The rise of low-carbon technology and its material inputs. An empirical analysis on aluminium imports

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Abstract

This paper analyses the incidence of the Paris Climate Agreement, signed in 2016, on the value of countries' aluminium imports, which, when used in vehicles, is more energy-efficient than its substitute, steel. For this study, trade data from BACI is used with various measures for a country's involvement in reaching the agreement's goals, in three main country fixed effects regressions. While results are inconclusive for the effect of simply joining the agreement, as well as having strong Nationally Determined Contributions to the Agreement, a decrease in aluminium imports was found for countries who publish a plan to reach Net Zero emissions in the next few decades. This unexpected negative result may be due to recycled aluminium, which is both cheaper and more energy-efficient (and thus favoured), or to importing aluminium from countries with lower carbon taxes and restrictions (and thus, at a cheaper price than at home). Results also suggest conducting further research as the race for net zero emissions intensifies over the next few decades.

1. Introduction

The Paris Climate Agreement is an international treaty, legally binding signed countries to its requirements. Nations have assembled to decide on its contents during COP21 (21st Conference of the Parties) in December 2015, and each country has proceeded to sign the agreement in April of the following year, with a few exceptions who have signed later ("Key Aspects", n.d.). Its main goal is to combat human-induced climate change, and prevent average temperatures from rising above 2 degrees Celsius, compared to those before the Industrial Revolution ("The Paris Agreement", n.d.). One of the channels through which global temperatures can be reduced is through control of greenhouse gas emissions, notably CO2 (carbon), which takes up a quarter of total emissions. For this, certain countries in the Paris Agreement have published and continue to update plans to reach net zero carbon emissions, such as the UK (Sharma & Johnson, 2020) and Costa Rica (Manuel Rodriguéz, n.d.). Meanwhile, all countries report their targets to reduce carbon emissions over time in Nationally Determined Contributions (NDCs) and exhibit varying levels of involvement: The extent to which an individual country makes efforts towards the Paris Agreement's goals is self-determined.

The global transportation sector is largely responsible for oil demand and so emits a significant amount of CO2 (Richardson, 2013). It is thus an important market to tackle for signers of the Paris Agreement. Electric vehicles (or EVs), vehicles that rely on a battery powered by electricity to function rather than combusting gasoline or diesel fuel, are viewed as a solution to reduce CO2 emissions, although the extent of this reduction depends on how the electricity for it is generated, in the regional grid. Increasing EV use therefore goes hand-in-hand with realizing the Paris Agreement's goals.

Aluminium is one of the most used metals in vehicle production (Mouak, 2010), and 30% of its total usage goes to the transport sector (Bergsdal et.al., 2005). This material's primary form, bauxite, is primarily mined in Guinea, Australia, Brazil and Jamaica. Alumine is then extracted from bauxite, and through a process called electrolysis, alumine can be transformed into aluminium. Primary aluminium production is mainly located in China, making it the largest producer since the 2000s (24% of global production in 2005), and

Russia is another notably large producer. This metal is highly traded on global markets, and competitiveness depends on regional energy costs, particularly for electrolysis which is the most energy-intensive process in its production (Sartor, 2012). In this paper, mentions of aluminum include both its pure form and its alloys.

In car production, aluminium has increasingly been used to substitute steel: it is three times lighter than the latter, adapting to produce more energy-efficient vehicles. In a previous study, Jones et. al. (2020) predict that 25% of aluminium demand growth will come from the road transport sector. By casting it, many structural components in a vehicle's body can be made such as the chassis, interior and doors (Hirsch, 2014). It is also used in the engine block and radiators. Although aluminium is present in all types of vehicles, manufacturers of EVs have a greater concern for reducing the vehicle's weight, thus using the metal more intensively.
Such links between aluminium, electric vehicles and goals of the Paris Agreement lead to this paper's main hypothesis:

Through an incentive to produce and consume more electric vehicles, a country's involvement in the Paris Climate Agreement positively influences aluminium imports.

This result is mainly expected due to a forecasted rise in demand of the metal for electric vehicle production (Jones et. al., 2020), which is itself currently increasing due to environmental concerns. However, another effect may mitigate this result. Aluminium can be recycled infinitely, and the recycled product is both cheaper and allows even more reductions to carbon emissions (Dunn et. al., 2015). This effect may decrease trade volumes. An empirical study could determine what the overall effect is.

This study combines two topics that are seemingly unrelated: climate agreements and metal markets. However, in a broad sense, many changes will be required in the coming decades to prevent irreversible global damage, and such changes will transform the economy in unexpected ways. To illustrate this, many economists have studied the effect of taxation on consumers, producers and the government, to find the optimal tax (Ramsey, 1927; Mankiw et. al., 2009; Pigou, 2013). Indeed, it is important to measure the impact of a policy on many economic parties to prevent undesired effects. Failing to do so may lead to many forms of social unrest, such as the carbon tax protests in France, in 2018 (Carattini et. al., 2019). The choice of variables is justified as follows: the Paris Agreement is a measure that can compare all countries, and the varying levels of involvement can be clarified with further methodology. It has also been signed during the same year for a large majority of countries party to it, and therefore most countries did not choose an opportunistic time to join, reducing the chance of a spurious correlation. Similarly, metal industries have a significant impact on many other sectors, as their final uses are diverse. Aluminium was chosen as a focus for this paper as it is a large and global market, and therefore any changes to its trade could have significant effects on the economies involved. Additionally, the industry is predicted to grow in value (Maida, 2020), therefore impacting more individuals. Furthermore, this paper contributes to the current body of literature, as there are few studies made on aluminium's relation to climate policy. The ones that exist are predictory in nature (such as Jones et. al., 2020), and thus none are ex-post. Other studies such as Sartor (2012) focus on a particular region's competitiveness rather than a global change caused by carbon reduction policies. Adversely, papers on international climate treaties' impacts on economic factors have focused more on those directly related to climate, such as green bond financing (Tolliver et. al., 2020) and patents for low-carbon technologies (Miyamoto, 2019).

In order to test the main hypothesis, several regressions with a country fixed effects specification will be conducted. This method has been chosen as it accounts for initial differences between countries, which likely play a large role in the value of imports of aluminium. The paper will begin by outlining the relevant literature and results already found on the topic, then introduce the data used and methodology design. Finally, regression results will be presented, along with interpretations, checks and balances. The paper will conclude by summarizing findings and explaining possible implications of the results for the aluminium industry and countries involved in it, as well as suggest further research to deepen understanding of the topic.

2. Literature review

Few studies have focused on the relationship between aluminium imports and a country's involvement in reducing carbon emissions. However, certain papers indicate a possible effect of the Paris Agreement on aluminium trade, by linking both factors to a common one: the development of low-carbon technology.

2.1. International Climate agreements

In recent years, papers have studied the Paris Climate Agreement and its consequence on the progress made towards a less wasteful economy. For example, Tolliver et. al. (2020) conducted a difference-in-difference regression to find the effect of a country's involvement in the Paris agreement on green bond financing of renewable energies. They used nationally determined contributions (NDCs) to measure the countries' involvement. NDCs include plans on climate targets and goals published for each participating country. The paper creates a score out of 10 for a sample of 66 countries' NDCs by quantifying the strength of different categories of climate progress, and assigns countries with a score above 6 to the treatment group. Findings are that countries in the treatment group face a significant increase in green bond financing from 2016 to 2017, compared to the control group. Tolliver et. al. therefore conclude that countries with stringent NDCs face an increase in the financing of green energy projects and assets.

Similarly, Miyamoto (2019) has studied the effect of the 1997 Kyoto Protocol, another international climate treaty, on the number of new technologies involving renewable energies, using a difference-in-difference specification. The number of patents deposited each year was used as the dependent variable. Countries with commitments to reducing greenhouse gas emissions were put into the treatment group, and a significant effect was indeed found of these commitments on an increase in patents for renewable energy technologies. An even stronger effect was found when only countries with more stringent commitments were included in the treatment group, therefore indicating a positive relationship. This paper therefore shows that results applicable to the Paris Agreement could extend to other climate treaties, supporting the general hypothesis that climate policies have an impact on the development of renewable goods' markets.

The effect of climate agreements and its decarbonization policies has not only affected domestic markets. According to Vrontisi et. al. (2020), who use a general equilibrium model, the Paris Agreement has reduced trade in-between countries for most sectors. One suggested explanation was that governments have competitiveness concerns: the Agreement has a bottom-up approach, meaning that each nation decides on its own contributions, leading to disparities in emission sanctions from country to country. This causes asymmetries on the international market, which are countered with various barriers to trade. Concerns for a decrease in competitiveness will be touched upon further when discussing the aluminium market and its trade between countries, in section 2.2. Finally, although this explanation was provided, the paper concludes that a large portion of the decrease in trade results from a lower demand for fossil fuels and a higher demand for electricity which tends to be produced domestically.
A notable exception for this decrease in trade following new climate policies exists in the trade of low-carbon technology, which have emerged in recent years coinciding with signing of the Agreement. The paper's findings also indicate that electric cars account for most of this increase in sustainable goods' trade, showing the importance of electric vehicles in the global low-carbon transition.

Overall, in recent years many findings have been made on the effect of climate agreements on low carbon technology markets. Difference-in-difference studies were particularly useful to find such results, as the Paris Agreement is a one-time event that cannot be simulated, and whose effect depends on the strength of NDCs in each country. The Agreement has increased innovation, financing and trade in renewable energy markets, which electric cars accounts for a large portion of. This paper will thus attempt to bridge the gap between such conclusions and existing knowledge on the aluminium market, which will be discussed in the next section.

2.2 Aluminium imports

Some recent studies cast a light on the relationship between the international aluminium market and the growing concern for carbon emissions, however conclusions are not as robust. Jones et. al. (2020) use a Cost, Macro, Infrastructure and Technology (CoMIT) framework to determine which metals will face a change in demand as a result of the growing market for electric vehicles. The CoMIT framework uses forecasts in all four economic areas, and reconciles them to predict future demand for several metals used in EV production, including aluminium (bauxite). Such forecasts include population growth, the development of public transport, vehicle and battery lifespans, subsidies, total cost of EV ownership, etc., and are modelled for ten large regions around the world. As expected, the results thus depend on the accuracy of such forecasts, and therefore equations can be re-evaluated over time with more up-to-date predictions. The current analysis shows an expected significant increase of aluminium demand in the next ten years, following the increase in electric vehicle production and its rising use of the lighter metal (replacing steel) in the body of the vehicle. Additionally, a sensitivity analysis shows that China accounts for a large portion of this demand, due to their production and consumption of EVs. To summarize, this paper predicts aluminium demand to increase in coming years, mainly due to an increase in demand for electric vehicles. However, results are dependent on trends and forecasts, which are subject to change in case of sudden technological advances and other unforeseen circumstances. Moreover, although it predicts an increase in demand, it does not indicate a change in trade volumes or patterns of these metals between countries. This area thus demands closer observation.

A relationship between an increase in aluminium demand and an increase in its trade could be explained by the existence of climate regulation disparities between countries, as mentioned previously. Sartor (2012) uses a multiple linear regression to estimate the effect of the Emissions Trading Scheme (ETS) implemented in Europe in 2005 on the EU's net aluminium imports. The ETS has introduced emission allowances that firms need to pay when they expel CO_2 during their production. A consequent increase in electricity prices in Europe has incurred higher costs for domestic aluminium producers, particularly during electrolysis which incurs the highest amount of energy. This reduces european competitiveness and increases net imports. Findings from the multiple linear regression including several control variables (exchange rate, industrial production, price of coal and natural gas), have shown that the price of CO_2 allowances did not play a significant role in the net import increase. Therefore, the disparities in environmental constraints between countries do not contradict or disprove the hypothesis made on the relationship between aluminium imports and climate regulations; this paper will attempt to further such conclusions.

To summarize, recent literature has shown a strong development of renewable energy markets in countries with stringent targets for Paris Agreement goals. Similar results have also been found for the Kyoto Protocol, another important climate treaty, and trade of low-carbon technologies have increased alongside the market's development. EVs have faced the largest trade increase, and therefore, as it requires aluminium in production, one could expect trade in the metal to increase as a result. However, this may not necessarily be the case. Although some papers forecast an increase in the demand for bauxite and aluminium, particularly from China, none have observed a change in its trade as a result of the Agreement. One concern with inferring an increase in net imports as a result from higher demand are results from Sartor, who show that CO2 regulations do not increase net imports in Europe. However, this paper was conducted before the Paris Agreement, and therefore new conclusions could be drawn with more recent data.

Moreover, another concern that could point against a relationship between aluminium demand and trade is the metal's infinite recyclability (Mouak, 2010). Indeed, recycling re-purpouses 100% of used aluminium, and both costs less and uses less energy than extracting it from bauxite. Therefore, although countries may face an increased demand of aluminium, they may recycle more domestically rather than import from other economies. The following analysis will therefore observe how the Paris Agreement concretely impacts aluminium imports, extending current knowledge to the international market.

3. Data

Information on aluminium imports were taken from BACI (international trade database at the product-level), compiled by CEPII, a french economic research institute (Gaulier & Zignago, 2010). Observations for both quantity and USD value are per year, product code and trading country-pair, from 2000 to 2019. To obtain imports per country, observations were summed based on the importing country. All product codes pertaining to aluminium were included in this analysis, including unwrought aluminium, alloys, scraps, and different forms such as sheets, wires and containers. A full list of product codes is presented in Appendix 1. As a control variable, gdp growth per country per year is retrieved from the International Monetary Fund's World Economic Outlook database (2020). Finally, information on motor vehicle production per country was found using production statistics from the International Organization of Motor Vehicle Manufacturers (2016). All data was reshaped to fit a long panel format.

Three different measures of a country's involvement with the Paris agreement are considered, all of varying degrees. For each one, a dummy variable tracks treatment and control groups: observations that face treatment (generally in years 2016 and up, with a few exceptions) take the value of one, while those who do not take the value of zero.

The first treatment, officially joining the Agreement, is found using the United Nations' Treaty collection (United Nations, n.d.), which has both signature and withdrawal dates for all signers of the Paris Agreement. Upon close observation, all countries have signed the agreement to this date, however a few are cited for not having officially joined it: Iran, Iraq, Eritrea, Libya, Turkey and Yemen (Friedrich, n.d.). These six countries therefore constitute the control group. The United States, although often cited for leaving the Agreement, has only done so officially in late 2019 according to the Treaty Collection, and therefore were placed into the treated category.

The second treatment includes only countries that have published a plan to reach net zero emissions: this information was retrieved from the Energy and Climate Intelligence Unit's net zero tracker (n.d.), including a subset of 130 countries, of which 25 published a net zero plan.

For the third and final treatment group, this paper follows the categorization made by Tolliver et. al. (2020), based on NDC scores created by the authors for 74 countries. As per this paper's method, countries with a score above 6.0 out of 10 are put into the treatment group.

Below is a summary of the variables used.

Table 1.

Summary statistics of main variables

Variable name	Description	N (countries)	Mean	Standard Deviation	Min.	Max.
Value	The value of net aluminium imports per country per year, in thousand (current) US dollars	4280 (214)	757790	2199910	0.642	2.64e+07
Net Zero Plan	Dummy variable. =1 when the country has published a net zero emission plan Agreement, =0 if it has not at the time.	2500 (125)	0.038	0.192	0	1
Joined	Dummy variable. =1 when the country has joined the Paris Agreement, =0 if it has not at the time.	3740 (187)	0.199	0.400	0	1
GDP Growth	GDP growth percentage for the given country and year. Not available for all years uniformly.	3850 (195)	3.8	6.0	-66.7	124.7
NDC Score	Score out of 10 representing the strength of each country's NDC.	1480 (74)	1.27	2.67	0	8.95
Vehicle producer	Dummy variable. =1 when the country is a car producer, =0 if it is not.	4520 (226)	0.27	0.44	0	1

Notes: N represents the number of observations, per country and year (years 2000-2019). In brackets is the number of countries observed for this variable. NDCs are nationally determined contributions, national goals published for the Paris Agreement. The "vehicle producer" dummy is based on 2016 data on global vehicle production.

Due to large variation between different countries' import values, measured in million USD, and quantities measured in metric ton, natural logarithms of both variables will be taken in further analysis. Below are figures representing the three treatments analyzed, discussed further under Results.

Figure 1.

Average Value of Aluminium imports per year for countries who joined the 2016 Paris Agreement (bottom line) and those who have not (upper line)

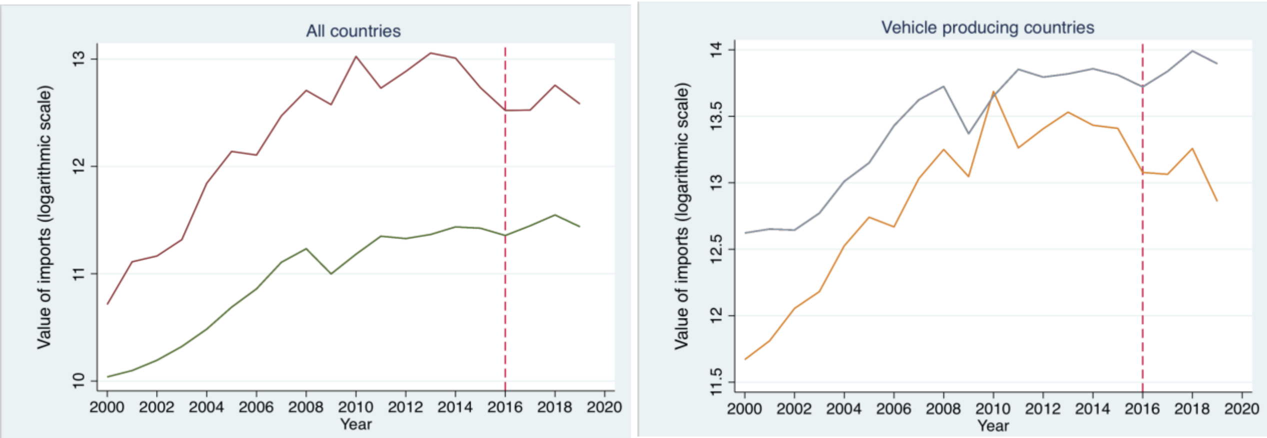


Figure 2.

Average Value of Aluminium imports per year for countries who published a Net Zero emissions plan for the 2016 Paris Agreement (upper line) and those who did not (lower line)

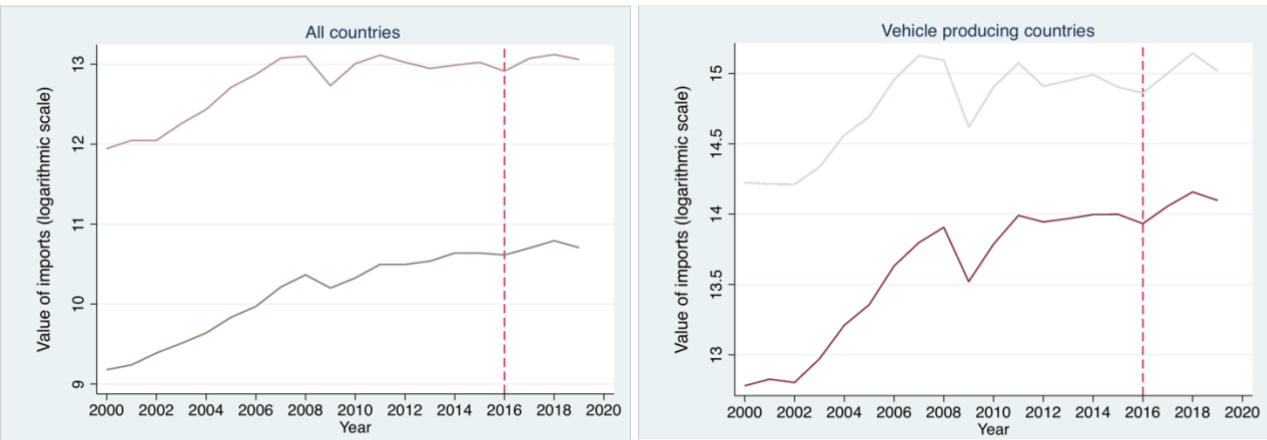


Figure 3.

Average Value of Aluminium imports per year for countries with a high Nationally Determined Contribution score for the 2016 Paris Agreement (above) and those with a low one (below)

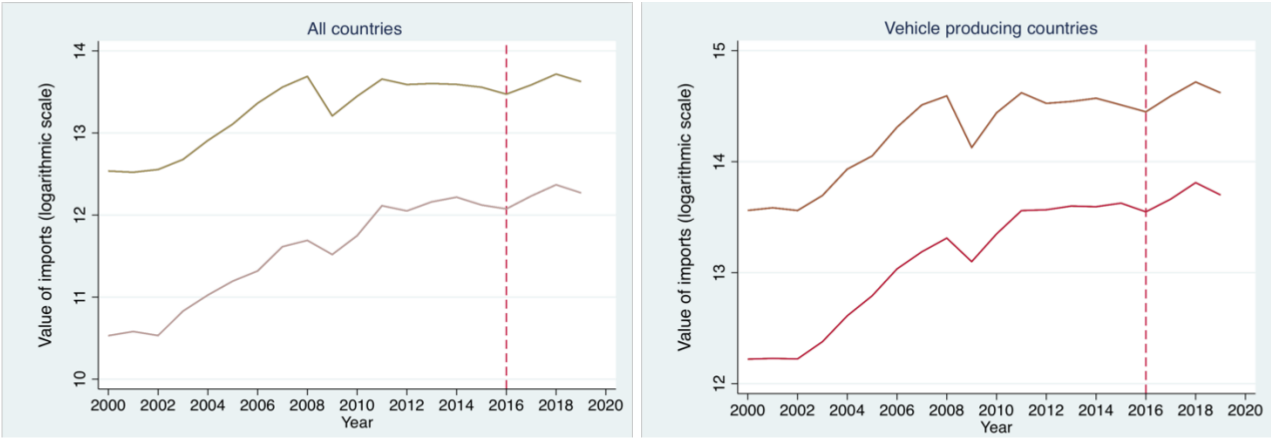
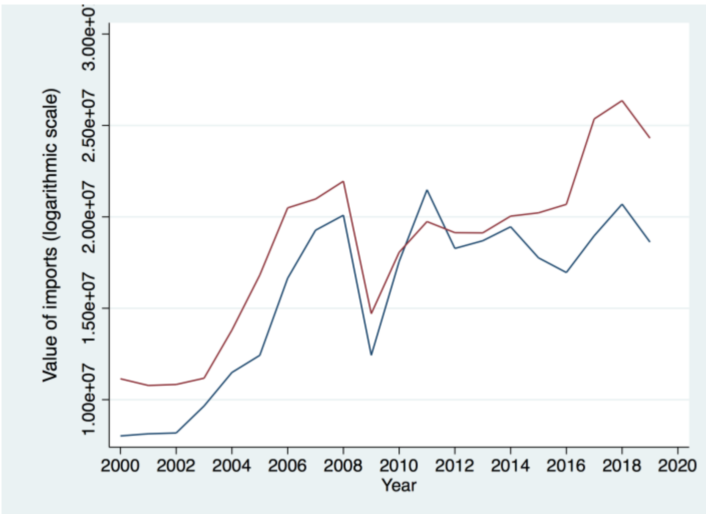


Figure 4.

Value of Aluminium imports per year for the two largest importers (in logarithmic format): USA (red) and Germany (blue)



4. Methodology

4.1. Fixed Effects specification

To evaluate the effect of involvement in the Paris Agreement of a country on aluminium imports, a few country fixed effect regressions will be conducted. With fixed effects, the effect of the treatment on the independent variable is estimated by taking the difference between aluminium imports pre-treatment (before 2016) for treated countries, and imports after the Agreement was signed. This means that nations are compared with themselves in a previous time period and therefore, any time-invariant factors that could affect a country's imports or commitment to the Agreement are already accounted for. This is useful when observations are at the country-level, as there could be an unobserved correlation between a country's imports and how involved its government is in meeting climate goals, due to a plethora of factors specific to a country's situation. This is for example illustrated by trade theories such as Stolper-Samuelson (Stolper & Samuelson, 1941), who state that countries differ in their abundant factors of production and thus export and import goods accordingly. Certain goods are inherently beneficial or harmful to the environment, and countries could promise more or less climate action according to what benefits their exporting industries. This potential difference between treated and non-treated countries is eliminated as it is time-invariant. Additionally, several papers relating to climate agreements have used difference-in-difference specifications (Tolliver et. al. (2020), Miyamoto et. al. (2019)), which provides a similar framework to fixed effects.

On the other hand, country fixed effects include several drawbacks, and ultimately cannot confirm a causal relationship between the treatment and the dependent variable. This is because the treatment and control groups were self-determined by the country rather than randomly assigned, and thus there may be a reason why such governments have decided to become more involved with the Paris Agreement, which simultaneously affects aluminium imports' value. Moreover, aluminium imports are expected to increase due to a change in vehicles, which may not occur over a single year. Indeed, due to slow changes in legislation such as an increase in carbon taxes, there may be a time lag between entry in force of the Agreement and significant changes in aluminium imports. There could also be an increase before 2016, as the Agreement was written by parties in 2015. A fixed effects specification cannot capture such dynamic effects.

Results will also be estimated using Ordinary Least Squares, or multiple linear regression, which is a specification that does not include aforementioned fixed effects. This will help to determine whether the country fixed effects contribute to lowering the estimator bias when included in the regression. The OLS regression will also include yearly dummy variables.

4.2. Model regressions

As mentioned earlier, three different treatments will be considered, each evaluating an increasingly more stringent criteria for what it means to be committed to the Paris Agreement. This was done according to Miyamoto 's results: when the treatment group was reduced to countries promising stronger policies for reducing greenhouse emissions, the treatment effect found as a result was greater. The first group, which is the least stringent, includes all countries that have joined the Agreement. Although joining is legally binding, not all countries are bound to the same commitments, for example developed countries face a greater responsibility to mitigate climate change than developing countries (Dimitrov, 2016). Therefore, a second stronger measure of commitment is then taken: only countries that have published a Net Zero plan are included. Publishing a concrete plan for the country to reach net zero emissions by its target date can be seen as a stronger commitment, as steps are outlined to reach Paris Agreement goals. The third and final treatment group was borrowed from Tolliver et. al.'s study, measuring countries' contributions to Paris Agreement goals by quantifying NDCs. Following this paper's methodology, countries with scores of 6.0 out of 10 and above will construct the treatment group, while those with a lower score (indicating lesser contributions to the Agreement's goals), make up the control group.

Finally, it is suspected that a change in aluminium imports will be stronger in countries that manufacture vehicles, as they are the ones to use aluminium in production. Once they are completed, such nations export the completed vehicles, and this exchange no longer counts as aluminium trade but rather vehicle trade. Therefore, a separate analysis will be conducted, only with countries who had a positive vehicle output in the year 2016.

The following country fixed effects model will be estimated:

$$Y_{it} = \alpha_i + \rho T_{it} + \beta X_{it} + \gamma_t + \varepsilon_{it}$$

Where Y_{it} is the net aluminium imports for country i and year t, α_i, the fixed effect for country i, X_{it} the GDP per capita of country i in year t, γ_t the effect of year t, and ε_{it} is the error term. T_{it} is the treatment, taking the value of 1 when the country has moved to the treatment group during and after 2016. Treatments represent turn in turn, (1), signing the agreement, (2), publishing a net zero plan, and (3), having a high NDC score.

4.3. Robustness check and falsification test

To strengthen regression results, additional analyses will be carried out. This helps to rule out potential spurious relations between the treatment and dependent variable. Additionally, if results are insignificant, robustness checks and falsification tests can confirm such conclusions.

The robustness check will omit observations from the USA and Germany: In all years observed, they have stood out with the largest logarithmic import values of the dataset. While Germany was part of all three treatment groups, the United States joined all except publishing a Net Zero Plan. Therefore, results should be carried out without these two countries, to ensure that results were not solely driven by their large import values. In the case that the effect found in main regressions is not significant, there should not be a change to this after removing US and Germany observations.

The second analysis will be a falsification test, verifying that no relation exists between the year of the Paris Agreement and imports in general, for reasons other than the Agreement entering into force. This could be a concern for a few reasons, notably the announcement of Brexit and the election of Donald Trump in the United States, that happened in the same year. While Brexit increases trade barriers between it and the European Union, Trump has been elected in part for anti-trade positions (Rodrik, 2018). Both of these political events thus potentially cause an overall decrease in trade. To ensure that this paper's results are not hindered by, or due to a general trend towards lower imports, a regression will be conducted using an unrelated dependent variable: imports of non-alcoholic beverages (excluding juices).

It was chosen as it is neither a low-carbon technology nor a product whose production emits CO2, and therefore according to Vrontisi et. al. 's findings, should not face a significant change due to entry into force of the Paris Agreement. Therefore, if a significant effect is found when testing for the value of non-alcoholic beverages, there is a chance that a significant effect found for aluminium is due to reasons other than involvement in the Paris Agreement. Additionally, if the null hypothesis of this paper is accepted, there should not be an effect for non-alcoholic beverages either.

5. Results

Below are the regression results for all three treatments outlined in the previous section, as well as using the sub-sample of vehicle-manufacturing countries. Two time frames were considered: 2000-2019 and 2010-2019. Regressions were also conducted over the 6 more recent years, however results were extremely similar to the 10-year frame (while further increasing p-values due to smaller sample sizes) and thus were not reported.

Before discussing results, it is also important to note that the parallel trends assumption does not hold for the first treatment (joining the Agreement): this can be seen on Figure 1. Indeed, countries who have not officially joined all have a significant reason not to, making them exceptions: Turkey, Iraq, Iran, Yemen, Eritrea and Libya (Apparicio & Sauer, 2021). Most of these have not joined as their economy is either highly oil-dependent, and thus vulnerable to any pledges to reduce emissions, or currently plagued by wars. Turkey does not follow this pattern, and did not join due to a disagreement with how the Agreement would apply to them. Thus, a reliable coefficient cannot be estimated in table 2.

5.1. Tables

Table 2

Results of country fixed effects and OLS regressions, impact of joining the Paris agreement on value of aluminium imports (in percentage change)

	(1) 2000-2019, FE	**(2) 2010-2019, FE**	**(3) 2000-2019, OLS**	**(4) 2010-2019, OLS**
Treatment	0.215 (0.205)	0.425** (0.134)	-0.873 (0.680)	-0.874 (0.683)
Years	yes	yes	yes	yes
GDP growth	0.003 (0.004)	0.006 (0.004)	-0.009 (0.013)	-0.009 (0.014)
Constant	10.232*** (0.055)	11.350*** (0.038)	10.433*** (0.225)	11.426*** (0.206)
N	3575	1798	3575	1798

Notes: N is the number of observations, and the dependent variable is the country joining the Paris Agreement in 2016, representing commitment to it. Treatment is a dummy variable for joining (=1 when joined). Standard deviations are in brackets. "Years" indicates the existence of dummy variables for each year where imports were observed, thus accounting for yearly fluctuations. FE is for fixed effects regressions, OLS for ordinary least squares. Significance levels: *=0.1; **=0.05, ***=0.01.

Table 3

Results of country fixed effects and OLS regressions, impact of publishing a plan for reaching net carbon emissions on the value of aluminium imports (in percentage change)

	(1) 2000-2019, FE	**(2) 2010-2019, FE**	**(3) 2000-2019, OLS**	**(4) 2010-2019, OLS**
Treatment	-0.297*** (0.068)	-0.149** (0.051)	2.405*** (0.586)	2.396*** (0.585)
Years	yes	yes	yes	yes
GDP growth	0.009 (0.005)	0.008 (0.006)	-0.044 (0.031)	-0.062 (0.039)

Constant	9.870*** (0.075)	10.922*** (0.048)	10.258*** (0.337)	11.207*** (0.324)
N	2415	1218	2415	1218

Notes: N is sample size, and the dependent variable is publication of a plan to reach net zero carbon emissions, representing stronger commitment to the Paris Climate Agreement. Treatment is a dummy variable for publication (=1 when published). Standard deviations are in brackets. "Years" indicates the existence of dummy variables for each year where imports were observed, thus accounting for yearly fluctuations. FE is for fixed effects regressions, OLS for ordinary least squares. Significance levels: *=0.1; **=0.05; ***=0.01.

Table 4

Results of country fixed effects and OLS regressions, impact of having a high Nationally Determined Contribution (NDC) score on the value of aluminium imports (in percentage change)

	(1) 2000-2019, FE	**(2) 2010-2019, FE**	**(3) 2000-2019, OLS**	**(4) 2010-2019, OLS**
Treatment	-0.420*** (0.099)	-0.147* (0.057)	1.020** (0.424)	1.027** (0.417)
Years	yes	yes	yes	yes
GDP growth	0.014* (0.006)	0.008 (0.005)	-0.137*** (0.049)	-0.130*** (0.049)
Constant	11.845*** (0.068)	12.865*** (0.043)	12.521*** (0.325)	13.455*** (0.290)
N	1439	720	1439	720

Notes: N is sample size, and the dependent variable is strength of the country's Nationally Determined Contributions to reduce emissions, representing stronger commitment to the Paris Climate Agreement. The measure for NDC strength was created by Tolliver et. al (2020). Treatment is a dummy variable for an NDC score higher than 6.0 out of 10 (=1 when above the threshold). Standard deviations are in brackets. "Years" indicates the existence of dummy variables for each year where imports were observed, thus accounting for yearly fluctuations. FE is for fixed effects regressions, OLS for ordinary least squares. Significance levels: *=0.1; **=0.05; ***=0.01.

Table 5

Results of country fixed effect and OLS regressions, impact of publishing a plan for reaching net carbon emissions on value of aluminium imports (in percentage change), on countries that produce vehicles

	(1) 2000-2019, FE	**(2) 2010-2019, FE**	**(3) 2000-2019, OLS**	**(4) 2010-2019, OLS**
Treatment	-0.271*** (0.068)	-0.092** (0.044)	0.816*** (0.457)	0.843* (0.450)
Years	yes	yes	yes	yes
GDP growth	0.009 (0.009)	0.022*** (0.006)	-0.148 (0.095)	-0.117 (0.096)
Constant	13.285*** (0.067)	14.121*** (0.035)	13.918*** (0.488)	14.662*** (0.406)
N	640	320	640	320

Notes: N is sample size, and the dependent variable is publication of a plan to reach net zero carbon emissions, representing stronger commitment to the Paris Climate Agreement. Treatment is a dummy variable for publication (=1 when published). Standard deviations are in brackets. "Years" indicates the existence of dummy variables for each year where imports were observed, thus accounting for yearly fluctuations. FE is for fixed effects regressions, OLS for ordinary least squares. Significance levels: *=0.1; **=0.05; ***=0.01.

Table 6

Results of country fixed effects and OLS regressions, impact of having a high Nationally Determined Contribution (NDC) score on value of aluminium imports (in percentage change), on countries that produce vehicles

	(1) 2000-2019, FE	**(2) 2010-2019, FE**	**(3) 2000-2019, OLS**	**(4) 2010-2019, OLS**
Treatment	-0.269*** (0.079)	-0.094* (0.055)	0.760* (0.405)	0.845** (0.398)
Years	yes	yes	yes	yes

GDP growth	0.020*** (0.005)	0.023*** (0.005)	-0.081 (0.063)	-0.036 (0.061)
Constant	13.037*** (0.061)	13.972*** (0.035)	13.435*** (0.379)	14.244*** (0.333)
N	780	390	780	390

Notes: N is sample size, and the dependent variable is strength of the country's Nationally Determined Contributions to reduce emissions, representing stronger commitment to the Paris Climate Agreement. The measure for NDC strength was created by Tolliver et. al (2020). Treatment is a dummy variable for an NDC score higher than 6.0 out of 10 (=1 when above the threshold). Standard deviations are in brackets. "Years" indicates the existence of dummy variables for each year where imports were observed, thus accounting for yearly fluctuations. FE is for fixed effects regressions, OLS for ordinary least squares. Significance levels: *=0.1; **=0.05; ***=0.01.

5.2. Interpretation

According to table 3 and using fixed effects, publishing a plan to reach net zero emissions has caused aluminium imports to decrease in value by nearly 30% in 2016 within the country when considering 20 years of data, and by 15% when considering 10 years. This effect is similar when only vehicle-producing countries are considered (table 5). It is also noteworthy that GDP growth, added in the model to control for a change in imports due to a boost in the economy, did not have a significant effect on aluminium imports. Meanwhile, as seen in tables 4 and 6, having stricter nationally determined contributions have led to a decrease in imports as well (by 42% when looking at 20 years of data and for all countries, and 27% for vehicle-producing countries). This could indicate that heterogeneous effects do exist within countries with high NDCs, between producers and non-producers. On the other hand, results for publishing a net zero plan are more homogenous within groups. Overall the regressions conducted show a high level of significance: treatments 2 and 3 show significance at the 1% level when 20 years are considered, and the 5 or 10 percent level when only ten years are taken.

Using linear regressions, the results outlined above no longer appear. Although coefficients remain at a similar significance, the treatment effect is entirely opposite, with for example a 240% increase in aluminium imports for countries that publish a net zero plan. This can be explained due to the lack of a measure for fixed effects: OLS compares countries that published a plan with those that did not, rather than looking at a yearly change. Since publishing a Net Zero plan may not be the main concern of a nation that faces other macroeconomic challenges, most countries that published it are well off, and therefore may be larger importers (even before signing). This would create a large positive bias in the coefficient, concealing the negative effect found under fixed effects. Therefore, in this paper, it is difficult to trust results reported by a multiple linear regression. The same observation can be made for having a high NDC score, and for the subset of car-producing countries.

Results indicating a decrease in imports, however, are opposed to the hypothesis formulated, which predicted an increase in import value rather than a decrease. As mentioned before, there are indeed certain effects expected to cause a lowering of aluminium trade, notably a preference for using recycled metal rather than new aluminium. This effect has been underestimated, and according to findings it dominates over any increase in demand for the metal. The preference for recycled metal can indeed be due to its lower cost and lower requirement for carbon (electrolysis requires more energy and is not needed when aluminium is already processed). Recycling can also be done domestically rather than abroad, as used aluminium is readily available (as opposed to bauxite which can only be mined in certain countries), favouring a trade surplus. Additionally, when formulating the hypothesis, only the vehicle market was studied, since it was expected to face the most significant transformation as a result of the Agreement. However, aluminium is also present in other sectors such as building and home appliances, in which respectively 85 and 65 percent of total aluminium is recycled (Mouak, 2012), and thus the environmental impact of recycling may have exceeded that of producing more energy efficient vehicles. Finally, when only accounting for vehicle-producing countries the decrease is slightly lesser, potentially because the positive effect (demand of the metal to produce more energy efficient vehicles) is stronger in these economies.

Overall, results of this analysis should be taken with caution, as various time-variant omitted variables could be correlated with the treatment. Entering the treatment, i.e. a country deciding to be more involved in reducing its carbon emissions, could likely be a result of factors unobserved in this analysis. National decisions of all kinds, but notably on topics of energy conservation and reducing emissions, often depend on time-sensitive factors that affect individuals' preferences on ecological matters. A country's population can become more or less likely to vote for stricter policies on climate based on current events and changing demographics (Anthoff & Tol, 2010). There could thus be a spurious correlation at play in the regressions, in case a change in decision-making preferences has affected both a country's willingness to enact climate action and its demand for imported aluminium. Moreover, as mentioned before, results could be skewed or partially influenced by an event other than entry in force of the Paris Agreement. This will later be evaluated with a robustness check and falsification test.

Finally, a fixed effects regression can only capture a one-off change in time, here therefore showing a change in imports after the Agreement had entered into force. However, it is likely that the effect here is more dynamic, and becoming more stronger over time: policies are often subject to lags, both in decision and implementation. A change in aluminium trade may therefore not face a one-off increase when the Agreement is signed, but rather appear over time as more industries slowly adapt and recycling technologies develop. Another effect that cannot be captured using fixed effects is that of a change prior to the signature of the Agreement, in anticipation of it.

5.3. Robustness check

The robustness check was carried out only with the second and third treatments, omitting the one for joining the agreement due to assumption violations mentioned above. Results are presented below:

Table 7

Results of country fixed effects regressions, impact of publishing a plan for reaching net carbon emissions on the value of aluminium imports (in percentage change), using data from 2000-2019 and excluding USA and Germany

	(1) All countries (except mentioned above)	**(2) Vehicle-producing countries (except mentioned above)**
Treatment	-0.296*** (0.069)	-0.281*** (0.073)
Years	yes	yes

GDP growth	0.009* (0.005)	0.010 (0.009)
Constant	9.765*** (0.075)	13.100*** (0.070)
N	2375	600

Notes: N is sample size, and the dependent variable is publication of a plan to reach net zero carbon emissions, representing stronger commitment to the Paris Climate Agreement. Treatment is a dummy variable for publication (=1 when published). Standard deviations are in brackets. "Years" indicates the existence of dummy variables for each year where imports were observed, thus accounting for yearly fluctuations. Significance levels: *=0.1; **=0.05; ***=0.01.

Table 8

Results of country fixed effects regressions, impact of having a high Nationally Determined Contribution (NDC) score on the value of aluminium imports (in percentage change), using data from 2000-2019

	(1) All countries (except mentioned above)	**(2) Vehicle-producing countries**
Treatment	-0.418*** (0.100)	-0.264* (0.081)
Years	yes	yes
GDP growth	0.014** (0.006)	0.020*** (0.006)
Constant	11.725*** (0.068)	12.874*** (0.064)
N	1399	740

Notes: N is sample size, and the dependent variable is strength of the country's Nationally Determined Contributions to reduce emissions, representing stronger commitment to the Paris Climate Agreement. The measure for NDC strength was created by Tolliver et. al (2020). Treatment is a dummy variable for an NDC score higher than 6.0 out of 10 (=1 when above the threshold). Standard deviations are in brackets. "Years" indicates the existence of dummy variables for each year where imports were observed, thus accounting for yearly fluctuations. Significance levels: *=0.1; **=0.05; ***=0.01.

As seen in table 7, removing the two importers with the largest values in the regression did not change the effect of publishing a Net Zero plan observed, neither for the main regression nor for the sub-sample of car producers. Therefore, results for this treatment were not skewed by the US and Germany. The same conclusion can be applied to the high NDC treatment, as observed in table 8.

5.4. Falsification test

The falsification test was carried out with treatment variables 1 and 2, for all importers and over 20 years of data.

Table 9

Results of country fixed effects regressions, impact of two treatment variables for involvement in the Paris Agreement on the value of imports of non-alcoholic drinks (excluding juices) (in percentage change), using data from 2000-2019

	(1) Publishing a Net Zero Emissions plan	**(2) Having high Nationally Determined Contributions**
Treatment	-0.084 (0.141)	-0.466** (0.205)
Years	yes	yes
GDP growth	0.009* (0.005)	0.026*** (0.010)
Constant	6.946*** (0.092)	7.754*** (0.122)
N	2191	1328

Notes: N is sample size, and the dependent variable is either publication of a plan to reach net zero carbon emissions or strength of the country's Nationally Determined Contributions to reduce emissions, both representing stronger commitment to the Paris Climate Agreement. Treatment is a dummy variable for two possible treatments: (1), publication of the Net Zero Plan (=1 when published), and (2), an NDC score higher than 6.0 out of 10 (=1 when above the threshold) . Standard deviations are in brackets. "Years" indicates the existence of dummy variables for each year where imports were observed, thus accounting for yearly fluctuations. Significance levels: *=0.1; **=0.05; ***=0.01.

As seen on table 9, countries who published a Net Zero plan did not face a significant decrease in the value of non-alcoholic drinks. This strengthens results found for treatment 2, as discussed in (5.1): it means that the effect captured in the main results was not a byproduct of an overall decrease in imports, thus ruling out a potential spurious relationship. However, this is not the case for treatment 3. When conducting the same falsification test on the regression based on countries' NDC scores, a decrease of 47% was found at the 5% significance level. This is similar to the effect found for aluminium imports, thus reducing validity of conclusions for the third treatment: it indicates that for the sampled countries considered in treatment 3, there could be a time-varying omitted variable causing the significant treatment effect. For the strong NDC treatment, the control variable of GDP growth has also consistently had the highest significance, through main results, checks and tests. The high significance of a time-varying control may indicate that others also play a large role in final results.

To summarize, while for treatments 2 and 3 a stronger involvement in the Paris Agreement leads to a significant decrease in aluminium imports, the high NDC score treatment does not pass the falsification test; there may be unobserved variables impacting trade overall in the sample. Meanwhile, the Net Zero Plan publishing treatment is robust to checks and tests.

6. Conclusion

To conclude, the overall effect of involvement in the Paris Agreement on aluminium trade is heterogenous to how the involvement is measured. The three measures taken in this paper each reach a different conclusion, however all of them can reject the hypothesis made at the beginning of the paper. A country's involvement in the Paris Climate Agreement either does not influence aluminium imports, or has a negative influence. Reasons for this unexpected result will now be discussed for each treatment considered.

Countries who publish a net zero emissions plan have faced a significant decrease in their aluminium imports, after the Agreement has taken place. This could be caused by stricter climate policy in these countries which favoured recycling of the metal, rather than importing it which has larger carbon emissions, as well as a higher cost of production (and therefore price) compared to the recycled material. Another hypothesis that has not been formulated thus far is that global value chains (the organization of production stages over several countries) have faced changes due to the Agreement. Not all countries face a decrease in aluminium imports, for example the United States, the second largest aluminium importer in terms of value, has increased imports in 2016 and even more in the following year. It is possible that countries who have placed stringent climate goals on themselves, such as those with net zero plans, shifted their production towards other countries with less strict requirements (thus increasing their imports of energy-efficient vehicles but not of aluminum). Instead of producing intermediary parts for vehicles, buildings, etc. that are made of aluminium themselves and incurring additional costs from carbon taxes, they import the part only after completion and thus avoid such a tax. Global value chains have been increasingly prominent in past decades (Gereffi et. al., 2006), and therefore may explain the effect found. This furthers the results found by Sartor (2012), who at the time had not reached a conclusion on how climate policy disparities affect aluminium trade. However, more thorough analysis is still required on this topic.

Overall, the initially hypothesized effect of increased demand due to vehicle production is not present with the net zero plan treatment, or not as strong as the negative effect. When taking the subgroup of vehicle-producing countries, the decrease is of a smaller magnitude: this could be because such economies need the material for production, thus creating the positive effect described above.

A similar effect has not been found in countries with stringent nationally determined contributions. This indicates that the decrease in aluminium imports is specifically due to a focus on reducing CO2 byproduct of the economy, rather than climate policies as a whole. Although an effect even stronger than that of net zero plans is initially reported by the fixed effects regression (double the decrease), the same strong significance was found in imports of non-alcoholic beverages, which should not be directly affected by stringent climate policies. This points towards the existence of unobserved factors within countries with a high NDC score as according to Tolliver et. al. 's research, that causes them to face a strong decrease in imports compared to other countries.

Similarly, simply joining the Agreement is not sufficient to witness a decrease in aluminium imports: most countries in the world have joined, but since the strength of involvement is a decision on the country-level, there are asymmetries between signers. Additionally, there is a disparity between developed and developing countries' requirements in the contract, meaning that a uniform effect among countries who joined against those that did not cannot be observed. Furthermore, the six countries who did not join are difficult to compare with the rest of the world, as they had particular reasons not to sign (oil dependence or war), thus constructing a non-representative control group with time-varying differences. One can thus conclude that there is no relationship between joining the Paris Agreement and a change in aluminium imports.

In summary, results of the analysis have pointed towards a disparity between total aluminium demand, forecasted to rise by Jones et. al. (2020), and demand for imported aluminium, which seems to decrease. Recent Reuters news delineating an increase in recycling facilities in China to meet carbon goals, coincides with these findings (Daly & Coghill, 2021). This indicates a change in the structure of global trade flows for the metal, wherein countries who have more stringent carbon reduction targets decrease their imports. Implications for the industry are twofold: first, the increased interest in recycled aluminium over firsthand will likely have a negative impact on profits from bauxite mining, refinery, alumine extracting and electrolysis, all unnecessary when recycling the metal. This leads to a decrease in exports for countries where these activities are prominent, which is especially harmful for developing countries who may rely more heavily on them. Meanwhile, in countries who have stringent targets to reduce CO2 emissions, the decrease in imports is unlikely to benefit home producers of aluminium: recycled aluminium is a perfect substitute, and causes much less emissions during production.

The second effect on the market is a positive one for metal recycling firms, who are likely to grow as an industry. Indeed, according to Reuters, China (the largest producer) has projects to more than double its production of secondhand aluminium by 2030. Before this change can take place, it has also planned to increase its imports of scrap and recycled aluminium, benefitting other countries' firms in the medium run. Globally, this change in how the metal is provided is likely to be a long-term trend (International Aluminium Institute, n.d.), as costs are reduced and efficiency is increased, jump-started by international climate treaties that urge countries to formulate targets and goals to reach net zero emissions.

There are certain limitations to this study. First, as discussed before, the methodology used cannot conclude on a causal relationship, as it does not use randomization of the treatment. The conclusions made above are conditional on the lack of a spurious relationship, caused by time-varying unobserved effects. However, as one cannot conduct an experiment by assigning random countries to the treatment or the control group, this cannot be corrected in later studies. A second limitation is that only a one-time treatment effect can be observed, occurring in 2016. Countries parties to the Paris Agreement are expected to decrease emissions over a few decades, and thus effects of strict carbon policy are expected to change over time. Similarly, anticipation effects prior to entry into force of the contract could exist. In further research, one could observe such effects by using alternative methods, more able to capture them.

Further research could build on conclusions, both by applying improved methods to strengthen result validity and by delving deeper into why the effect is observed. Studies could expand on the hypothesis made on a change in global value chains, as outlined above. Additionally, one could look at different types of aluminium imports rather than grouping them together, to check for any heterogeneous effects that may hint at which industry is specifically responsible for the decrease in imports. Trade flow analyses can be applied to determine which country pairs are trading more or less of the metal. Finally, climate policy will likely play a large role in industries in the next few decades, and to improve external validity of results, developments in the topic should be analyzed as they unfold.

7. Bibliography

Anthoff, D., & Tol, R. S. (2010). On international equity weights and national decision making on climate change. *Journal of Environmental Economics and Management*, *60*(1), 14-20.

Apparicio, S., & Sauer, N. (2021, March 1). *Which countries have not ratified the Paris climate agreement?* Climate Change News. https://www.climatechangenews.com/2020/08/13/countries-yet-ratify-paris-agreement/.

Bergsdal, H., Strømman, A. H., & Hertwich, E. G. (2005). Environmental Assessment of Two Waste Incineration Strategies for Central Norway (10 pp). *The International Journal of Life Cycle Assessment*, *10*(4), 263-272.

Carattini, S., Kallbekken, S., & Orlov, A. (2019). How to win public support for a global carbon tax.

Daly, T., & Coghill, K. (2021, June 16). *Rusal sees China's recycled aluminium output almost tripling by 2030*. Reuters. https://www.reuters.com/article/us-metals-aluminium-rusal-china-idUSKCN2DS0ZB.

Dimitrov, R. S. (2016). The Paris agreement on climate change: Behind closed doors. *Global Environmental Politics*, *16*(3), 1-11.

Dunn, J. B., Gaines, L., Kelly, J. C., James, C., & Gallagher, K. G. (2015). The significance of Li-ion batteries in electric vehicle life-cycle energy and emissions and recycling's role in its reduction. *Energy & Environmental Science*, *8*(1), 158-168.

Energy & Climate Intelligence Unit. (n.d.). *Net Zero Tracker*. Energy & Climate Intelligence Unit. https://eciu.net/netzerotracker.

Friedrich, J. (n.d.). *Paris Agreement Tracker*. Paris Agreement Tracker CAIT.

Gaulier, G., & Zignago, S. (2010). Baci: international trade database at the product-level (the 1994-2007 version).

Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The governance of global value chains. *Review of international political economy*, *12*(1), 78-104.

Hirsch, J. (2014). Recent development in aluminium for automotive applications. *Transactions of Nonferrous Metals Society of China*, *24*(7), 1995-2002.

IMF Research Dept. (2020). *World Economic Outlook, October 2020*. USA: International Monetary Fund. Retrieved Jun 10, 2021, from https://www.elibrary.imf.org/view/books/081/29296-9781513556055-en/front-1.xml

International Aluminium Institute. (n.d.). IAI Material Flow Model- 2021 Update.

Jones, B., Elliott, R. J., & Nguyen-Tien, V. (2020). The EV revolution: The road ahead for critical raw materials demand. *Applied energy*, *280*, 115072.

Key aspects of the Paris Agreement. unfccc.int. (n.d.). https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement/key-aspects-of-the-paris-agreement.

Maida, J. (2020, November 24). *Aluminum Market: Global Demand, Growth Analysis & Opportunity Outlook 2020-2024: Technavio*. Business Wire. https://www.businesswire.com/news/home/20201123005999/en/Aluminum-Market-Global-Demand-Growth-Analysis-Opportunity-Outlook-2020-2024-Technavio.

Mankiw, N. Gregory, Matthew Weinzierl, and Danny Yagan. "Optimal taxation in theory and practice." *Journal of Economic Perspectives* 23.4 (2009): 147-74.

McCullough, E., & Nassar, N. T. (2017). Assessment of critical minerals: updated application of an early-warning screening methodology. *Mineral Economics*, *30*(3), 257-272.

Miyamoto, M., & Takeuchi, K. (2019). Climate agreement and technology diffusion: Impact of the Kyoto Protocol on international patent applications for renewable energy technologies. *Energy Policy*, *129*, 1331-1338.

Mouak, P. (2010). *Le marché de l'aluminium: structuration et analyse du comportement des prix au comptant et à terme au London Metal Exchange* (Doctoral dissertation, Université d'Orléans).

The Paris Agreement. unfccc.int. (n.d.).

https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

Pigou, A. C. (2013). *The economics of welfare*. Palgrave Macmillan.

Ramsey, Frank P. (1927). "A Contribution to the Theory of Taxation". *The Economic Journal*. 37 (145): 47–61

Richardson, D. B. (2013). Electric vehicles and the electric grid: A review of modeling approaches, Impacts, and renewable energy integration. *Renewable and Sustainable Energy Reviews*, *19*, 247-254.

Rodrik, D. (2018). Populism and the economics of globalization. *Journal of international business policy*, *1*(1), 12-33.

Sartor, O. (2012). Carbon Leakage in the Primary Aluminium Sector.

Sharma, A., & Johnson, B. (2020, December 3). *UK sets ambitious new climate target ahead of UN Summit*. GOV.UK. https://www.gov.uk/government/news/uk-sets-ambitious-new-climate-target-ahead-of-un-summit.

Tolliver, C., Keeley, A. R., & Managi, S. (2020). Policy targets behind green bonds for renewable energy: Do climate commitments matter?. *Technological Forecasting and Social Change*, *157*, 120051.

United Nations. (n.d.). *United Nations Treaties*. United Nations. https://treaties.un.org/Pages/CNs.aspx?cnTab=tab2&clang=_en.

Vrontisi, Z., Charalampidis, I., & Paroussos, L. (2020). What are the impacts of climate policies on trade? A quantified assessment of the Paris Agreement for the G20 economies. *Energy Policy*, *139*, 111376.

8. Appendix

Appendix 1. List of products and their codes included in calculation of aluminium imports (retrieved from the BACI dataset)

251010: Natural calcium phosphates, natural aluminium calcium phosphates and phosphatic chalk: unground

251020: Natural calcium phosphates, natural aluminium calcium phosphates and phosphatic chalk: ground

260600: Aluminium ores and concentrates

262040: Ash and residues: (not from the manufacture of iron or steel), containing mainly aluminium

281810: Aluminium oxide: artificial corundum

281820: Aluminium oxide: other than artificial corundum

281830: Aluminium hydroxide

282612: Fluorides: of aluminium

282732: Chlorides: of aluminium

283322: Sulphates: of aluminium

853222: Electrical capacitors: fixed, aluminium electrolytic

760110 to 761690, in ascending order:

- Aluminium: unwrought, alloys
- Aluminium: waste and scrap
- Aluminium: powders of non-lamellar structure
- Aluminium: powders of lamellar structure, flakes
- Aluminium: (not alloyed), bars, rods and profiles
- Aluminium: alloys, hollow profiles
- Aluminium: alloys, bars, rods and profiles, other than hollow
- Aluminium: (not alloyed), wire, maximum cross-sectional dimension exceeds 7mm
- Aluminium: (not alloyed), wire, maximum cross-sectional dimension is 7mm or less
- Aluminium: alloys, wire, maximum cross-sectional dimension exceeding 7mm
- Aluminium: alloys, wire, maximum cross-sectional dimension is 7mm or less

- Aluminium: plates, sheets and strip, thickness exceeding 0.2mm, (not alloyed), rectangular (including square)
- Aluminium: plates, sheets and strip, thickness exceeding 0.2mm, alloys, rectangular (including square)
- Aluminium: plates, sheets and strip, thickness exceeding 0.2mm, not alloyed, (not rectangular or square)
- Aluminium: plates, sheets and strip, thickness exceeding 0.2mm, alloys, (not rectangular or square)
- Aluminium: foil, (not backed), rolled (but not further worked), of a thickness not exceeding 0.2mm
- Aluminium: foil, (not backed), rolled (but not further worked), of a thickness not exceeding 0.2mm
- Aluminium: foil, backed with paper, paperboard, plastics or similar backing materials, of a thickness (excluding any backing) not exceeding 0.2mm
- Aluminium: tubes and pipes, not alloyed
- Aluminium: tubes and pipes, alloys
- Aluminium: tube or pipe fittings (eg couplings, elbows, sleeves)
- Aluminium: structures (excluding prefabricated buildings of heading no. 9406) and parts of structures, doors, windows and their frames and thresholds for doors
- Aluminium: structures (excluding prefabricated buildings of heading no. 9406) and parts of structures, n.e.s. in heading no. 7610, plates, rods, profiles, tubes and the like
- Aluminium: reservoirs, tanks, vats and similar containers, for material (not compressed or liquefied gas), of a capacity over 300l, whether or not lined, not fitted with mechanical/thermal equipment
- Aluminium: collapsible tubular containers, for any material, (not compressed or liquefied gas), 300l capacity or less, whether or not lined, not fitted with mechanical/thermal equipment
- Aluminium: casks, drums, cans, boxes and the like for any material (not compressed or liquefied gas), 300l capacity or less, whether or not lined or heat-insulated, no mechanical or thermal equipment
- Aluminium: containers for compressed or liquefied gas

- Aluminium: stranded wire, cables, plaited bands and the like, (not electrically insulated), with steel core
- Aluminium: stranded wire, cables, plaited bands and the like, (not electrically insulated), other than steel core
- Aluminium: table, kitchen or other household articles and parts thereof, pot scourers and scouring or polishing pads, gloves and the like
- Aluminium: table, kitchen or other household articles and parts thereof, pot scourers and scouring or polishing pads, gloves and the like
- Aluminium: nails, tacks, staples (other than those of heading no. 8305) screws, bolts, nuts, screw hooks, rivets, cotters, cotter-pins, washers and similar articles
- Aluminium: articles n.e.s. in heading no. 7616