	1505
Mitsubishi	1802	145	0	112	243	1389	1010	2385
Nissan	3627	157	0	130	298	1408	940	2417
Opel	6457	151	27	129	265	1557	1050	2359
Peugeot	4903	136	0	118	226	1441	890	2454
Porsche	969	222	145	202	275	1919	1415	2336
Quattro	542	233	212	222	337	1756	1650	2710
Renault	8061	144	0	119	236	1389	958	2355
Seat	3761	142	79	128	198	1438	929	1945
Skoda	8186	142	89	130	237	1374	929	1741
Smart	891	97	0	72	120	846	825	995
Ssangyong	266	190	157	181	235	1795	1666	2179
Subaru	4640	161	115	148	250	1499	1015	1711
Suzuki	3564	140	99	129	225	1202	930	1797
Toyota	5606	123	49	99	308	1340	875	2815
Volvo	3261	158	0	134	269	1676	1278	2196
VW	19376	143	87	127	290	1446	929	2775

Table 10: Make statistic 2013 (CO_2 emissions in g/km and weight in kilogram)

Make	Registrations	Avg. CO_2	min CO_2	Avg. CO_2 (75%)	max CO_2	Avg. weight	min weight	max weight
Alfa Romeo	1929	138	98	131	262	1329	995	1670
Aston Martin	218	312	116	294	388	1747	1063	2065
Audi	19376	150	88	137	346	1614	1115	2515
Bentley	162	296	246	277	393	2477	2370	2760
BMW	19441	153	0	138	325	1718	1270	2380
Cadillac	113	255	182	233	396	2068	1659	2842
Chevrolet	3993	164	27	132	350	1568	939	2058
Citroen	10535	129	0	117	226	1384	875	2454
Dacia	5040	141	99	128	185	1263	1072	1490
Ferrari	335	339	270	324	545	1768	1475	1965
Fiat	9402	130	90	118	262	1217	935	2715
Ford	14371	134	0	123	227	1462	940	2597
Honda	5451	140	94	127	213	1430	1131	1876
Hyundai	7829	147	93	134	270	1488	984	2345
Infiniti	80	249	114	234	316	2070	1715	2248
Jaguar	823	208	139	195	292	1991	1719	2150
Jeep	2013	217	172	201	329	2253	1605	2522
Kia	3543	142	85	128	208	1466	959	2287
Lancia	876	169	97	149	252	1696	1040	2330
Land Rover	3121	207	133	190	348	2203	1720	2772
Lexus	639	139	87	121	379	1926	1445	2525
Lotus	78	216	149	210	236	1270	966	1517
Maserati	187	289	158	269	385	2006	1845	2065
Mazda	7424	142	104	134	224	1394	1030	1940
Mercedes	16233	163	0	146	397	1736	1275	2960
Mini	4508	145	99	136	184	1316	1145	1505
Mitsubishi	4369	140	0	112	250	1381	920	2385
Nissan	7099	154	0	129	288	1424	930	2500
Opel	13707	147	27	134	265	1525	1063	2413
Peugeot	11216	131	0	119	226	1367	875	2454
Porsche	2339	220	71	209	315	1830	1385	2366
Quattro	632	252	212	247	346	1857	1600	1995
Renault	13297	131	0	104	289	1385	939	2355
Seat	8811	136	79	125	198	1404	929	2087
Skoda	17383	135	79	124	237	1362	929	1736
Smart	1668	95	0	67	120	853	825	1020
Ssangyong	443	185	147	176	250	1881	1666	2248
Subaru	7299	161	113	150	243	1547	1080	1726
Suzuki	8225	140	94	132	225	1222	930	1797
Tesla	208	0	0	0	0	2171	2074	2175
Toyota	11859	122	49	105	308	1363	895	2815
Volvo	7392	158	48	134	269	1682	1331	2212
VW	38754	139	0	126	289	1462	929	2859

Table 11: Make statistic 2014 (CO_2 emissions in g/km and weight in kilogram)

Make	Registra-tions	Avg. CO_2	min CO_2	Avg. CO_2 (80%)	max CO_2	Avg. weight	min weight	max weight
Alfa Romeo	2045	137	98	130	211	1315	995	1514
Alpina	69	182	142	176	282	1847	1525	2085
Aston Martin	149	323	120	317	388	1816	1063	2065
Audi	19904	149	39	138	349	1627	1115	2500
Bentley	158	297	246	282	393	2491	2370	2760
BMW	20242	150	0	135	325	1747	1270	2380
Cadillac	141	229	190	216	370	1945	1678	2842
Chevrolet	1782	170	27	135	355	1561	939	2058
Citroen	10878	120	0	111	226	1337	902	2533
Dacia	4676	138	99	127	185	1264	1072	1490
Ferrari	337	300	251	285	415	1661	1485	1955
Fiat	8761	128	88	116	262	1232	933	2650
Ford	12456	135	85	126	227	1490	940	2597
Honda	4399	134	94	123	213	1430	1131	1876
Hyundai	9092	143	93	133	248	1464	980	2323
Infiniti	114	196	114	171	307	1977	1670	2258
Jaguar	559	209	139	196	297	1939	1719	2150
Jeep	3029	199	120	184	327	2199	1543	2522
Kia	4566	147	0	137	208	1468	950	2215
Lamborghini	65	337	290	326	500	1675	1505	1830
Lancia	790	180	97	167	252	1839	1040	2330
Land Rover	3059	199	133	182	348	2167	1645	2772
Lexus	838	124	88	113	270	1873	1465	2525
Lotus	75	214	149	208	236	1221	951	1517
Maserati	718	242	158	228	360	1999	1440	2055
Mazda	7385	136	104	129	261	1403	1045	2135
Mercedes	17907	158	65	145	397	1711	1360	2975
Mini	4283	138	89	130	184	1316	1150	1505
Mitsubishi	3510	133	0	101	243	1480	920	2385
Nissan	6928	133	0	116	275	1417	930	2417
Opel	12825	146	27	136	259	1526	1030	2413
Peugeot	11121	123	0	114	226	1337	880	2454
Porsche	2956	212	70	202	378	1870	1385	2578
Renault	11561	123	0	104	220	1361	920	2355
Seat	9048	133	79	125	198	1431	929	2108
Skoda	18897	132	79	124	217	1368	929	1761
Smart	1650	93	0	75	120	869	825	1020
Ssangyong	554	185	147	178	235	1918	1667	2248
Subaru	6063	164	113	152	246	1565	1180	1787
Suzuki	8346	135	94	128	221	1215	905	1734
Tesla	494	0	0	0	0	2172	2074	2175
Toyota	10573	125	49	109	308	1401	885	2815
Volvo	6652	153	0	136	289	1692	1357	2212
VW	38302	137	0	124	290	1494	870	2859

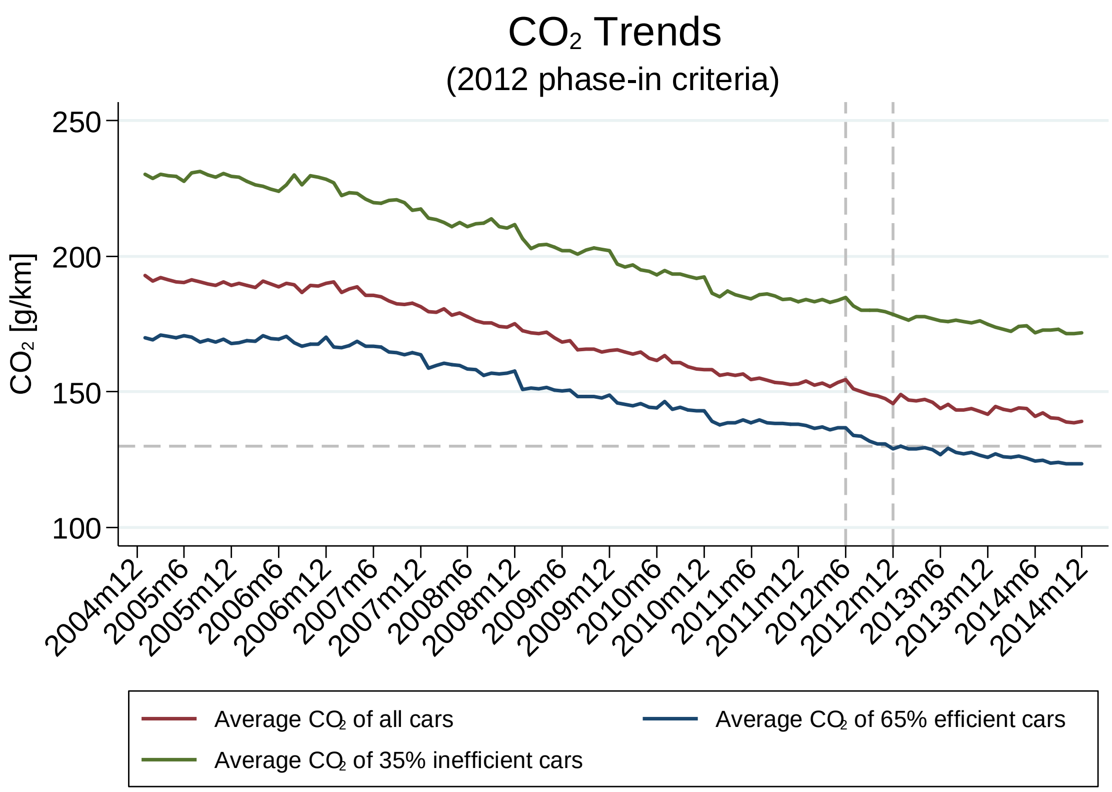

Figure 19: Trend of average CO_2 emissions of total fleet and 2012 phase-in criteria

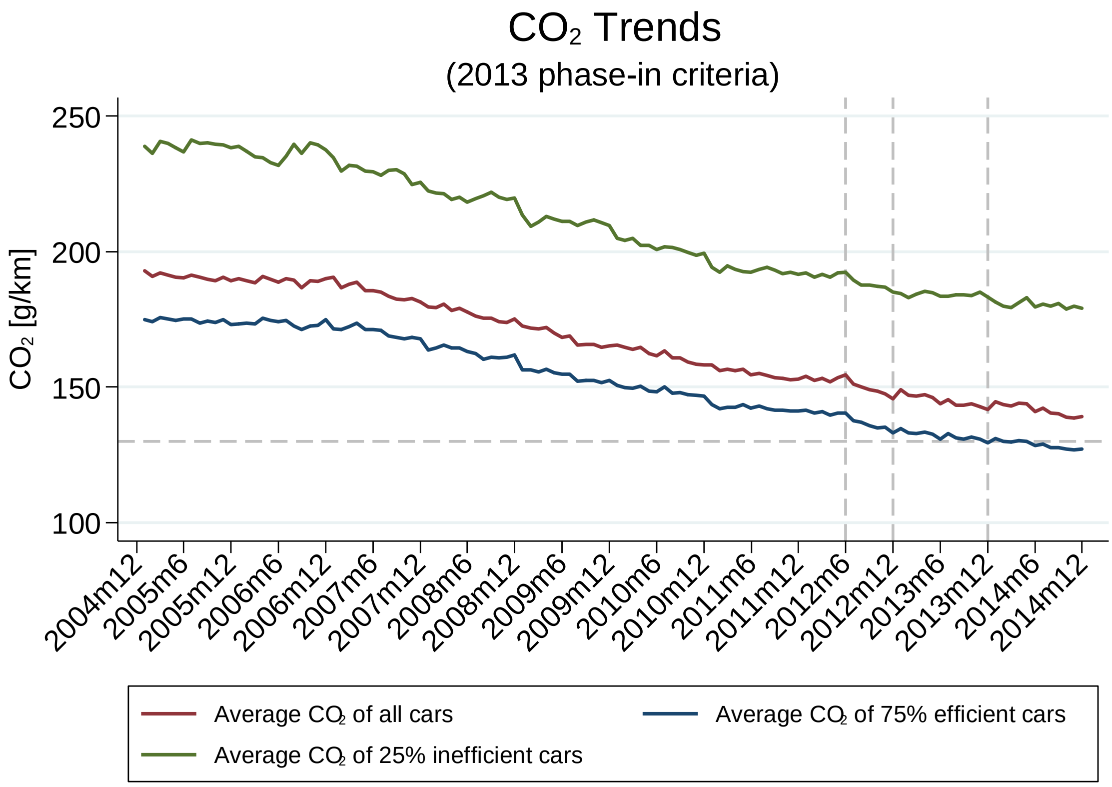

Figure 20: Trend of average CO_2 emissions of total fleet and 2013 phase-in criteria

Appendix B

Table 12: Regressions with 65% most efficient cars per make and year (only makes with at least 50 registrations)

	(1)	(2)	(3)	(4)
Time trend	-0.452***	-0.452***	-0.456***	-0.456***
	(-78.89)	(-76.35)	(-77.54)	(-74.96)
Policy dummy	-2.528***	-2.513***	-13.17***	-13.19***
	(-6.80)	(-6.54)	(-4.96)	(-4.96)
Policy*Time trend			0.103***	0.103***
			(4.01)	(4.02)
Dummy May/June 2012		0.118		0.296
		(0.16)		(0.39)
Constant	176.3***	176.3***	176.4***	176.5***
	(493.15)	(486.80)	(483.57)	(476.58)
Observations	5415	5415	5415	5415
R^2	0.929	0.929	0.929	0.929

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 13: Regressions with average CO_2 emissions of 75% most efficient cars per make and year

	(1)	(2)	(3)	(4)
Time trend	-0.467***	-0.467***	-0.471***	-0.472***
	(-79.53)	(-77.20)	(-78.27)	(-75.91)
Policy dummy	-2.018***	-1.969***	-13.45***	-13.49***
	(-5.29)	(-5.02)	(-4.78)	(-4.79)
Policy*Time trend			0.110***	0.111***
			(4.07)	(4.10)
Dummy May/June 2012		0.372		0.563
		(0.47)		(0.71)
Constant	181.2***	181.3***	181.4***	181.5***
	(497.01)	(490.44)	(487.42)	(480.23)
Observations	5423	5423	5423	5423
R^2	0.929	0.929	0.929	0.929

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 14: Regressions with average CO_2 emissions of 35% most inefficient cars per make and year

	(1)	(2)	(3)	(4)
Time trend	-0.600^{***}	-0.604^{***}	-0.610^{***}	-0.615^{***}
	(-72.96)	(-71.28)	(-72.95)	(-71.40)
Policy dummy	1.267^{*}	1.563^{**}	-27.45^{***}	-27.61^{***}
	(2.17)	(2.61)	(-6.21)	(-6.24)
Policy*Time trend			0.278^{***}	0.283^{***}
			(6.47)	(6.58)
Dummy May/June 2012		2.133		2.621^{*}
		(1.70)		(2.10)
Constant	236.1^{***}	236.2^{***}	236.6^{***}	236.7^{***}
	(494.58)	(487.69)	(486.85)	(479.52)
Observations	5361	5361	5361	5361
R^2	0.912	0.912	0.913	0.913

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 15: Regressions with average CO_2 emissions of 25% most inefficient cars per make and year

	(1)	(2)	(3)	(4)
Time trend	-0.618^{***}	-0.622^{***}	-0.629^{***}	-0.635^{***}
	(-69.38)	(-68.01)	(-69.48)	(-68.24)
Policy dummy	1.439^{*}	1.754^{**}	-31.39^{***}	-31.56^{***}
	(2.26)	(2.71)	(-6.80)	(-6.84)
Policy*Time trend			0.318^{***}	0.323^{***}
			(7.11)	(7.22)
Dummy May/June 2012		2.253		2.811^{*}
		(1.59)		(1.99)
Constant	245.2^{***}	245.4^{***}	245.8^{***}	245.9^{***}
	(474.41)	(468.45)	(467.35)	(460.99)
Observations	5311	5311	5311	5311
R^2	0.909	0.909	0.910	0.910

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Robustness check:

Table 16: Regression results of robustness check with 2012 phase-in criteria

	(1) Before 2012 (65% efficient cars)	(2) After 2012 (65% efficient cars)	(3) Before 2012 (35% inefficient cars)	(4) After 2012 (35% inefficient cars)
Time trend	-0.454***	-0.294***	-0.608***	-0.249***
	(-69.10)	(-17.39)	(-67.79)	(-9.17)
Constant	175.8***	158.3***	235.9***	201.4***
	(491.89)	(86.23)	(535.47)	(68.80)
Observations	3889	1034	3845	1025
R^2	0.936	0.970	0.933	0.951

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

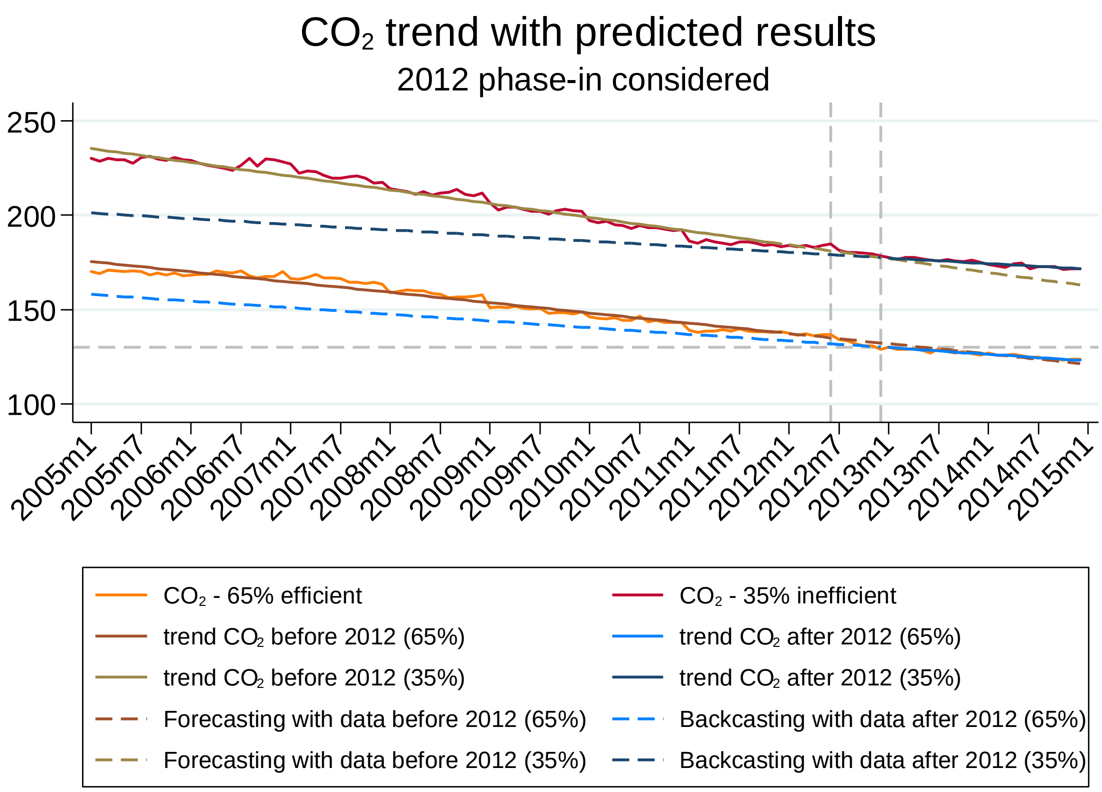

Figure 21: Illustration of robustness check results with 2012 phase-in criteria

Table 17: Regression results of robustness check with 2013 phase-in criteria

	(1)	(2)	(3)	(4)
	Before 2012 (75% efficient cars)	After 2012 (75% efficient cars)	Before 2012 (25% inefficient cars)	After 2012 (25% inefficient cars)
Time trend	-0.469***	-0.301***	-0.629***	-0.224***
	(-70.53)	(-16.80)	(-64.28)	(-8.52)
Constant	180.8***	162.9***	245.2***	206.3***
	(498.91)	(83.87)	(513.42)	(72.66)
Observations	3895	1036	3806	1008
R^2	0.937	0.968	0.930	0.957

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

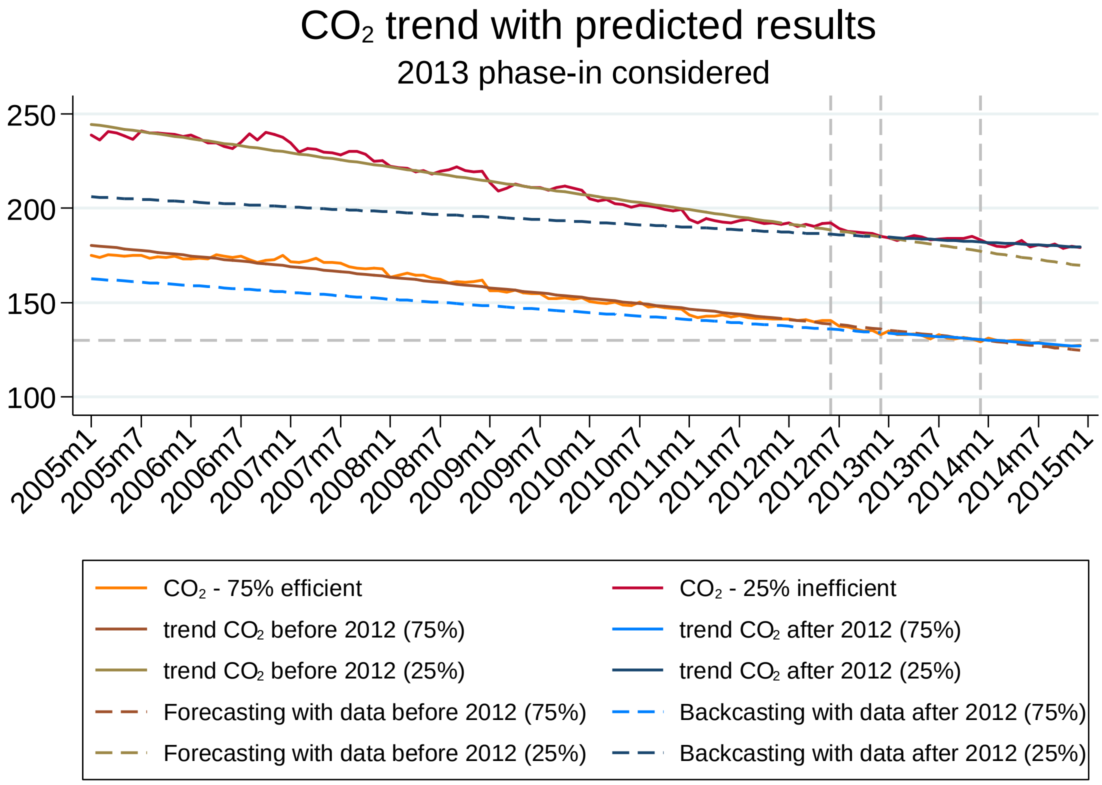

Figure 22: Illustration of robustness check results with 2013 phase-in criteria