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Dissertation

THE IMPACT OF RENEWABLE ENERGY SOURCES IN EUROPEAN ELECTRICITY MARKET PRICES

ALEXANDRE XAVIER FERNANDEZ DIAS

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TUTORING:

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Acknowledgements

Being granted access to higher education as a first-generation university student has opened many opportunities to me that my parents, unfortunately, were not privileged to access. To them, and to my sister I dedicate this dissertation, and everything that has come before this. I hope everyone that is willing to, can have access to higher education, and for that, I must acknowledge that both my studies, and my stay in Lisbon, would have not been possible would it not have been for social scholarships and social student housing. I hope that these support policies stay in place so that many more people can get a fair shot at higher education.

To all my friends, my family members, my partner and my professors, I thank you all for teaching me everything that lead me to this dissertation, and all of you have, in one way or another, shaped the study that you all see here. I hope this study can help bring a brighter view of the green transition, and that more people trust that climate change can be fought without creating many burdens to those most vulnerable, and that this study brings you as much hope for a brighter future as it did to me.

Abstract

The green energy transition has been in the spotlight of EU policy makers for half a century, is it already paying off, or are we still experiencing transition pains, and paying more for electricity just because it is more environmentally friendly? This study helps at demystifying this belief and show the steps that led to the current situation and to the conclusions drawn. A brief contextualization and literature review suggests that renewable energy technologies for electricity (RET-E) have been evolving in unprecedented levels that fossil-fuel based technologies (FFBT-E) could not keep up with. It is expected that renewable energy sources of electricity (RES-E) will inevitably replace FFBT-E in the power market. RES-E are no longer replacing their pollutant counterparts on the basis of political decisions for greener electricity, but on the basis of price competitiveness. The path is created for RES-E to take over the head role in the following decade in the European continent.

The empirical analysis of data from Austria, France, Germany, Luxembourg, Portugal and Spain attests that prices in the power market are still set by fossil fuel prices, due to the nature of the market's merit order effect. However, a trend may be noticed that an additional 1 percentual point of the weight of RES-E in total generation may lead to a 0.5-to-2-euro price reduction per MWh traded, however, predictors may be over/underestimated to clarify their true impact. The future of the power market will be to become fully renewable, and during that transition it is expected, *ceteris paribus*, to see lower electricity prices. The challenges of the energy sector going forward will be to understand what to do with cheap and intermittent power.

Keywords: electricity affordability, renewable energy, green transition, energy independence, European Union

Resumo

A transição para a energia verde tem estado no centro das atenções dos decisores políticos da UE há meio século. Será que já está a dar frutos, ou ainda estamos a enfrentar dificuldades de transição, ou a pagar mais pela eletricidade só porque é mais amiga do ambiente? Este estudo ajuda a desmistificar esta ideia e mostrar os passos que levaram à situação atual e às conclusões dele tiradas. Uma breve contextualização e revisão da literatura sugere que as tecnologias de eletricidade renovável tem evoluído em níveis sem precedentes, que a as tecnologias para a geração elétrica proveniente de combustíveis fósseis (TGEPCF-E) não conseguiram acompanhar. É expectável que as fontes de eletricidade renovável (FER-E) inevitavelmente substituam as TGEPCF-E no mercado de eletricidade. As FER-E já não substituem os seus homólogos poluentes com base em decisões políticas de eletricidade mais verde, mas com base na competitividade de preços. Está criado o caminho para que as FER-E assumam a liderança no mercado, na próxima década no continente europeu.

A análise empírica dos dados da Alemanha, Áustria, Espanha, França, Luxemburgo, e Portugal atesta que os preços no mercado de eletricidade ainda são definidos pelos preços dos combustíveis fósseis, devido à natureza do efeito da ordem-de-mérito do mercado. No entanto, pode notar-se uma tendência de que um aumento de um ponto percentual do peso da FER-E, na geração elétrica, possa levar a uma redução de 0,5 a 2 euros no preço por MWh comercializado. No entanto, os resultados podem estar sobre/subestimados para uma correta análise dos seus impactes. O futuro do mercado de eletricidade será tornar-se totalmente renovável e, durante essa transição espera-se, *ceteris paribus*, que os preços da eletricidade continuem a baixar. Os futuros desafios no sector da energia serão compreender o que fazer com esta eletricidade barata e intermitente.

Palavras-chave: eletricidade acessível, energias renováveis, transição verde, independência energética, União Europeia

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Abbreviations

CA – Competitive Auctions

DE/LU – Germany and Luxembourg

DE/LU/AT – Germany, Luxembourg and Austria

ETD – Energy Taxation Directive

ETS – European Trading Scheme

EU – European Union

FFBT - Fossil Fuel-Based Technologies

FFBT-E - Fossil Fuel-Based Technologies of Electricity

FIT – Feed-in-tariffs

GHG – Greenhouse Gases

MOE – Merit Order Effect

PV – Photovoltaic

RES – Renewable Energy Sources

RES-E - Renewable Energy Sources of Electricity

RET - Renewable Energy Technologies

RET-E - Renewable Energy Technologies of Electricity

TGC – Tradable Green Certificates

1- Introduction

Renewable Energy Sources (RES) have been the main focus of European Union (EU) energy policies. From the get-go they were seen as a means to guarantee energy independence in the European Community. This study was set forth to understand how the EU responded to the energy crisis caused by the Ukrainian Invasion by the Russian Federation (henceforth Ukrainian War), and how renewable energy would play a part in minimizing the impacts of the energy market shock that would soon follow, more specifically in terms of affordability.

The green energy transition has been impactful beyond its environmental labelling. For countries with no natural reserves of fossil fuels they have been crucial to create a resilient energy and electricity market. Europe has been one of the main drivers in the growth and development of renewable energy technologies (RET) since the 1970s, to respond to the first of many crude oil price shocks. The latter revisions of RES goals were aimed at reducing the dependence fossil fuels, and therefore on external price shocks caused by offer constraints, whilst also reducing GHG emissions.

This study aims at being accessible and easy to interpret by anyone with the interest in this subject. Other approaches may be more helpful at guiding policy makers and industry players, by analysing the benefits of specific policies and evolutions in certain technologies. However, this study has a simpler view in mind, and the focus on electricity prices and the weight of renewable energy sources of electricity (RES-E) is meant to provide both a simple and easy to understand connection between both values.

The EU's goals have been both been hindered and strengthened by the Ukrainian War. Whilst the long-term goals for RES penetration in the energy market were updated, and the path to carbon neutrality sped up. By updating the goals set by the second Renewable Energy Directive (RED) (Directive(EU) 2018/2001, 2018) with the 2023/2413 EP/CEU directive, to increase the 32% RES share in total energy consumption to 45% by 2030 (European Commission, 2023).

In the short-term compromises had to be made, as energy imports from the Russian Federation had to be reduced, if not completely halted, to stop financing Russia's war effort. With that, older and more pollutant fossil fuels were called to fill in the gaps, EU member states reconsidered coal and lignite power plants either by reactivating them or deferring their shutdown (Borowski, 2022).

The boycott came from the buyer's side, and one that heavily depended in at least one of the goods being embargoed. As such, Europe cornered itself into a position where short-term solutions had to be found in order to limit Russia's war effort. The EU's response always had a single goal: energy security in the long-term, and this would just strengthen their bet.

Additionally, it had shown that reliance on external players would be dangerous beyond energy security risks, and the Russian Federation was now also a military risk. The EU could not keep sponsoring a war machine which could change its target to EU borders and values, and could no longer rely on the cheap fossil fuels coming from the Russian Federation. In addition, the prices charged by Russia could not easily be replicated by other fossil fuel exporters (Perdana et al., 2022). As such, the European Commission soon understood that Europe would have to emerge from this crisis much less dependent on fossil fuels, with plans to never come back.

In the short-term the biggest concern would be natural gas storing, more specifically during winter, as natural gas consumption is seasonal since it is used mainly for heating (Perdana et al., 2022), but it is also used more predominantly for electricity production in the winter. Europe would have to act in two timelines, on the short term, it would have to fill storage capacity before winter, and from non-Russian (or Belarusian) sources, and reduce consumption by creating contingency plans.

With a lesser worry, crude oil would be easier to find alternatives, as OPEC and the United States were prepared to cover the gap opened in the European market, yet prices would not be as competitive as those charged by Russia (Perdana et al., 2022). Meaning that it would not be a sustainable position to remain for long, and the EU would have to further plan to reduce their crude oil consumption in the transportation sector, for example. When it comes to coal, it was asked to give its last push until the total discontinuation from the continent, as it is primarily used in the electricity sector, to guarantee a stable electricity. For coal, new partners and domestic producers could help suppress the gap left by Russia. Interestingly, natural gas was always sold as a bridge fuel to phase-out coal from the electricity sector, and now coal would temporarily be the bridge fuel to phase-out Russian natural gas (Borowski, 2022).

In addition, the natural gas and oil industries have survived years without scrutiny on their emissions. In the case of natural gas, despite having a cleaner combustion than other fossil fuels, methane leaks can be much more lethal for the environment than emissions from other FFBT. They have been either underestimated or not reported at all, as they rely on voluntary reporting from companies that benefit from not reporting, or under reporting, to avoid paying fines (Stern, 2020). Methane leaks are an unavoidable byproduct of natural gas extraction, storage and distribution. As such, some studies place natural gas on par with coal energy and petroleum when it comes to lifecycle emissions, and ask for natural gas to be phased out at a similar rate than those other FFBT (Kåberger, 2018; Tizzoni, 2020).

Evidently, one clear path for the long-term opens, which corroborates with the energy policies taken decades prior, the only escape for the EU is to promote the development and integration of RES into the energy mix. Each short-term solution may carry extra costs that Europeans will pay either with their wallet, or with their national sovereignty and planet. All these solutions assume that these costs can be mitigated in the long-term if the EU changes its market structure away from fossil fuels. Additionally, support for cleaner energies are high across the entire political spectrum, due to the Ukrainian war. Meaning that the EU, Member States and other policy makers can, and should, focus their attention to RES as a means to protect the continent from an energy crisis, and expect public support (Steffen & Patt, 2022).

This study will start by understanding how renewable energy technologies of electricity (RET-E) have evolved over the years, and how that development allowed for policymakers to adapt regulations and goals. Later, the adaptations in EU regulations will be addressed, so as to show which directions were taken by EU policymakers and their main ambitions with each policy package. Additionally, this study will analyse the available literature on the impact of RES-E, and their respective support programs, in electricity prices in EU Member States. In the chapter after, the method used to analyse the available data will be explained, so that in the last chapter the results will be analysed, and a conclusion will be drawn.

2- Contextualization

2.1 - Technological evolutions

The increase in rated power of RET-E has mainly comprised in ways to increase the capacity to gather and transform kinetic energy into torque and then convert it to electricity. Or to maximize the capacity to gather electrons from photons, as to generate has much electrical current as possible. This increase in rated power, coupled with a reduction in RET-E costs in some technologies has been, in conjunction with raises in fossil fuel prices, led to an increase in investment in RES, as they became more competitive.

In addition, electricity from FFBT-E has not seen any decrease in prices, this is due to two reasons. The first one being the increase of fossil fuels prices, as producers gauge the supply artificially to increase profit margins; and the technology has been exhausted for long, and efficiency gains have been limited (Kåberger, 2018). This premise is what lead EU policy makers to look at RETs other than further exhausting domestic fossil fuel sources.

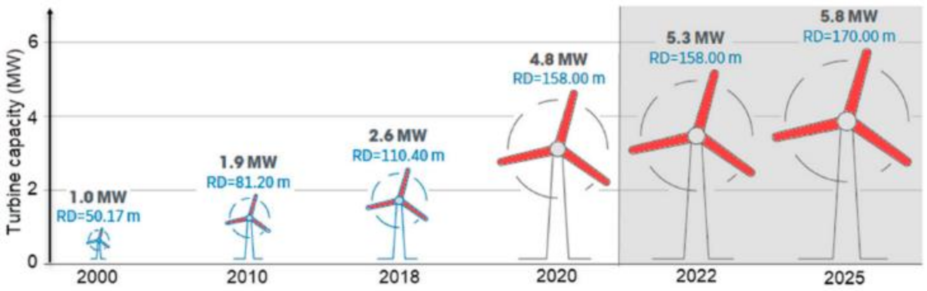
As such, more mature technologies such as FFBT-E and hydropower have seen their importance in the power sector decrease overtime (European Commission, 2017), additionally, most of the opportunities for hydropower have already been exploited. With that, the growth of RES-E in the EU can be mainly linked to newer RET-E, such as solar PV, wind power and other emerging technologies (Mac Domhnaill & Ryan, 2020).

The increase in rated power from wind turbines can be attributed mainly to an increase in rotor diameter size, and rotor height. Rated power grows more than proportionately in relation to the radius of the blades and is positively affected by rotor height. Rotor height also helps at stabilizing power delivery, as winds are both stronger and more constant the furthest from the ground. Technological advancements in wind turbines have been focused on improving materials to create bigger rotors, to build higher and create bigger gearboxes. In addition, other advances such as changing rotor direction and blade pitch further optimize power generation to different wind conditions (Bošnjakovi et al., 2022).

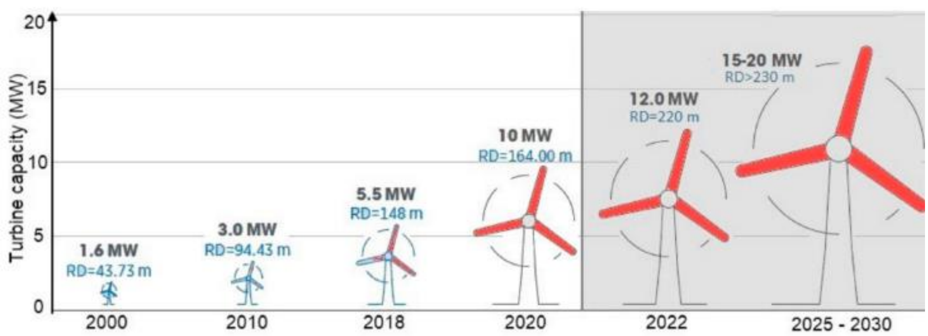
As such, between the 1980s and 2020, for new onshore installations, rotor diameter on new wind power installations grew fivefold from 30 m to 158 m, and rated power grew nearly sixteen-fold, from 300 kW to 4.8 MW (Serrano-gonzález & Lacal-arántegui, 2016). In the case of offshore wind farms the increase was bigger, as new onshore installations have found limitations with transportation, whilst offshore installations do not face such problems. New installation costs increased as technology progressed, but not as fast as the technological progress, meaning that the price per kWh produced has, and will, lower with time, as noted in (Bošnjakovi et al., 2022).

Table 1: Levelized cost of electricity from wind energy, source (Bošnjakovi et al., 2022)

Year	**2010**	**2018**	**2030**	**2050**
Onshore wind ($/kWh)	0.08	0.06	0.03-0.05	0.02-0.03
Offshore wind ($/kWh)	0.16	0.13	0.05-0.09	0.03-0.07



Power and rotor diameters of existing and planned onshore wind farms [2].



Power and rotor diameters of existing and planned offshore wind farms [2]

Figure 1 : Evolution of new wind power installations size and rated power, source (Bošnjakovi et al., 2022)

On the other hand, new photovoltaic (PV) installation costs also reduced over the last few years, especially as components production shifted to China away from Europe and the United States. As such, the cost per watt in rated power, for new installations dropped drastically from 4.5-euro cents per watt in 2007, to around 0.75-euro cents per watt in 2019 (Benda & Černá, 2020). In the same note, the cost per watt per square meter of PV module has also decreased greatly over the last two decades, meaning that producers could generate more electricity for cheaper, and with the same (or less) land usage. As such, the weight of PV module costs has decreased when considering the total cost structure of new installations. This means that PV technology has evolved enough to the point of it not being the main cost in a solar farm, and other costs like land accessibility, grid connectivity and BOS (balance of system) costs, such as current alternators, have become the most significant part of new installations, all of this in the span of two decades.

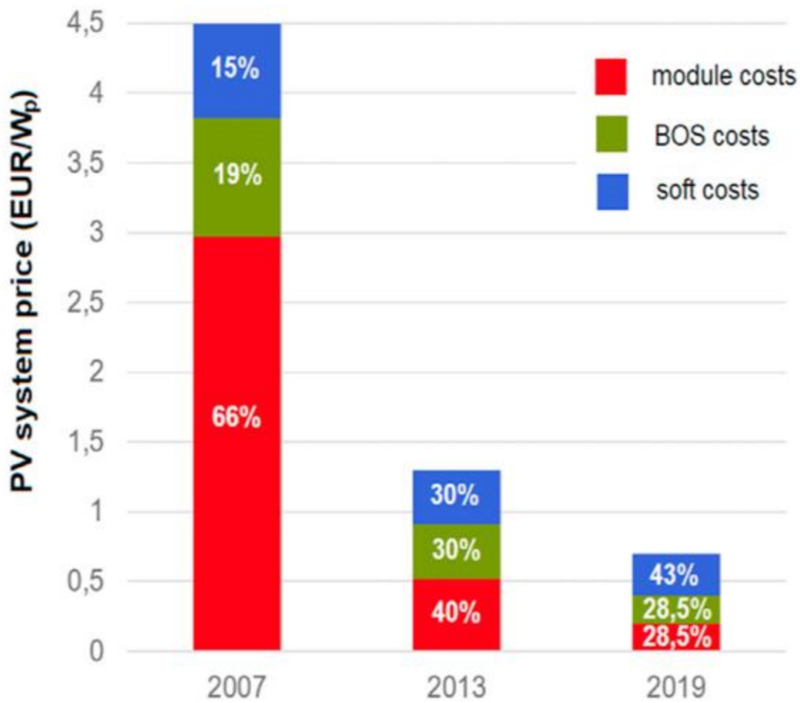


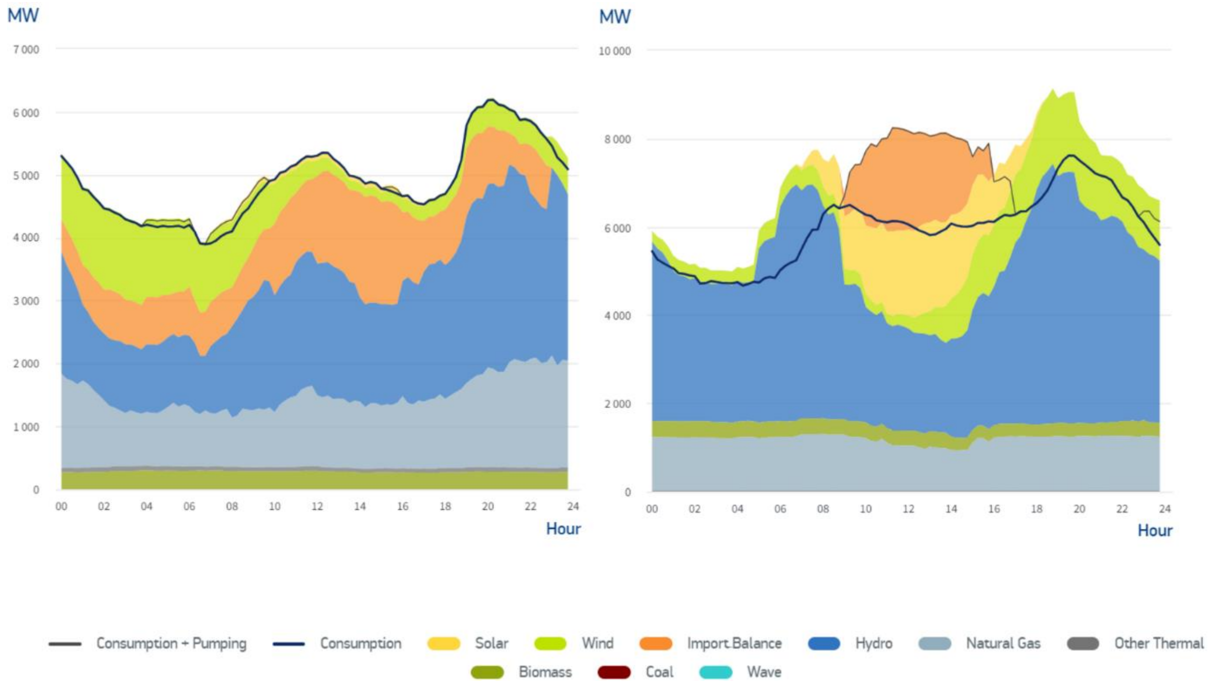
Figure 2 : Evolution of cost breakdowns of new solar PV installations, source (Benda & Černá, 2020)

However, RET-E face many more market barriers that are equally limitative of its large-scale deployment (Painuly, 2001). Some of the challenges faced in 2001 are still being tackled, but many have been reduced as technologies developed and became more accessible (Gajdzik et al., 2023). These will be addressed in the next chapter.

One of the biggest challenges is that RET-E are intermittent and unreactive to demand and supply, with that being one of the biggest perceived weaknesses for further market penetration. In addition, RES-E producers, mainly solar PV and wind farms mainly cannot just shut down production, nor accumulate the resources needed to generate more electricity, which means that they have zero (or negative) opportunity costs to dispatch every MWh they produce. It's usual for countries with higher levels of solar PV and wind farms to have hours, and even full days where prices are below zero. This is caused by having more negative-price supply than total demand.

Future developments in RET-E, and in electricity grids should aim at both expanding cross-border transmission infrastructure, and methods to store energy or potential energy to use in peak demand hours. Technologies such as hydro pumped storage, or electrolysis to generate green hydrogen can be used to take advantage of technology and consumption seasonality, and arbitraging electricity prices depending on the market production structure, the change in the production structure has significantly altered the market's behaviour regarding hydro pumped storage. Additionally, by further investing in cross-border infrastructure, neighbouring countries can benefit from each's RES-E endowments.

These trends can already be noticed in Portugal's case when comparing both spring equinox from 2011 and 2024, as pumping now happens during solar PV production peak as solar PV became more prominent, vs back in 2011 where pumping happened in the middle of the night when wind production was high and consumption low.



Graph 1 and Graph 2: Comparison of two production breakdown graphs from Portugal, from 20/3/2011 (left) and 20/03/2024 (right), source (REN, 2024)

As revealed by the graph, Portugal now has much more hydro pumped storage consumption (shown as the gap between the consumption and the consumption + pumped storage lines), and more prominent during the peak in solar PV generation both from national producers and from Spanish imports, a major solar PV electricity producer. Furthermore, hydro power now works as a filler between sunset and sunrise, and pumped storage can help dampen any imparity in RES-E production and demand needs.

FFBT-E may still be called to meet demand, but they are now the exception and not the rule, remaining online to guarantee supply stability (Gallego-Castillo & Victoria, 2015). Inversely, it is common but less habitual, lead to situations where FFBT plants, and even hydro plants halt production to safe minimums because sun and wind farms are producing more energy than required or predicted by the market. In the next subchapter, the focus will be on the policies created to promote RET-E development and higher RES-E deployment.

2.2 - EU Energy Policy

The European Community started paying more attention to the energy policy after the oil crisis in the 1970s, with fears of it being too dependent on external players. From then on, the aim was to make the European market more resilient, by diversifying energy sources and by promoting internal production. Since natural fossil fuel reserves in the European Community were limited, the response was obvious, use RES. The importance of RES was beyond its lower environmental impact when compared to conventional energy sources, they were a way into EU energy market resilience.

With each version of the legislation regarding EU Energy Policy, the goal of RES integration grew, with exponential growth, as technologies developed, they got more competitive and more accessible. These regulations placed legally binding goals, and mandated Member States to implement policies that aimed to reach such goals. The initial aim was to reduce the impact of price shocks, and to develop innovative technologies to introduce to the market whilst becoming industry leaders. Newer legislation packages focus on further integrating those technologies into the market so that they can coexist with, and eventually replace, fossil fuels and to reduce GHG emissions.

In brief, the first wave of legislation came in the 1970s and created the initial efforts to address energy security and reduce dependence on imported fossil fuels. In this policy package, the reduction of GHG emissions was not a central concern, but a byproduct since the focus was mainly posed on reducing imported fossil fuels to mitigate the level of energy dependence. The main selling point of RET was not their reduced level of GHG associated emissions, but their ability to generate energy locally and without the need for imported fossil fuels, with the promise of creating energy with little to no marginal costs.

Only after the Kyoto Protocol, and after deepening the powers of EU institutions, did the EU start creating binding GHG reduction goals. The increased attention given to the reduction of GHGs served to gather public support, and create more awareness on the theme of RET, as climate change became a fight familiar to many Europeans (Anderson et al., 2017). RET became a mean to multiple ends, from energy supply resilience to technological/industrial leadership.

Over time, the European Union implemented more comprehensive regulatory framework, and action plans, to increase the penetration of RES in the energy and electricity market. This effort began with the plan set forth in the "White Paper for a Community Strategy and Action Plan" in 1997, which aimed to double the share of RES in the Union's overall energy consumption by 2010, when compared to 1996, which would be 12 per cent of total energy consumed (European Commission, 1997). Later in 2001, those goals were made legally binding in Directive 2001/77/EC (Directive 2001/77/EC on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Energy Market, 2001).

In 2000 the Green Paper on Energy Supply Security assumed the failure of previous measures and claimed that Energy Security was a structural weakness of the European Union (European Commission, 2000), however Green Papers are not legally binding documents nor action plans, but documents that the European Commission released to start a discussion for later legislation packages. Later in 2008, the European Council's created yet another binding target of 20% RES by 2020 (European Commission, 2008; European Parliament & European Council, 2009) which also meant that the rate of RES integration was accelerating as technologies and policies advanced.

In the meantime, in 2003 the EU created the Energy Taxation Directive (ETD) to more fairly tax energy sources according to their social cost (Council of the European Union, 2003). Fiscal policies are ways to signal the market the correct prices for each energy source, and also to direct investment to, and away, certain technologies, by helping to promote cleaner technologies, while penalizing inefficient and polluting ones. The advantages of RES are not fully reflected in private costs, and the same goes for FFBT social, environmental and health costs. In addition, Directive 2003/87/EC created an emission trading system (ETS) that sets the cost of CO2 emissions through a market mechanism. This system can finance greener alternatives, such as RES by selling carbon credits to producers that emit a lot of CO2 when they generate electricity (European Commission, 2003; Pietzcker et al., 2021).

Additionally, the Directive on the Promotion of Energy from Renewable Sources, also known as RED 1, Directive 2009/28/EC (European Parliament & European Council, 2009) , set mandatory national targets for RES share in energy consumption and established measures. In addition to demanding for Members States to draft plans and policies to reach the RES integration levels set by other Community Policies, and by promoting further liberalization of the market (Jäger-Waldau et al., 2011).

These regulatory measures have contributed to stabilizing and potentially reducing electricity prices by diversifying energy sources, by not having a single dominant energy source, whilst also enhancing competition in the market. By prioritizing the integration of both large and small-scale renewable energy generation, support schemes and cooperation measures between Member States encouraged investment in RES (Jäger-Waldau et al., 2011). This in turn created a vicious cycle that fostered innovation that made RET more competitive. The easier access to the grid for RES-E producers tackled one of the major barriers to RET market penetration.

Furthermore, the European Union must legislate for a heterogeneous market, with different RES endowments and consumption patterns. Meaning that these policies must be applied by Member States, that can adapt their policies depending on current levels of consumption of FFBT, and their endowments of RES, meaning that some Member States can be more prone to produce electricity from certain RES-E, and some might be more willing to invest in RES-E depending on public and political support. This can be advantageous if Member States can import and export electricity to each other, therefore burden-sharing the costs of this transition.

The action plan, called “Fit for 55” aims at turning the European Union carbon neutral by 2030. The goal of 42.5% RES is set for total energy consumed and not just electricity, as it aims at electrifying the transport and heating sector and creating synergies with the power market and other forms of energy consumption. The goal for 2030 was initially set at 32%, in RED 2 (Directive(EU) 2018/2001, 2018), later revisited in 2023 with the RED 3 setting the minimum goal of 42.5% for the same time-period (European Commission, 2023). Adding to a complete revision of most policies aforementioned to further promote RES-E relative to FFBT-E. To reach those goals the EU also aims at streamlining RES-E project permits to ensure fast deployment of new installed capacity. Technologies such as wind and solar PV will be key for large-scale deployment (*Fit for 55 - The EU’s Plan for a Green Transition - Consilium*, n.d.; Piebalgs & Jones, 2021).

Additionally, RED3 and the “Fit-for-55” plan set aside even more funding reserved for cross-border and grid stability infrastructure, to be able to respond to peak demand without relying on FFBT-E. And optimize for each region’s differing renewable sources strengths and weaknesses. In addition, some seeds are planted to large-scale generation of green hydrogen to mix with natural gas, so that benefits of RES-E can reach parts of the economy that were not electrified, as a retrofit approach. The original RED 2 has already seen multiple revisions to accommodate new market trends, new environmental goals, and strategic needs to respond to the Ukrainian War.

At the same time, the Taxonomy Complementary Climate Delegated Act, TCCDA (European Commission, 2022a), drafted before the start of the Ukrainian War aimed at defining what energy sources were deemed as sustainable, and therefore signalled policy makers, and the market itself, that nuclear energy and natural gas can be considered as transitional energies, if they serve to replace dirtier fossil fuels. However, this definition was kept despite other Community plans and communications aiming at reducing natural gas consumption such as the RePowerEU plan, and the Council recommendation to discourage natural gas consumption (Council of the European Union, 2024; European Commission, 2022b), and backlash claiming that RES, and not fossil fuels, are the best way to discard the dirty fossil fuels. This regulation seemed very counterintuitive since the TCCDA will be used as a base for long-term policies and guide who has access to public and community funds, while in the short term, the EU wants to reduce the consumption of natural gas.

In conclusion, all regulations set forth by the European Union and its Member States aimed at reducing as many barriers as possible that RET-E face when entering a market that is optimized for FFBT-E (Painuly, 2001), in (Pepermans, 2019) a look at EU’s power market liberalization process shows some work still needs to be done for the EU to have a liberalized and harmonized power market.

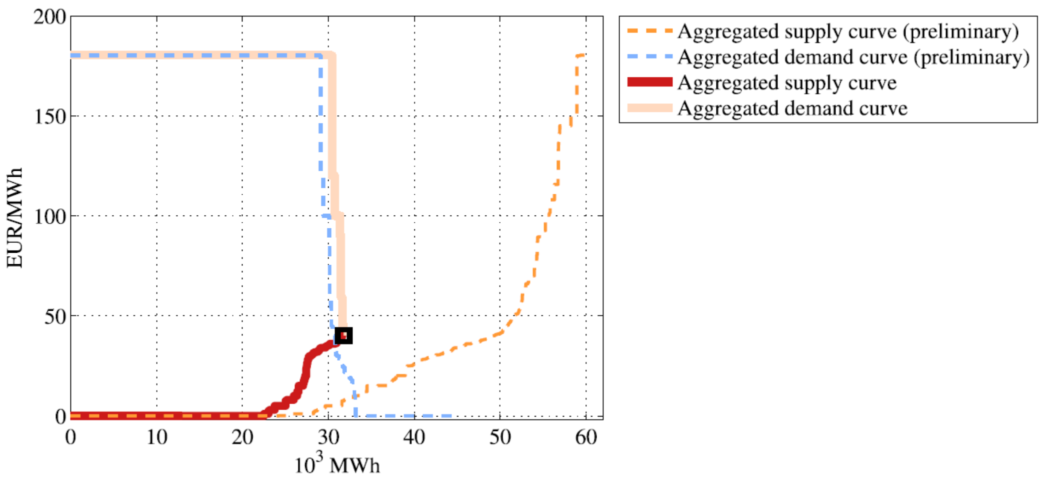
When looking at the policy packages implemented in these last decades, it can be noted that they have scientific backing, despite some hiccups. Tackling the RES challenge through various fronts and approaches can be seen as a strength. And has lead to the EU being at the forefront of the green transition. As technology and deployment levels progressed the approaches changed, and barriers were overcome or minimized, policies had to repeatedly adapt to those changes to optimize for efficacy and efficiency, as will be seen in the next chapter.

3- Literature Review

The presence of RES-E in the electricity market should be expected to reduce consumer prices, however multiple policy packages have generated more costs than savings to end-consumers. As such, one cannot separate RES-E implementation and diffusion without addressing the costs and benefits of such policies, by definition, the impact of RES-E on consumer prices is highly influenced by the efficiency and effectiveness of such policies. However, the data analysis will be done in the context of the power market where all electricity is traded from producers and consumers (distributors, not end consumers), this means that the following analysis will focus on the incentive systems used by each European country to call more RES-E into their power market, and their burdens.

The following policies are implemented with the goal of promoting the merit-order effect by promoting new investments in RES-E, whilst also incentivizing producers to remain online, and be paid for each MWh they generate. This effect is characterized as a market mechanism that prioritises plants and technologies with lower marginal costs, and therefore lower prices. This effect has been looked into in multiple studies that attest that it promotes lower prices in several European markets (Antweiler & Muesgens, 2021; Keeley et al., 2020; Macedo et al., 2020, 2022). Likewise, it expels less productive plants and technologies, such as coal or petrol based thermal power plants.

The MOE can be seen when looking at aggregated auction curve graphs, when analysing the supply curve, one can clearly see a near flat line, very close to zero euros per MWh, including with negative prices. After a certain quantity, the supply line takes a very steep inclination (orange dotted line and the red continuous line on the following graph), representing the marginal costs of FFBT-E entering the market when both RES-E and the base FFBT-E supply. This is because FFBT-E can have contracts that mandate suppliers to sell electricity for zero euros per MWh, or less, whilst being paid through an off-market mechanism, in order to guarantee grid stability (Gallego-Castillo & Victoria, 2015).



Graph 3: Aggregated curves of the day-ahead market, in Spain, for the 21st hour on 29 January, 2010 (Gallego-Castillo & Victoria, 2015)

The impact of RES-E in the energy market is measured not by their own efficiency, but by their ability to expel inefficient FFBT-E from the market. The benefit, in terms of electricity prices, is measured by the difference between the most inefficient FFBT-E and the next most inefficient FFBT-E. In a perfect scenario for RES-E, the aggregated supply curve would be flat like the first 20 GW, and not sharply inclined like those thereafter. The methodology used in this study will use RES-E and its relationship with electricity prices, so one must be aware of the limitations of this approach.

The European continent was a testing ground for RES deployment policies, and the sociopolitical context promoted these policies to be implemented and improved. As such, Directive 2001/77/CE (Directive 2001/77/EC on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Energy Market, 2001) enabled Member States of the European Union to choose the mechanisms they would use to reach the legally binding goals set in itself (García-Alvarez & Mariz-Pérez, 2012).

National policymakers created policies that would be optimized to their country's needs and endowments. With the main goal to signal the market to invest in RET-E and deploy RES-E in large quantities. Countries opted for different approaches on how to integrate RES-E into the electricity grid with some opting for Feed-in-Tariffs (FIT), others opting for Tradable Green Certificates for renewable electricity (TGC), and Competitive Auctions (CA), among many other. Each with their strengths and weaknesses. All of the countries in the empirical analysis have used a FIT system in their early RES-E implementation phases, and most have transitioned to auction based systems, or other mixed systems.

All the aforementioned support schemes carry burdens, promoted by the needs and wants of policy makers to reach specific RES-E market penetration goals. The approach was to go beyond a taxation system, and more into a market-based approach that promoted more RES-E in the energy mix to an optimal level defined by regulators and policy makers, that both pushes the market and doesn't hurt consumers or producers.

However, the objective of policy makers is to reduce prices, and to create a framework where they can directly compete with FFBT-E without the need for subsidies. Every policy implemented has, as expected, costs either from State Budgets of Member States and the European Union Budget when subsidizing RET-E and RES-E suppliers, or regulation costs, meaning that some costs are passed down to consumers. This will be relevant later in the chapter, to understand why most countries in the EU have transitioned competitive auction-based schemes (Fitch-Roy et al., 2019).

Furthermore, from 2003 to 2005, the ETS and the ETD were formally introduced in the European Union. These mechanisms went beyond the energy sector but gave clear signals to the power market that carbon intensive industries, such as FFBT-E, would have to pay for their pollution, and those with less-pollutant industries would be compensated for their lower impact on climate change. Yet, in a context where pollutant technologies dominated the market, this may have positively impacted energy prices although preparing the market for a fairer competition (Pietzcker et al., 2021).

The rates defined in the ETD have previously been defined as sub-optimal for the expected quantities of energy consumed, and to properly speed-up the transition process to renewable energy sources, both for climate change mitigation and energy independence (Gawel et al., 2014). However, one must always consider that they can be economically optimal, since policy makers must consider other factors such as affordability, transition costs and social impacts. Meaning that most policies are sub-optimal from an energy and climate policy standpoint. Hence why European policy makers have been trying to further implement RES into the energy mix through various fronts and policies, as to mitigate negative impacts that could arise from using a single policy instrument.

As such, support schemes were the main tool used for the power market. With the key takeaway being that higher RES-E does not necessarily lead to more affordable electricity prices every time. Nonetheless, the gains from a higher percentage of RES-E in the electricity mix go beyond the current electricity market prices and help to have a cleaner air and fighting climate change. Studies do not seem to always find a positive correlation between higher levels RES-E in the energy mix and a reduction in electricity prices (Gallego-Castillo & Victoria, 2015; García-Alvarez & Mariz-Pérez, 2012; Poponi et al., 2021). This could be due to the fact that instruments such as FIT, that guarantee a specific tariff for RES-E suppliers transfer costs to consumers, in addition to the previously mentioned ETD and ETS impacts (Pietzcker et al., 2021). The goal in this literature review is to understand if the savings that arise from the MOE overcome the costs, and what changes to policies were taken to reduce said costs.

One of the main instruments used were the FIT, which had two aims, to internalise the advantages of RES-E into their cost structure, by mitigating the risk of those who are taking the financial risk of investing in a very capital-intensive sector. And to promote economies of scale that are required for a large-scale RES-E deployment, since the risk for a larger energy farm can be reduced if they are guaranteed a stable revenue stream (Gallego-Castillo & Victoria, 2015). They serve as a compensation mechanism for RES-E producers, because the opportunity costs of producing any extra MWh of electricity are equal to zero, so a market-only response would be ineffective.

The usage of FIT models was a way to guarantee a continuous market mechanism to promote more RES-E penetration. It was not necessarily meant to be costly, nor require any public funding as it would be paid for by electricity consumers. FIT's main purpose was to pay RES-E producers a fair price for the MWh they added to the electricity grid, or they could go beyond a fair rate and serve also to promote more RES-E production. This is because the day-ahead market, a market that sets the prices for most of the electricity that will be traded on the next day is based off the marginal costs that suppliers set for every MWh they intend to sell. This means that technologies such as Solar PV, Wind and Hydroelectric, which have high upfront costs and near-zero marginal costs, are penalized in the electricity market, and so FIT schemes aim to reduce those inequalities by transforming it into an 'average price' market, where producers can be compensated for their initial investment (Gallego-Castillo & Victoria, 2015).

Therefore, studies have found different impacts in each Member States regarding the costs of these policies (Ciarreta et al., 2017; Gallego-Castillo & Victoria, 2015; García-Alvarez & Mariz-Pérez, 2012). This was due to a mix of national endowments, policy mechanisms used, or the scope at which they were applied, their efficiency, their efficacy, their costs, and the goals that policymakers aimed to achieve. In countries such as Spain, once the country with the biggest solar PV endowment in the world, studies found that the FIT system implemented created net savings for consumers (Gallego-Castillo & Victoria, 2015). The way this is usually computed, is by comparing a hypothetical market where RES are not present, which tend to lead to an increase in consumer prices, by shifting the supply curve to the left, versus the current market scenario with RES negatively impacting market prices and adding the costs from FIT. An effective FIT scheme is one that can create more savings by reducing market prices more than the cost of FIT.

In other studies, it was found that FIT systems have passed costs to consumers such as the case in Danish wind farms in 2000, that instead of opting for a fixed FIT, opted for a mixed system that comprised of a premium above the market rate in the first years, meaning that consumers paid a premium to consume wind power. (Munksgaard & Morthorst, 2008) notes that even considering a market where those wind farms would not exist, consumers would see lower electricity price. This is a very early example and may just reflect a time where compromises had to be made to promote RET-E development.

However, the case of Italy's Conto Energia support scheme, from 2006 to 2018 it showed that FIT schemes need to adapt to avoid generating a rent to RES-E producers (Poponi et al., 2021). Whilst the implementation of such systems in electricity markets can help to ensure a large-scale RES-E deployment. The analysis in (Poponi et al., 2021) noted that the same level of RES-E penetration could have been reached for 70% lower costs, saving Italian consumers a total of 58 billion euros. For the case of Germany's FIT scheme, from 2000 to 2009, and with payments due until 2029, it was revealed that despite having cost consumers, its FIT scheme also had little impact in improving energy security for the long-term (Frondel et al., 2010).

Alternatively, TGC were used as a tool to set a goal of RES-E deployment levels and pay producers for their contribution to the electricity markets, this payment is made by FFBT-

E producers that are forced to promote the integration of a certain percentage/ratio of RES-E into the grid (Ciarreta et al., 2017). TGC are seen as one of the cheapest options, because of their market-based approach, however they naturally prioritise more mature technologies that are cheaper and more productive whilst not allowing for newer technologies to have access to the contributions, as those would be taken by the former, and don't promote RES-E production beyond the defined ratio defined.

On the other hand, FIT can have discretionary tariffs for different RET-E, and different plant sizes to compensate smaller producers for their higher costs and can provide support payments to all producers even when RES-E share reach one hundred percent of total electricity consumption (Gallego-Castillo & Victoria, 2015; Munksgaard & Morthorst, 2008). In (Ciarreta et al., 2017) it points out that TGC could reach the same results as FIT in the Spanish market for lower costs. However, they were aware that policy makers must be careful choosing the correct RES-E ratio intended. To prevent cost-burdening consumers or delay the deployment of RES-E which can also be costly.

Despite seeing a positive impact of the MOE it does not mean that FIT schemes have *carte blanche* to set premiums that will attract as much RES-E suppliers as possible, mainly because FIT premiums should not be the sole responsible mechanism for the energy transition, in fears of having FIT act as transfer of wealth from consumers to RES-E producers, as was the case of Italian Conto Energia, Danish wind farm FIT, and Germany's FIT scheme (Frondel et al., 2010; Munksgaard & Morthorst, 2008; Poponi et al., 2021).

However, such schemes must be reevaluated as technology and penetration levels evolve and should try to reflect as much as possible the average costs of RES-E, and the capability to welcome for more installed capacity, whilst compensating producers for their risk without creating any unnecessary burdens on consumers and taxpayers. The inability to do so will lead to situations where RES-E presence in the market can create net losses for consumers.

Consequently, most markets have transitioned to a CA system, which works by having authorities identifying areas where the electricity grid still has available capacity. As such, they set auctions that allow for RES-E producers to bet on the prices per unit of energy they will charge, and the lowest bidder wins (Fitch-Roy et al., 2019). Producers are left with a long-term contract where they will be compensated for the energy they deliver to the grid, similar to FIT.

On the other hand, consumers benefit by having lower electricity costs, as support schemes now prize the lowest prices available in the market versus administratively set tariffs (Anatolitis et al., 2022).

Most countries have switched to CA, as those systems are more easily adaptable to technological advances, as bids that won the year prior may not be competitive this year. Additionally, the setting of criteria can allow for a wider range of problems to be addressed, not just low electricity prices, even beyond the scope of the power market. CA still have risks such as speculative biddings, that bid too low to guarantee contracts but then cannot realize them, leading to no RES-E deployments (Anatolitis et al., 2022). However, they have been replacing FIT systems in some European countries, due to a higher flexibility as each auction can be different than the one before (Anatolitis et al., 2022; Gephart et al., 2017), each year multiple auctions can happen, each with its own characteristics giving policy makers more control over these support schemes. In sum, CA can act as FIT systems, however, the market, based on the criteria, will set the FIT rate that more accurately represents the market conditions (Gephart et al., 2017).

In sum, RES-E are altering the market dynamics in the electricity market, and policy makers need to adapt to the technological and institutional changes, since soon these markets will be more dependent on the regulations. It is important that consumers do not carry a burden that should be bringing savings, as this transition must be accessible to all, including the most vulnerable.

As such, all literature considered for this study has noted that before subsidies and support schemes, RES-E can reduce electricity market prices. However, this does not mean that one could evaluate the real impact of RES-E on electricity prices. One cannot remove RES-E from all the support schemes that, in practice, set a price on the electricity sold by RES-E producers, and transfer those costs to other market agents, hence impacting the prices in the market. As such, even if in the empirical data there are results indicating lower electricity prices due to higher RES-E integration levels, it may not necessarily mean that consumers will see a lower electricity bill. However, as support schemes payments decrease, due to their adaptation to technological advances, a lower market price will inevitably lead to lower prices for end-consumers. (OMIP, 2024)

4- Methodology

In this section the methodology will ty to show whether the literature review findings can be found when looking at electricity prices data and the factors that influence it. The methodology will be based on the hypothesis that electricity prices have lowered as RES-E penetration levels increased. An econometric approach will be used to assess if the price per MWh changes with more RES-E integration.

The data analysis will be comprised of multiple linear regressions. Linear regressions are good for a *ceteris paribus* analysis as they serve to model incremental changes that predictors assert to the modelled dependent variable, assuming all else remains. They provide a simple analysis through their linearity that most people can interpret. Even if a linear analysis is not the optimal, as these markets are complex and not necessarily linear, it is more accessible for both interpretation and replication in future studies. Not all factors can be measured or gathered to create the model.

Using data from Portugal’s, Spain’s, France’s, Germany’s, Austria’s and Luxembourg's electricity and natural gas markets, the approach will be done considering spot electricity day-ahead prices and daily RES-E integration levels, as well as consumption levels and day-ahead natural gas prices. The electricity data is organized not by countries but in bidding zones, for Portugal, Spain and France only their corresponding European continental territories are considered, as their ultramarine territories and islands are considered separate bidding zones, or more simply, different markets, with different suppliers and consumers with different bidding curves. For Germany, Luxembourg and Austria, they function as a single bidding zone, that is later split into two bidding zones, one being Germany and Luxembourg, and the other being Austria. All data, expect of that found in Bloomberg, regarding natural gas prices for Central European countries is publicly available, meaning this model can be replicated with little limitations.

In the first approach, only data from Portugal will be considered, with data regarding the power market itself will be used, such as daily prices, daily weight of RES-E and electricity consumption. Why was only Portugal considered for the first methodology approach? Firstly, because Portugal is the country with the most data points available for this approach, spanning from 2010 to September 2024. Secondly, the results from this approach showed that the 2 predictors (*resepc and cons*) were not capable enough to create a robust model. As such, the second approach, the prices for natural gas will be considered, for more limited time frames due to natural gas data access limitations but considering all of the aforementioned countries.

As mentioned before, the day-ahead market is responsible for most of the electricity that is consumed and generated on the day it refers to. The variable corresponds to the arithmetic average of all the hourly prices that make up the day on which the delivery of electricity is in place (OMIP, 2024), it will act as the independent variable in the econometric regressions that follow.

The data sources for the variable *price* respect the following equation:

$$price = \frac{\sum_{i=1}^{n} SMP(p)^{i}}{n} \quad {}^{1}$$

The day-ahead market has in factor the expected consumption and production levels for the following day from all sellers and buyers, including foreign consumers and producers. As in any market, the price is set by the last unit (MWh) sold, in the intercept between the demand and the supply lines. In this case, ceteris paribus, a reduction of consumption can expel the least efficient plants, meaning that in days with lower consumption, RES-E will be more capable of influencing the prices.

To assess the RES-E weight, the quantity RESE(q) was created to assesee all electricity that is produced via hydro (with pumped storage included due to data standardization), solar (thermal and PV), wind turbines, biomass and other measured emerging RET-E, will be considered as RES-E for this methodology.

[1] n = number of hours in a calendar day; i = each CET hour being used to compute the daliy price; SMP(p)i = marginal hourly price for the corresponding country for the i-th hour, set as € per MWh up to 2 decimal places (source: OMIP)

To assess total (q) and *cons*, all production and consumption., respectively, will be accounted for, as imports, exports and pumped storage affect both demand and supply sides of the day-ahead market, and therefore prices. This means that total production will include the sum of all national generation, plus net importing. This will in turn benefit countries that export a lot of electricity, by having RES-E percentages above 100%, and possibly hurt those that highly rely on imports. Additionally, it showcases the importance of cross-border transmission infrastructure investments, that has been one of the *foci* of the EU. As such, the variable *cons* represents the total grid load for the day in consideration.

The calculations used to measure the predictors respect the following equations:

$$resepc = \frac{\sum_{j=1}^{m} RESE(q)^j}{\sum_{j=1}^{m} total(q)^j} \times 100$$ [2]

$$cons = \sum_{j=1}^{m} cons(c)^j$$ [3]

The inclusion of the consumption aims at showing market demand fluctuations and seasonality, as markets naturally promote lower prices when less efficient power plants do not partake in the trading for most, if not all trading hours of that day.

The generation and consumption data were gathered from each country's electricity transmission operator (REN, 2024) (Red Elétrica, 2024), (RTE France, 2024). For the case of Germany, Luxembourg and Austria, the data source was the German Federal Network Authority (Bundesnetzagentur, 2024) from which pricing data for those markets was also gathered. Pricing data for Portugal, Spain and France was gathered from OMIP, the Portuguese operator in the Electricity Iberian Market (OMIP, 2024). The consumption data for Spain is the

[2] m= number of quarters of an hour in a calendar day; j=each CET quarter of an hour being used to compute the daily consumption and generation data; q= quantity of electricity produced for each corresponding country for the j-th quarter of an hour, both total and RES-E

[3] m= number of quarters of an hour in a calendar day; j= each CET quarter of an hour being used to compute the daily consumption and generation data; c=total grid load, meaning consumption and pumped storage consumption in the j-th hour

only one showcased in GW, whilst all others are shown in MW for more preciseness in the econometric models.

The following linear regression was selected for the first approach:

$$price = \beta 0 + \beta 1\ resepc + \beta 2\ cons + u$$

Regarding the statistical significance, a p-value of 0.05 is the norm in the scientific world and will be one used for this study. Hence, any independent variable with a statistical significance higher than 0.05 will be noted as inconclusive.

As such, this study is aiming to find if $\beta 1<0$, meaning that RES-E can reduce prices, however, for a simpler analysis this study will focus mainly not on the *betas*, but on the unstandardized B for *resepc*, which measures the savings or costs from any additional percentual point of RES-E weight in the energy mix. It is also expected that $\beta 2$ will be higher than 0, meaning that an increase in consumption leads to an increase in prices. This regression may not be accurate in assessing the variance of the *price* that can be measured by the independent variables since *price* is a continuous variable, but signals might be interpretable. Additionally, this approach represents more directly the nation of this study, that aims at showing if RES-E can impact the power market.

Table 2 : Model and corresponding country used for the first model approach

Country/Bidding zone	**Time frame in analysis**	**Data rows**
Portugal (Continental)	From 01/01/2010 to 31/08/2024	5377

The second approach will add the variable *ngprice* that represents the price of natural gas in the spot day-ahead market, measured in eur/MWh.

The data sources for the variable *ngprice* respect the following equation:

$$ngprice = \frac{\sum_{i=1}^{n} naturalgas(p)^{i}}{n}$$ [4] or *ngprice*= last price of the trading session in consideration[5]

The following linear regression was selected for the second approach:

$$price = \beta 0 + \beta 1\ resepc + \beta 2\ cons + \beta 3\ ngprice + u$$

Since what sets the price in the day-ahead market is the last MWh sold, representing the producers with the highest marginal costs, those MWh tend to be produced by FFBT-E and are therefore linked to fossil fuel prices as they directly affect the marginal costs of any additional MWh. In the study (Zakeri et al., 2023), it notes that FFBT-E in Europe, and more specifically natural gas, tend to set the electricity prices in a disproportionally higher weight than their contribution to the energy mix. In its analysis, it shows that natural gas set 39% of the spot electricity prices, whilst only having a 18% weight in the energy mix for electricity generation. The addition of another independent variable should serve to both add more information until here unobservable by the model, and to further isolate the effects of the remaining independent variables, so that their predictors can be better assessed.

As such the variable *ngprice* represents natural gas prices traded in the day-ahead market in their corresponding market. The spot day-ahead market also represents most of the natural gas traded for the delivery day in consideration. Only the price of natural gas will be considered and not the weight in the energy mix, due to a risk of near-perfect correlation, as it may be inversely related to *resepc*, due to the nature of the merit-order-effect in the power market. It is expected that $\beta 3>0$.

[4] n = number of all MWh sold in that day; i = each MWh being used to compute the daliy price; naturalgas(p)i = price for the corresponding country for the i-th MWh sold, set as € per MWh up to 4 decimal places, for Portugal and Spain (Mibgas, 2024)

[5] According to Bloomberg's Terminal definition for the extracted data, for France, Germany, Luxembourg and Austria - (Bloomberg, 2017)

Table 3 : Models and corresponding countries used for the second model approach

Country/Bidding zone	**Time frame in analysis**	**Data rows**
Portugal (Continental)[6]	15/01/2016 to 31/08/2024	3152
Spain (Peninsular)	15/01/2016 to 31/08/2024	3152
France (Continental)[7]	11/09/2017 to 31/08/2024	2547
Germany/Luxembourg/Austria[8] (DE/LU/AT)	05/09/2017 to 30/09/2018	390
Germany/Luxembourg (DE/LU)	01/10/2018 to 31/08/2024	2161
Austria	01/10/2018 to 31/08/2024	2161

5- Results and findings

When analysing the following outputs from the models, several coefficients/tests must be considered. Firstly, the ANOVA test notes that all the following models are statistically significant and the relationships between *price* and the predictors (*resepc*, *cons* and *ngprice*) are not due to random chance. Additionally, R^2 measures how much of the dependent variable's variance can be explained by the predictors' variance, it spans from 0 to 1, with 0 meaning no variance can be explained, and 1 perfect prediction of the variance. Moreover, Adjusted R^2 acts as an extension of R^2 to understand if a model has a high R^2 due to a high number of unnecessary predictors, penalizing for adding irrelevant variables. In the first approach, both

[6] Portugal's natural gas bidding zone was shared with Spain from MIBGAS' conception back in December 2015 to 01/01/2018, however consistent data for Portugal's bidding zone is only available from 01/01/2024 onwards, therefore from 2018 to 2023, Portugal's *ngprice* variable share the same prices as Spain's model

[7] From France's PEG natural gas spot market

[8] Both German, Austrian and Luxembourgian referent models use price data from German's THE natural gas spot market

R^2 are below 0.1, indicating that the model with only those two predictors cannot be very reliable. As such, the first approach will not be a good metric. On the second approach, all models indicate both R^2 above 0.7 which means that these models are more reliable, and therefore the predictors may also be more reliable.

Additionally, variables may act in consonance, there's a risk of having collinearity between the predictors, and that may constitute a risk of having two or more variables explaining the same effect and therefore having wrongly measured parameters for both predictors and predicted variables. For VIF and tolerance tests, results are promising, however some raise some concerns on moderate to severe multicollinearity on multiple models, such as the Condition Index in the linearity diagnostics show values very close to 30, considered a red line from which all interpretation must be carefully taken. These tests are presented on the annexes.

Table 4 : Descriptive statistics for the data used in the first approach

Model	**Variable**	**Mean**	**Std. Variation**
Portugal	*price*	61.458	45.391
	resepc	54.641	21.425
	cons	567228.863	58293.942

Table 5 : Model summary for the first approach

Model	**R^2**	**Adjusted R^2**	**Std. Error of Estimate**	**ANOVA (p-value)**	**Durbin-Watson test**
Portugal	.086	.086	43.395	<.001	.108

Table 6 : Coefficients for the models in the first approach

Model	**Variable**	**Unstd. Coeff. B**	**SE (B)**	**Beta (Std. Coeff)**	**p-value (sig.)**	**95% Conf. Int. for B**	
						Lower Bound	Upper Bound
Portugal	constant (*$\beta 0$*)	-.758	5.802		.896	-12.133	10.617
	resepc	-.553	.028	-.261	<.001	-.609	-.498
	cons	.000	.000	.209	<.001	.000	.000

Table 7 : Descriptive statistics for the data used in the second approach

Model	**Variable**	**Mean**	**Std. Variation**
Portugal	*price*	72.942	55.352
	resepc	57.194	21.671
	cons	573957.682	58339.664
	ngprice	34.191	31.672
Spain	*price*	72.9418	55.35167
	resepc	47.042	15.523
	cons	669.067	73.519
	ngprice	34.189	31.672
France	*price*	93.463	100.044
	resepc	26.929	7.489
	cons	3098248.490	1027716.395

	ngprice	36.283	33.447
DE/LU/AT	*price*	39.184	14.970
	resepc	47.926	12.083
	cons	1580489.251	181647.886
	ngprice	21.115	3.895
DE/LU	*price*	93.776	92.872
	resepc	51.388	16.404
	cons	1338537.228	164041.217
	ngprice	44.322	46.690
Austria	*price*	101.966	99.306
	resepc	79.307	23.410
	cons	167429.3040	22892.686
	ngprice	44.254	46.608

Table 8 : Model Summary results from the second approach

Model	**R^2**	**Adjusted R^2**	**Std. Error of Estimate**	**ANOVA (p-value)**	**Durbin-Wattson test**
Portugal	.713	.713	29.631	<.001	.322
Spain	.710	.710	29.804	<.001	.239
France	.870	.870	36.111	<.001	.549
DE/LU/AT	.729	.726	7.830	<.001	.939
DE/LU	.900	.900	29.371	<.001	.809
Austria	.911	.911	29.621	<.001	.694

Table 9 : Coefficients for the models in the second approach

Model	**Variable**	**Unstd. Coeff. B**	**Std. Error (B)**	**Beta (Std. Coeff)**	**p-value (sig.)**	**95% C.I. for B**	
						Lower bound	Upper Bound
Portugal	Constant ($\beta 0$)	9.631	5.222		.065	-.607	19.870
	resepc	-.506	.025	-.198	<.001	-.556	-.456
	cons	.000	.000	.082	<.001	.000	.000
	ngprice	1.389	.017	.795	<.001	1.356	1.422
Spain	Constant ($\beta 0$)	40.209	5.136		<.001	30.139	50.280
	resepc	-.648	.034	-.182	<.001	-.716	-.581
	cons	.020	.007	.026	.008	.005	.034
	ngprice	1.465	.017	.838	<.001	1.431	1.499
France	Constant ($\beta 0$)	46.097	3.351		<.001	39.527	52.668
	resepc	-1.731	.098	-.130	<.001	-1.923	-1.540
	cons	-.000	.000	-.015	.034	.000	.000
	ngprice	2.179	.022	.909	<.001	2.677	2.761
DE/LU/AT	Constant ($\beta 0$)	58.687	4.819		<.001	49.213	68.161
	resepc	-.970	.034	-.783	<.001	-1.037	-.903
	cons	.000	.000	.022	.417	.000	.000
	ngprice	1.139	.102	.296	<.001	.939	1.340
DE/LU	Constant ($\beta 0$)	68.210	6.351		<.001	55.756	80.665
	resepc	-1.356	.040	-.240	<.001	-1.435	-1.278
	cons	.000	.000	.021	.004	.000	.000

	ngprice	1.799	.014	.904	<.001	1.772	1.825
AT	Constant (*β0*)	-79.327	7.451		<0.001	-93.938	-64.715
	resepc	.076	.033	.018	.021	.012	.141
	cons	.001	.000	.118	<0.001	.000	.001
	ngprice	2.024	.014	.950	<0.001	1.997	2.052

6- Analysis

In the case of the initial regression that only accounted for RES-E weight in the energy mix and consumption, the statistical significance for the *resepc* and *cons* independent variables impact on electricity prices was confirmed, and their signal matched the initial hypothesis. However, the modelled regression could at best assess the signal of the coefficients but cannot accurately predict the prices for the day-ahead market if it only has those two independent variables.

This constituted a big limitation on the takeaways from this model and shows that an increased weight of RES-E does not necessarily mean lower electricity prices, and that there are many other factors at play. This first methodology approach would be the most representative approach to embody the contextualization and literature review, however, it soon showed that it would not be significant enough for any relevant takeaway, since much of the dependent variable's (*price*) variance would be left to explain.

As mentioned before, the last MWh sold sets the price for the entire market which means that RES-E, when it does not cover all electricity demanded by the market, can only shift the supply to the right and therefore push the prices lower by removing less efficient technologies or power plants from the market. As such, it cannot set the price for that hour of electricity traded but it is possible to understand the effect of RES-E, yet it cannot be known to which extent it can impact the price. As such, the robustness of this statistical model is both hindered by its low R-square, and highly polarized Durbin-Watson test (very close to zero).

Future studies could also include lagged variables in order to mitigate such low results for the Durbin-Watson test.

Regarding the second approach, in 5 of the 6 regressions, the models have found that a higher RES-E weight can help reducing electricity prices, with Austria being the exemption. However, a trend can be noticed that corroborates with the initial hypothesis. In those 5 regressions, the impact of an additional percentual point (p.p) of RES-E in the energy mix may generate savings ranging from 0.5 to 2 euros per MWh traded. Looking at the mean prices of electricity from the modelled countries this can constitute a 0.3 to 2 p.p. decrease for each additional RES-E p.p.in the energy mix. This should come as no surprise, as it is possible to see market prices plunging when RES-E reaches a weight above 90% of all electricity generated, when looking at some of the data rows from the empirical analysis.

Likewise, the difference between each country/bidding zone in the *resepc* predictor can be linked to how advanced each country is in their energy transition. With higher impacts for countries with a lower *resepc* mean. This can further explain the MOE, as countries that are still generating electricity with inefficient FFBT-E, will see higher gains (a lower value for the unstandardized B coefficient for *resepc*) from RES-E increases than those that were already able to expel those inefficient plants and technologies. For the case of Austria, it might be suffering from a lot of influence from cross-border trade, and their own RES-E might be being bought by other countries, as producers export to make more profits, since export costs are minimal. Or maybe it is just a byproduct of multicollinearity.

Although there is no clear explanation for the results found in Austria, it shows that this study cannot guarantee that RES-E can always lead lower electricity prices. As such, these findings should be interpreted with care, as linear model may not be capable of showcasing the relation between RES-E and electricity prices.

Additionally, both the COVID-19 pandemic, its aftermath and the Ukrainian War have altered the market structure by both decreasing and increasing fossil fuel prices in an unprecedented and persistent manner. This is noted in the DE/LU/AT model that presents the lowest standard error estimate by a long shot, the best Durbin-Watson test which might signify that the model is more predictable of future outcomes, and the lowest *beta* for *ngprices*, which reflects how natural gas price volatility highly disturbed the power market structure. On future studies, one could add dummy variables that consider if the market is going through unprecedented times, with both exceptionally high or low fossil fuel prices.

On the other hand, all regressions showed that higher natural gas leads to more expensive power. Fossil-fuels still rule in the power market and can undermine all the savings created by RES-E, in all regressions the unstandardized B coefficient for *ngprices* was proportionally higher than that of *resepc*, meaning that a few euros price increase in natural gas can increase electricity prices even if it's a sunny and windy day.

7- Conclusion

This study was able to attest that RES-E can promote a reduction in electricity prices. The additional supply of electricity from RES-E at near-zero and even negative prices has created conditions for lower prices. It should be noted that even if it was not possible to confirm this claim, RES-E could create more savings for European taxpayers and governments on other fronts. Gains from a reduction in emissions of GHG and other toxic pollutants, and a gain in energy sovereignty were not accounted in this study. In the meantime, as RES-E increases, Europeans can expect cleaner air and a dampening from electricity price shocks.

Additionally, this study showed that we are past the point of transition pains, when it comes to the green energy transition. According to the literature, RET-E has evolved in the last few decades to a level where they can easily compete with FFBT-E in the electricity market. As such, European Energy policies have adapted to those market changes and improved RET-E penetration levels with each legislation package. On the other, the EU has also tried to even the playing field by taxing more pollutant and less efficient technologies, and fuels that make them run. Additionally, literature and data suggest that beyond the gains set by the EU related to energy independence and environmental impacts, lies lower marginal costs and therefore lower electricity prices. The empirical data also found connections between higher RES-E levels and lower electricity prices.

However, this might help to justify the results found in Austria. If one looks at the descriptive statistics from the data used in the second approach, one can notice that Austria has the highest mean of *resepc*. This could mean that Austria has already expelled the most inefficient FFBT-E and that they are seeing lower benefits as they further advance in the energy transition. It would be a good theme to explore in future works, for example, analysing the impact of RES-E depending on how advanced each country is in the energy transition, and for curiosity, analyse the impact of expelling the last FFBT-E present in the market.

This, however, leads to another limitation of this econometric approach, and may also help explain the results seen in Austria. The interconnected nature of European grids may lead to a situation of markets being so connected to each other that they are not self-defined. Meaning that Austria may have a day where RES-E can cover all of their internal demand with cheap electricity, but if neighbouring countries are experiencing higher electricity prices, they will be equalized or at least normalized across all connected markets. This in turn shows that future studies should find ways to analyse how imports and exports may impact market prices, especially in the case of European countries, being that interconnection is one of the biggest EU energy goals.

By looking at spot prices of natural gas, it is easier to understand why electricity prices spiked in late 2021 and continuing into early 2023 despite being a period where RES-E share had been in an all-time high. The power market is still heavily dependent on fossil fuels. As such, the key takeaway from this study is that Europe's investment on RES-E is paying off, and that the path forward should be to keep investment.

Each extra MW of RES-E installed capacity impacts not only the supply by increasing total production, but also to further remove FFBT-E, and be the new price-setters in the market. Portugal was already capable of shutting down the last coal fired power plant back in 2021 (ZERO - Associação Sistema Terrestre Sustentável, 2021), responsible for 4% of all national GHG emissions, and it was mainly due to RES-E increased production capacity. Many countries are planning to do the same, and petrol, fuel oil and natural gas will likely see the same fate.

Natural gas prices have since dropped back to below 50 euros per MWh, but they are still 50-100% above the prices practiced in the spring of 2021. According to the tested model, an increase in natural gas prices can easily slash the savings created by an increase in the weight of RES-E. In the case of Germany and Luxembourg, with the lowest ratio between resepc and ngprice, this would mean a 20,000 MW of RES-E added capacity being as impactful in the electricity prices as a price increase of just 1 euro per natural gas MWh. In the case of Spain, that same 1 euro increase, would undermine an increase of 15,000MW of RES-E installed capacity.

Likewise, RET-E has evolved to be able to dethrone FFBT-E as the leader in European markets. When consumption reduces, such as on weekends and holidays, little to no FFBT-E is dispatched to the grid. However, they are still needed when RES-E cannot cover demand. Therefore, further developments in the electricity market must both install more RES-E capacity and promote forms of energy storage so that the benefits from RES-E can be felt throughout the entirety of the day.

Yet, as countries try to understand what to do with a lot of cheap green energy, new opportunities for price arbitrage may arise to help dampen price and supply fluctuations. The generation of green hydrogen, due to its electricity intensive process is a possible bridge between the electricity sector and the transportation and heating sector. The hydrogen can then be mixed with other fossil fuels such as methane to create hybrid gases that work similarly to heat up our stoves and heating systems (Bošnjakovi et al., 2022). Furthermore, investing more in cross-border infrastructure, and pumped storage, will bring more stability and share the burdens and gains of the green transition between EU Member-States.

To conclude, the green energy transition, beyond its environmental label and beyond the promotion of energy security in the EU, can also make electricity more affordable. This study focuses on the energy transition, meaning that the findings now, may be very different in 5 to 10 years. Meaning that this study’s methodology might be rendered useless if all electricity comes from RES-E, when Europe reaches that position, other questions will be asked, and other methodologies will be needed. Until then we are expected to see even lower electricity prices, cleaner air, and a continent more resilient to Putin’s threats.

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Annexes

Model 1 - Portugal - first approach

Annex 1 - Correlations from Portugal's first approach model

		Price	resepc	cons
Pearson Correlation	Price	1.000	-.212	.148
	resepc	-.212	1.000	.235
	cons	.148	.235	1.000
Sig. (1-tailed)	Price	.	<.001	<.001
	resepc	.000	.	.000
	cons	.000	.000	.
N	Price	5357	5357	5357
	resepc	5357	5357	5357

cons	5357	5357	5357

Annex 2 - Model Summary from Portugal's first approach model

					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.294[a]	.086	.086	43.395001304303750	.086	252.961	2	5354	<.001	.108

Annex 3 - ANOVA test from Portugal's first approach model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	952715.049	2	476357.524	252.961	<.001[b]
	Residual	10082257.344	5354	1883.126		
	Total	11034972.393	5356			

Annex 4 - Coefficients from Portugal's first approach model

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-.758	5.802		-.131	.896	-12.133	10.617					
	resepc	-.553	.028	-.261	-19.435	<.001	-.609	-.498	-.212	-.257	-.254	.945	1.059
	cons	.000	.000	.209	15.575	<.001	.000	.000	.148	.208	.203	.945	1.059

Annex 5 - Coefficient correlations from Portugal's first approach model

Model			cons	resepc
1	**Correlations**	cons	1.000	-.235
		resepc	-.235	1.000
	Covariances	cons	1.095E-10	-7.006E-8
		resepc	-7.006E-8	.001

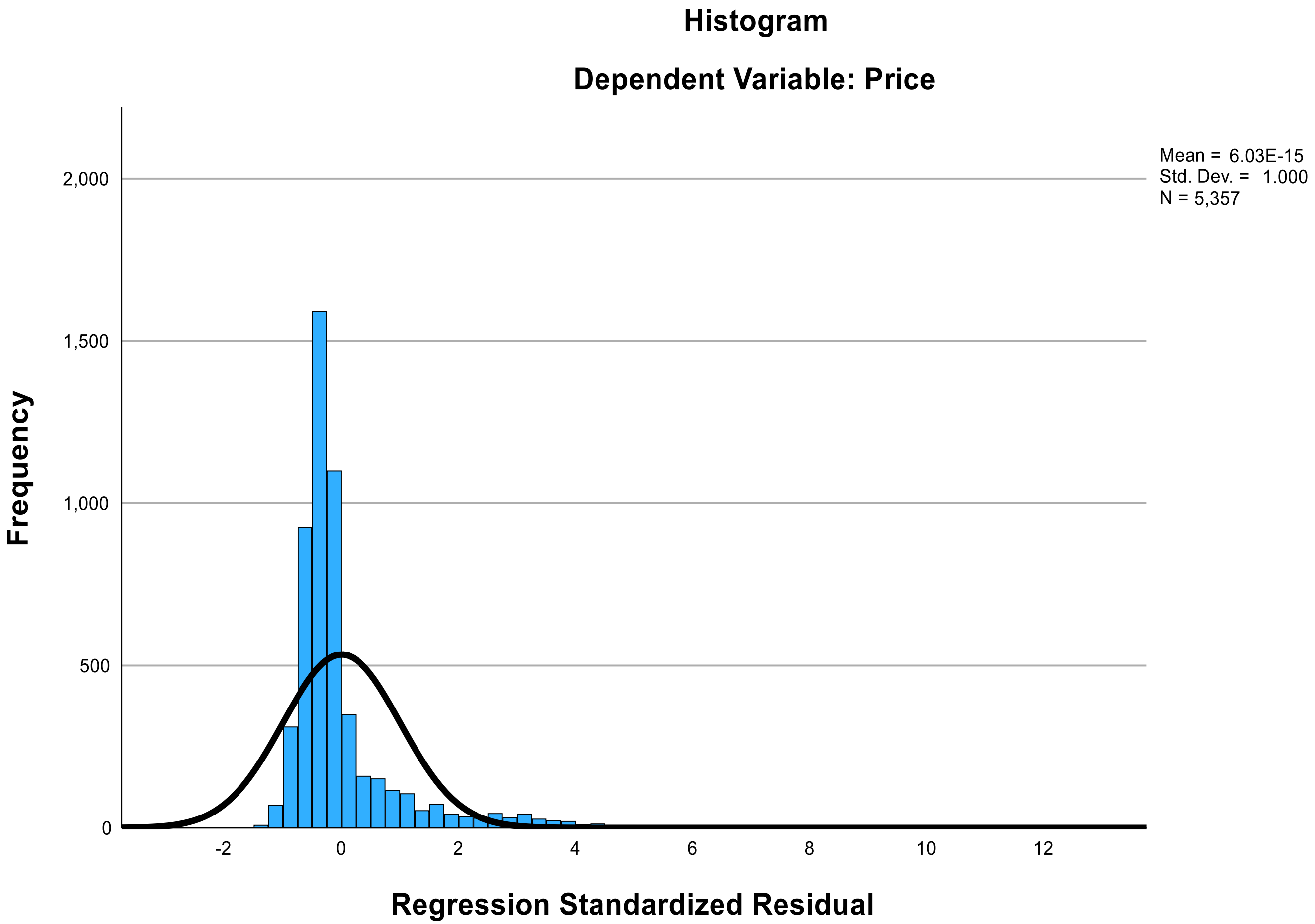
Annex 6 - Collinearity Diagnostics from Portugal's first approach model

				Variance Proportions		
Model	**Dimension**	**Eigenvalue**	**Condition Index**	**(Constant)**	**resepc**	**cons**
1	1	2.907	1.000	.00	.01	.00
	2	.087	5.767	.02	.97	.02
	3	.005	23.703	.98	.01	.98

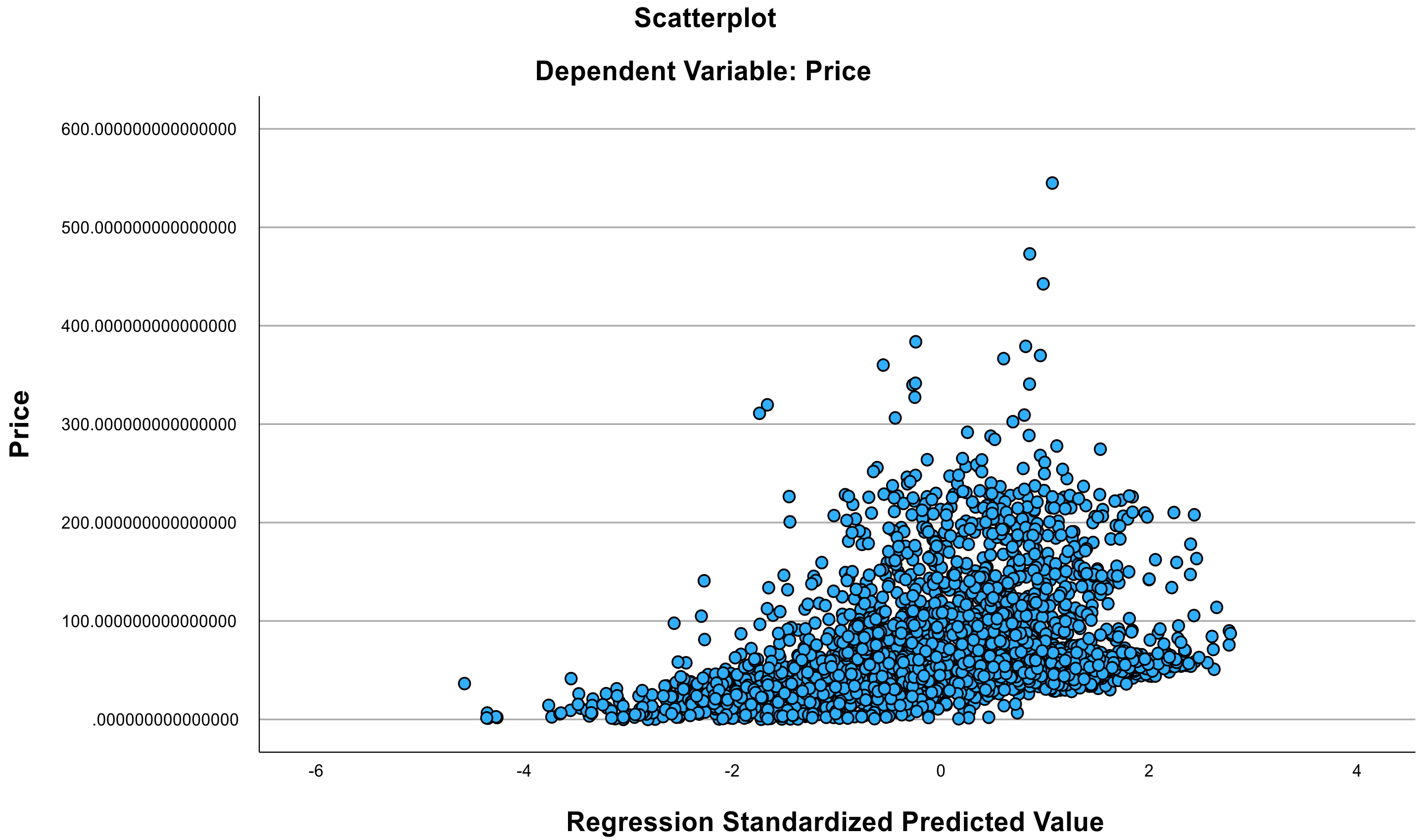
Annex 7 - Residuals Statistics from Portugal's first approach model

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.333190083503723	98.514572143554690	61.457657270860140	13.337094503707370	5357
Std. Predicted Value	-4.583	2.778	.000	1.000	5357
Standard Error of Predicted Value	.593	2.893	.979	.310	5357
Adjusted Predicted Value	.172568157315254	98.546829223632810	61.459163100070690	13.336599008987259	5357
Residual	-65.392555236816400	469.301055908203100	.000000000000313	43.386898419104850	5357
Std. Residual	-1.507	10.815	.000	1.000	5357
Stud. Residual	-1.508	10.817	.000	1.000	5357
Deleted Residual	-65.522682189941400	469.549682617187500	-.001505829210147	43.408142463986440	5357
Stud. Deleted Residual	-1.509	10.937	.000	1.002	5357
Mahal. Distance	.001	22.797	2.000	2.146	5357
Cook's Distance	.000	.021	.000	.001	5357
Centered Leverage Value	.000	.004	.000	.000	5357

Annex 8 – Histogram of Regression Standardized Residuals for *price* from Portugal's first approach model



Annex 9 – Scatterplot of Actual *price* vs. Predicted *price* from Portugal's first approach model



Model 2 - Portugal - second approach

Annex 10 - Correlations from Portugal's second approach model

		Price	resepc	cons	ngprice
Pearson Correlation	Price	1.000	-.244	.136	.823
	resepc	-.244	1.000	.268	-.086
	cons	.136	.268	1.000	.134
	ngprice	.823	-.086	.134	1.000
Sig. (1-tailed)	Price	.	<.001	<.001	<.001
	resepc	.000	.	.000	.000
	cons	.000	.000	.	.000
	ngprice	.000	.000	.000	.
N	Price	3152	3152	3152	3152

	resepc	3152	3152	3152	3152
	cons	3152	3152	3152	3152
	ngprice	3152	3152	3152	3152

Annex 11 – Model summary from Portugal's second approach model

					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
2	.845[a]	.714	.713	29.631252787024625	.714	2615.797	3	3148	<.001	.322

Annex 12 – ANOVA tests from Portugal's second approach model

Model		Sum of Squares	df	Mean Square	F	Sig.
2	Regression	6890096.690	3	2296698.897	2615.797	<.001[b]

Residual	2763979.074	3148	878.011
Total	9654075.765	3151	

Annex 13 - Coefficients from Portugal's second approach model

		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
2	(Constant)	9.631	5.222		1.845	.065	-.607	19.870					
	resepc	-.506	.025	-.198	-19.839	<.001	-.556	-.456	-.244	-.333	-.189	.913	1.095
	cons	7.795E-5	.000	.082	8.187	<.001	.000	.000	.136	.144	.078	.903	1.107
	ngprice	1.389	.017	.795	81.921	<.001	1.356	1.422	.823	.825	.781	.966	1.035

Annex 14 – Coefficient correlations from Portugal's second approach model

Model	ngprice	resepc	cons

2	**Correlations**	ngprice	1.000	.128	-.164
		resepc	.128	1.000	-.283
		cons	-.164	-.283	1.000
	Covariances	ngprice	.000	5.524E-5	-2.645E-8
		resepc	5.524E-5	.001	-6.874E-8
		cons	-2.645E-8	-6.874E-8	9.064E-11

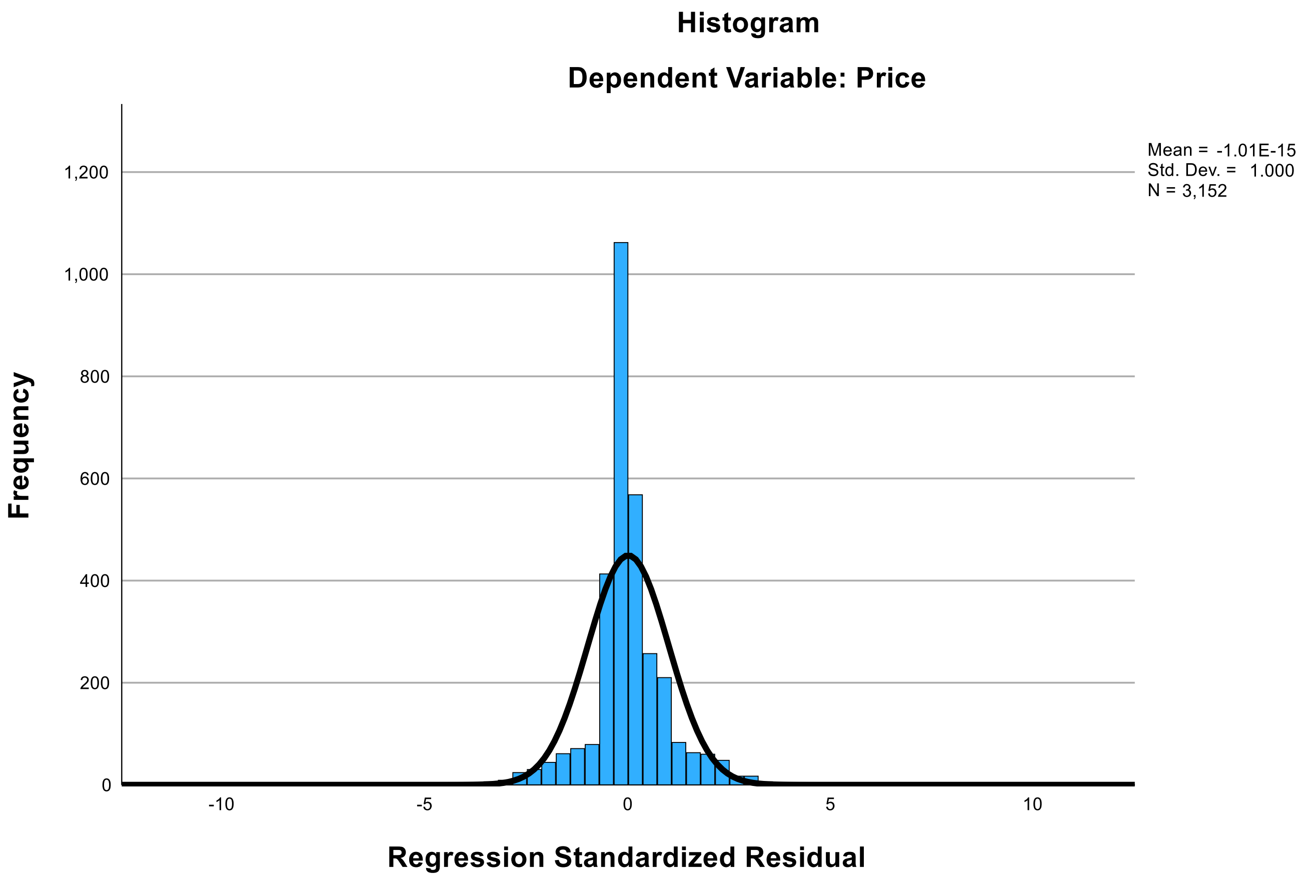
Annex 15 - Collinearity Diagnostics from Portugal's second approach model

				Variance Proportions			
Model	**Dimension**	**Eigenvalue**	**Condition Index**	**(Constant)**	**resepc**	**cons**	**ngprice**
2	1	3.519	1.000	.00	.01	.00	.02
	2	.400	2.966	.00	.04	.00	.88
	3	.076	6.808	.03	.93	.02	.08
	4	.005	26.609	.97	.03	.98	.01

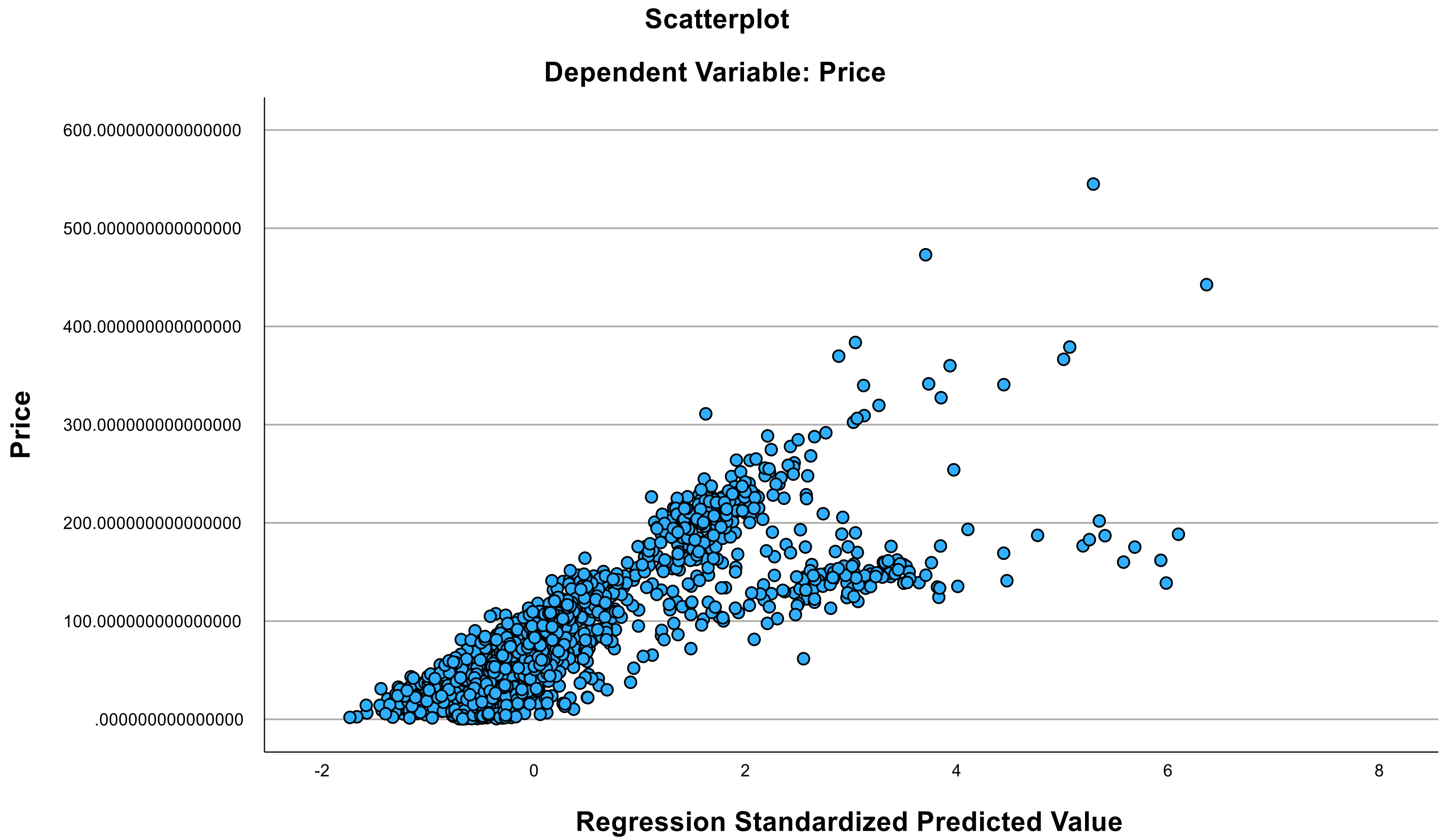
Annex 16 - Residuals Statistics from Portugal's second approach model

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-8.724371910095215	370.431976318359400	72.942366751268980	46.761502454818356	3152
Std. Predicted Value	-1.746	6.362	.000	1.000	3152
Standard Error of Predicted Value	.529	3.568	.989	.368	3152
Adjusted Predicted Value	-8.797936439514160	369.414184570312500	72.951219161054300	46.797286848558755	3152
Residual	-213.827011108398440	226.885726928710940	-.000000000000022	29.617143785611773	3152
Std. Residual	-7.216	7.657	.000	1.000	3152
Stud. Residual	-7.269	7.676	.000	1.001	3152
Deleted Residual	-216.973251342773440	228.028457641601560	-.008852409785301	29.721452824245400	3152
Stud. Deleted Residual	-7.330	7.748	.000	1.003	3152
Mahal. Distance	.006	44.692	2.999	3.696	3152
Cook's Distance	.000	.194	.001	.007	3152
Centered Leverage Value	.000	.014	.001	.001	3152

Annex 17 – Histogram of Regression Standardized Residuals for *price* Portugal's second approach model



Annex 18 – Scatterplot of Actual *price* vs. Predicted *price* from Portugal's second approach model



Model 3 – Spain

Annex 19 - Correlations from Spain's model

		price	resepc	cons	ng_price
Pearson Correlation	price	1.000	-.081	.224	.823
	resepc	-.081	1.000	.031	.119
	cons	.224	.031	1.000	.243
	ng_price	.823	.119	.243	1.000
Sig. (1-tailed)	price	.	<.001	<.001	<.001
	resepc	.000	.	.039	.000
	cons	.000	.039	.	.000
	ng_price	.000	.000	.000	.
N	price	3152	3152	3152	3152
	resepc	3152	3152	3152	3152
	cons	3152	3152	3152	3152

	ng_price	3152	3152	3152	3152

Annex 20 – Model summary from Spain's model

					Change Statistics					
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**R Square Change**	**F Change**	**df1**	**df2**	**Sig. F Change**	**Durbin-Watson**
3	.843[a]	.710	.710	29.80366	.710	2573.509	3	3148	<.001	.239

Annex 21 – ANOVA tests from Spain's model

Model		Sum of Squares	df	Mean Square	F	Sig.
3	Regression	6857819.484	3	2285939.828	2573.509	<.001[b]
	Residual	2796236.532	3148	888.258		
	Total	9654056.016	3151			

Annex 22 - Coefficients from Spain's model

		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
3	(Constant)	40.209	5.136		7.829	<.001	30.139	50.280					
	resepc	-.648	.034	-.182	-18.814	<.001	-.716	-.581	-.081	-.318	-.180	.986	1.014
	cons	.020	.007	.026	2.638	.008	.005	.034	.224	.047	.025	.941	1.063
	ng_price	1.465	.017	.838	84.207	<.001	1.431	1.499	.823	.832	.808	.929	1.077

Annex 23 – Coefficient correlations from Spain's model

Model	ng_price	resepc	cons

3	**Correlations**	ng_price	1.000	-.115	-.241
		resepc	-.115	1.000	-.003
		cons	-.241	-.003	1.000
	Covariances	ng_price	.000	-6.879E-5	-3.120E-5
		resepc	-6.879E-5	.001	-6.707E-7
		cons	-3.120E-5	-6.707E-7	5.542E-5

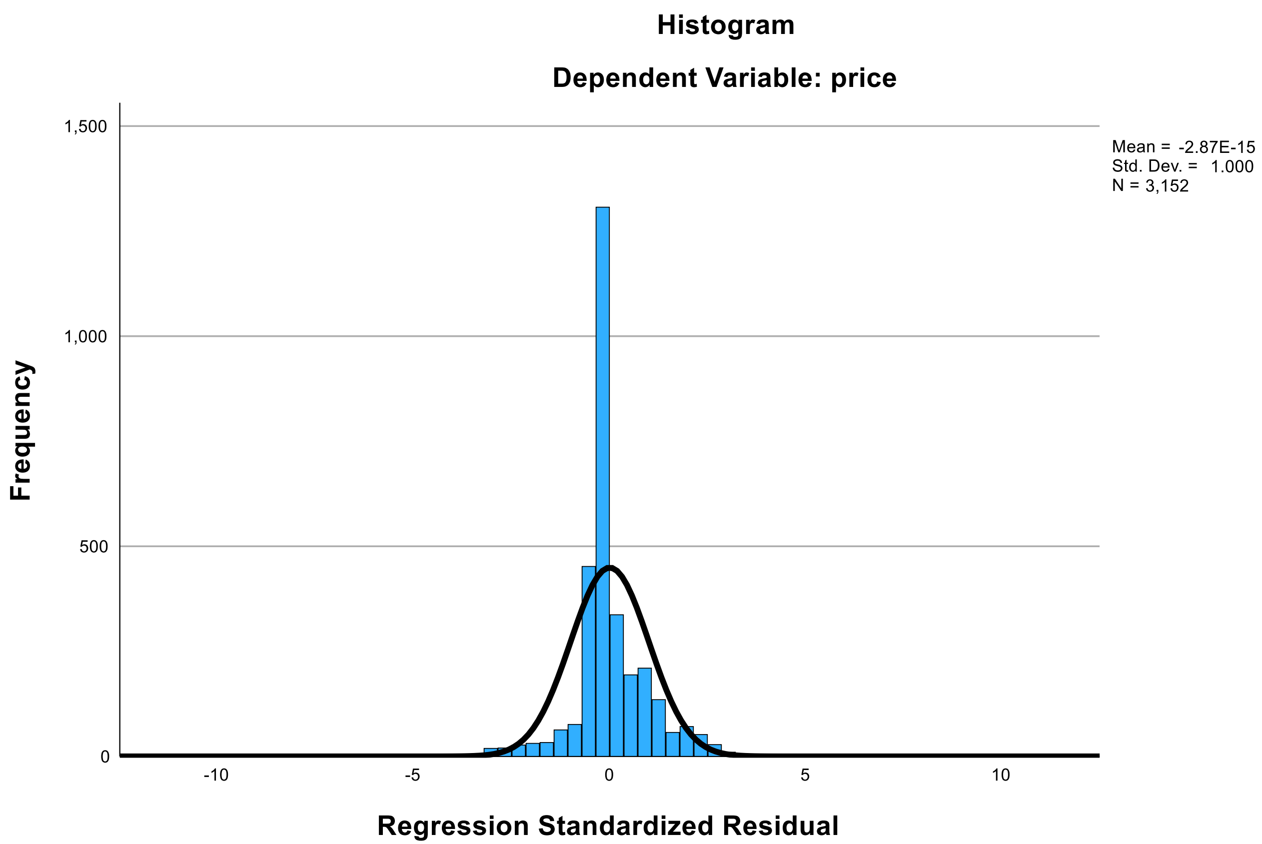
Annex 24 - Collinearity Diagnostics from Spain's model

				Variance Proportions			
Model	**Dimension**	**Eigenvalue**	**Condition Index**	**(Constant)**	**resepc**	**cons**	**ng_price**
3	1	3.558	1.000	.00	.01	.00	.02
	2	.368	3.110	.00	.02	.00	.93
	3	.068	7.230	.02	.95	.03	.00
	4	.006	25.145	.97	.03	.97	.04

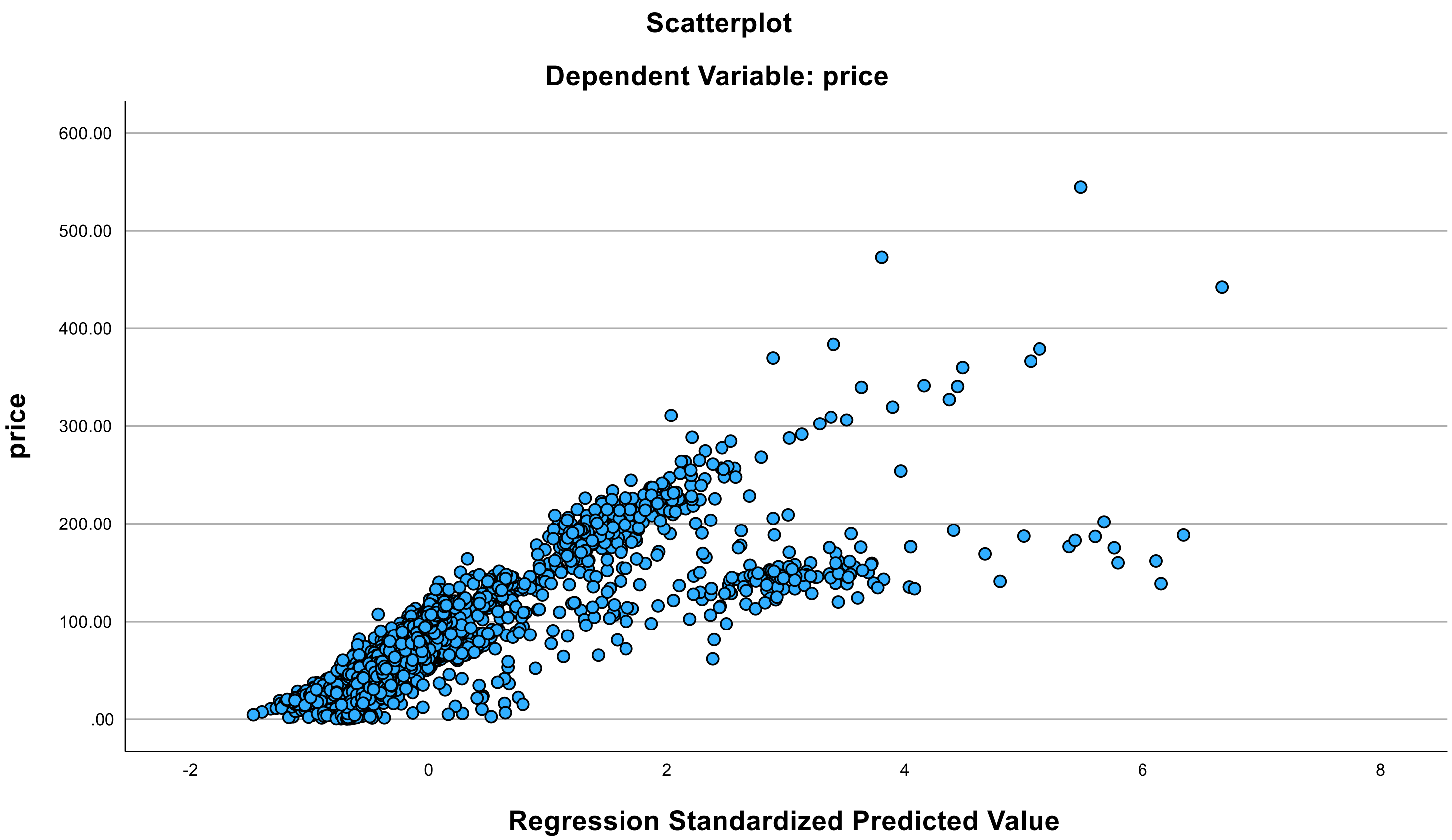
Annex 25 - Residuals Statistics from Spain's model

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	3.9544	383.7205	72.9418	46.65184	3152
Std. Predicted Value	-1.479	6.662	.000	1.000	3152
Standard Error of Predicted Value	.535	3.682	1.006	.339	3152
Adjusted Predicted Value	3.9523	382.8089	72.9518	46.68874	3152
Residual	-221.16391	222.63844	.00000	29.78947	3152
Std. Residual	-7.421	7.470	.000	1.000	3152
Stud. Residual	-7.471	7.490	.000	1.001	3152
Deleted Residual	-224.15068	223.80278	-.00999	29.89476	3152
Stud. Deleted Residual	-7.537	7.556	.000	1.003	3152
Mahal. Distance	.016	47.090	2.999	3.381	3152
Cook's Distance	.000	.188	.001	.007	3152
Centered Leverage Value	.000	.015	.001	.001	3152

Annex 26 – Histogram of Regression Standardized Residuals for *price* from Spain's model



Annex 27 – Scatterplot of Actual *price* vs. Predicted *price* from Spain's model



Model 4 - France

Annex 28 - Correlations from France's model

		price	resepc	cons	ngprice
Pearson Correlation	price	1.000	-.229	-.067	.923
	resepc	-.229	1.000	.183	-.106
	cons	-.067	.183	1.000	-.030
	ngprice	.923	-.106	-.030	1.000
Sig. (1-tailed)	price	.	<.001	<.001	<.001
	resepc	.000	.	.000	.000
	cons	.000	.000	.	.064
	ngprice	.000	.000	.064	.
N	price	2547	2547	2547	2547
	resepc	2547	2547	2547	2547
	cons	2547	2547	2547	2547

	ngprice	2547	2547	2547	2547

Annex 29 – Model summary from France's model

					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
4	.933[a]	.870	.870	36.111098086610080	.870	5666.124	3	2543	<.001	.549

Annex 30 – ANOVA tests from France's model

Model		Sum of Squares	df	Mean Square	F	Sig.
4	Regression	22166072.883	3	7388690.961	5666.124	<.001[b]
	Residual	3316101.003	2543	1304.011		
	Total	25482173.886	2546			

Annex 31 - Coefficients from France's model

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound	Correlations Zero-order	Correlations Partial	Correlations Part	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	46.097	3.351		13.757	<.001	39.527	52.668					
	resepc	-1.731	.098	-.130	-17.719	<.001	-1.923	-1.540	-.229	-.331	-.127	.956	1.046
	cons	-1.503E-6	.000	-.015	-2.122	.034	.000	.000	-.067	-.042	-.015	.966	1.035
	ngprice	2.719	.022	.909	126.345	<.001	2.677	2.761	.923	.929	.904	.989	1.011

Annex 32 – Coefficient correlations from France's model

Model			ngprice	cons	resepc
4	**Correlations**	ngprice	1.000	.011	.102
		cons	.011	1.000	-.181

	resepc	.102	-.181	1.000
Covariances	ngprice	.000	1.682E-10	.000
	cons	1.682E-10	5.019E-13	-1.255E-8
	resepc	.000	-1.255E-8	.010

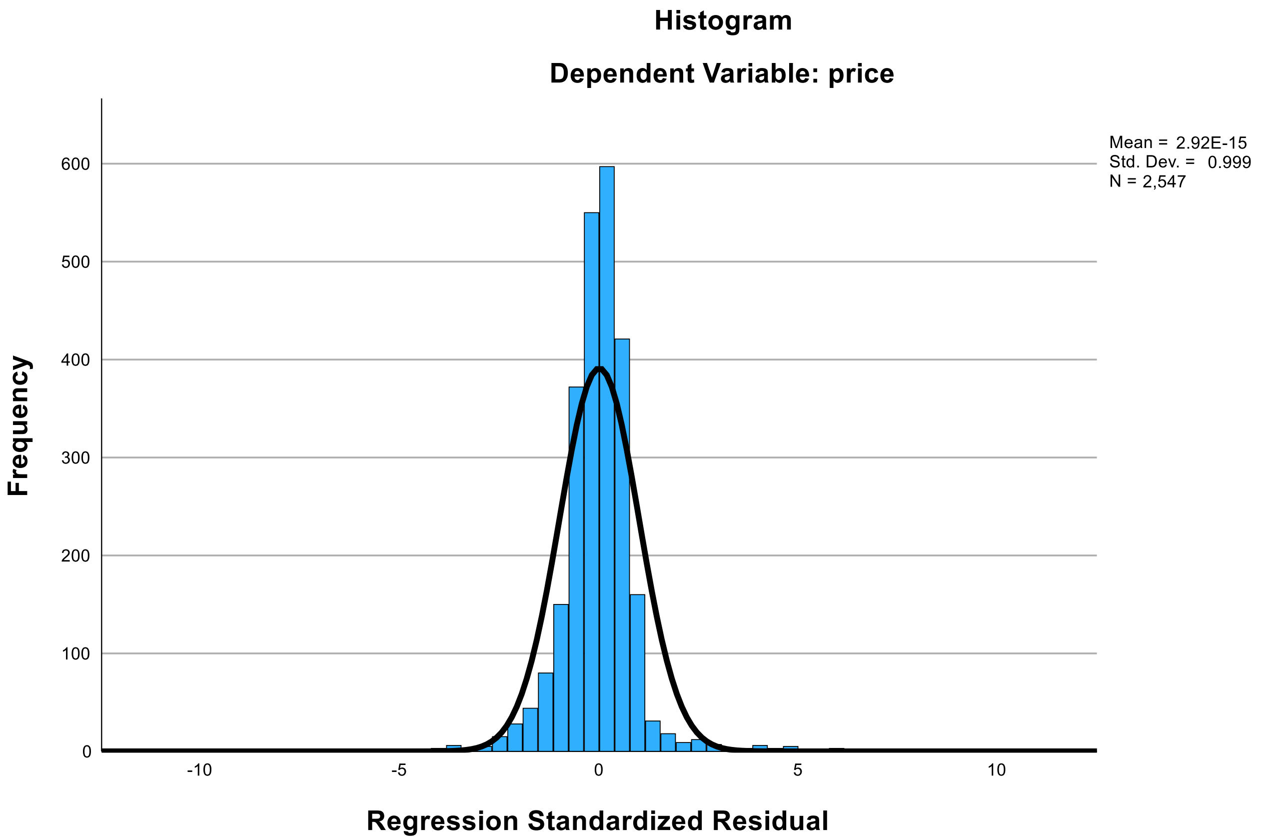
Annex 33 - Collinearity Diagnostics from France's model

				Variance Proportions			
Model	**Dimension**	**Eigenvalue**	**Condition Index**	**(Constant)**	**resepc**	**cons**	**ngprice**
4	1	3.494	1.000	.00	.01	.01	.03
	2	.404	2.942	.00	.01	.02	.90
	3	.072	6.973	.02	.35	.81	.00
	4	.031	10.651	.97	.63	.17	.07

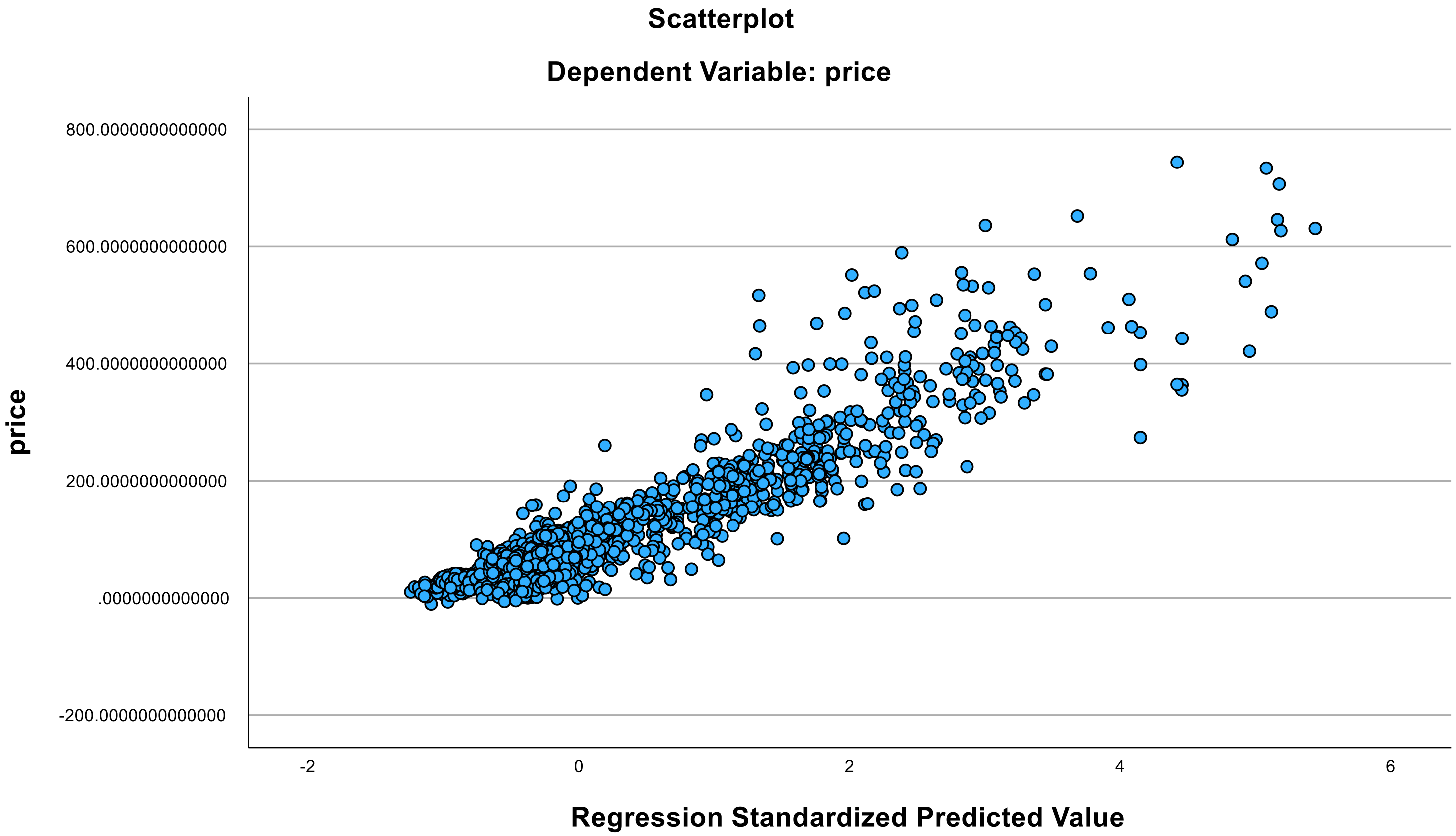
Annex 34 - Residuals Statistics from France's model

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-23.008239746093754	601.073059082031200	93.463415783274230	93.307204649791710	2547
Std. Predicted Value	-1.248	5.440	.000	1.000	2547
Standard Error of Predicted Value	.779	4.010	1.358	.452	2547
Adjusted Predicted Value	-23.150320053100582	600.704101562500000	93.459401179453820	93.299043735102770	2547
Residual	-206.338607788085970	299.362396240234400	.000000000000106	36.089816620413856	2547
Std. Residual	-5.714	8.290	.000	.999	2547
Stud. Residual	-5.735	8.296	.000	1.001	2547
Deleted Residual	-207.828384399414030	299.825927734375000	.004014603820636	36.190947780058070	2547
Stud. Deleted Residual	-5.771	8.409	.000	1.004	2547
Mahal. Distance	.186	30.401	2.999	3.204	2547
Cook's Distance	.000	.091	.001	.004	2547
Centered Leverage Value	.000	.012	.001	.001	2547

Annex 35 – Histogram of Regression Standardized Residuals for *price* from France's model



Annex 36 - Scatterplot of Actual *price* vs. Predicted *price* from France's model



Model 5 – DE/LU/AT

Annex 37 - Correlations from DE/LU/AT 's model

		price	resepc	cons	ngprice
Pearson Correlation	price	1.000	-.800	.237	.328
	resepc	-.800	1.000	-.262	-.039
	cons	.237	-.262	1.000	.032
	ngprice	.328	-.039	.032	1.000
Sig. (1-tailed)	price	.	<.001	<.001	<.001
	resepc	.000	.	.000	.222
	cons	.000	.000	.	.265
	ngprice	.000	.222	.265	.
N	price	390	390	390	390
	resepc	390	390	390	390

cons	390	390	390	390
ngprice	390	390	390	390

Annex 38 – Model summary from DE/LU/AT's model

					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
5	.854[a]	.729	.726	7.830288724135039	.729	345.270	3	386	<.001	.939

Annex 39 – ANOVA tests from DE/LU/AT's model

Model		Sum of Squares	df	Mean Square	F	Sig.
5	Regression	63509.107	3	21169.702	345.270	<.001[b]
	Residual	23666.981	386	61.313		
	Total	87176.088	389			

Annex 40 - Coefficients from DE/LU/AT's model

		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
5	(Constant)	58.687	4.819		12.179	<.001	49.213	68.161					
	resepc	-.970	.034	-.783	-28.462	<.001	-1.037	-.903	-.800	-.823	-.755	.930	1.075
	cons	1.842E-6	.000	.022	.813	.417	.000	.000	.237	.041	.022	.931	1.075
	ngprice	1.139	.102	.296	11.166	<.001	.939	1.340	.328	.494	.296	.998	1.002

Annex 41 – Coefficient correlations from DE/LU/AT's model

Model			ngprice	cons	resepc
5	**Correlations**	ngprice	1.000	-.023	.032
		cons	-.023	1.000	.262

	resepc	.032	.262	1.000
Covariances	ngprice	.010	-5.216E-9	.000
	cons	-5.216E-9	5.133E-12	2.018E-8
	resepc	.000	2.018E-8	.001

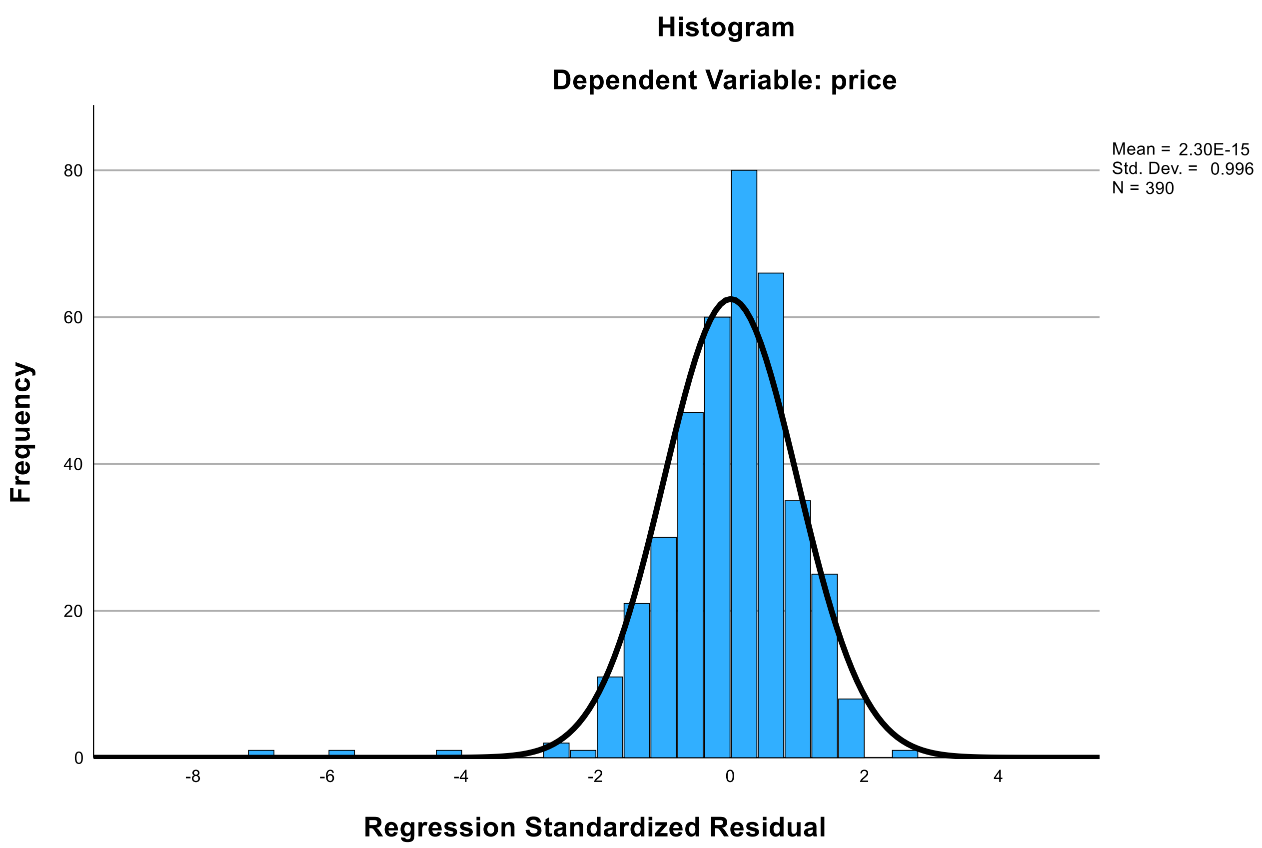
Annex 42 - Collinearity Diagnostics from DE/LU/AT's model

				Variance Proportions			
Model	**Dimension**	**Eigenvalue**	**Condition Index**	**(Constant)**	**resepc**	**cons**	**ngprice**
5	1	3.916	1.000	.00	.00	.00	.00
	2	.055	8.433	.00	.73	.02	.09
	3	.024	12.777	.02	.02	.17	.80
	4	.005	29.271	.98	.25	.80	.11

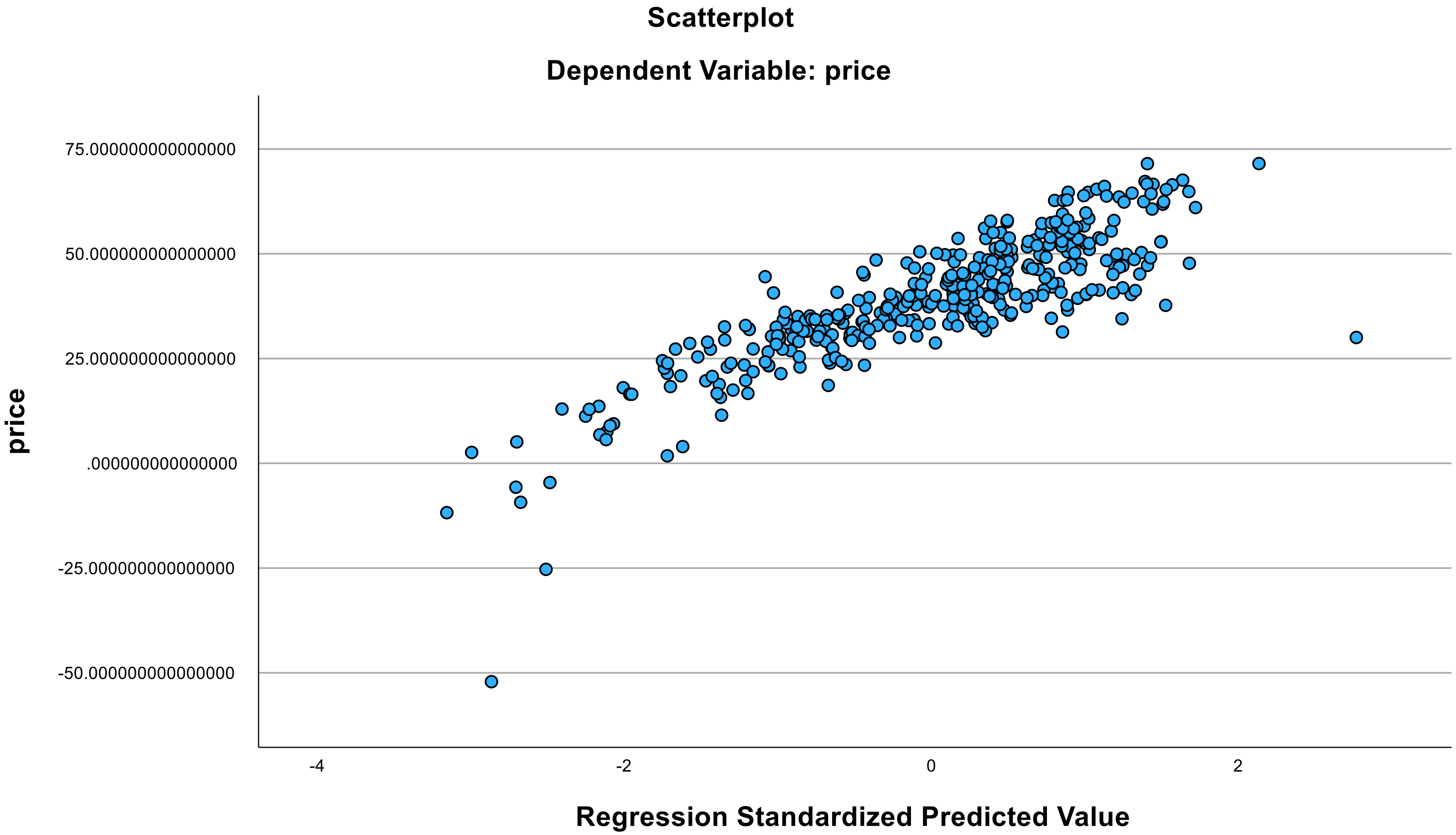
Annex 43 - Residuals Statistics from DE/LU/AT'S model

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-1.212377071380615	74.550361633300780	39.184256410256410	12.777420942771960	390
Std. Predicted Value	-3.162	2.768	.000	1.000	390
Standard Error of Predicted Value	.403	4.199	.741	.282	390
Adjusted Predicted Value	-.873528540134430	92.529724121093750	39.246759793710020	12.932838936120150	390
Residual	-54.617534637451165	19.215547561645508	.000000000000020	7.800036368691176	390
Std. Residual	-6.975	2.454	.000	.996	390
Stud. Residual	-7.060	2.466	-.004	1.020	390
Deleted Residual	-62.509719848632810	19.410066604614254	-.062503383453619	8.215856366682353	390
Stud. Deleted Residual	-7.556	2.483	-.007	1.038	390
Mahal. Distance	.035	110.889	2.992	6.047	390
Cook's Distance	.000	4.583	.015	.233	390
Centered Leverage Value	.000	.285	.008	.016	390

Annex 44 – Histogram of Regression Standardized Residuals for *price* from DE/LU/AT's model



Annex 45 - Scatterplot of Actual *price* vs. Predicted *price* from DE/LU/AT's model



Model 6 – DE/LU

Annex 46 - Correlations from DE/LU's model

		price	resepc	cons	ngprice
Pearson Correlation	price	1.000	-.293	.059	.916
	resepc	-.293	1.000	-.273	-.053
	cons	.059	-.273	1.000	-.030
	ngprice	.916	-.053	-.030	1.000
Sig. (1-tailed)	price	.	<.001	.003	<.001
	resepc	.000	.	.000	.007
	cons	.003	.000	.	.081
	ngprice	.000	.007	.081	.
N	price	2161	2161	2161	2161
	resepc	2161	2161	2161	2161

	cons	2161	2161	2161	2161
	ngprice	2161	2161	2161	2161

Annex 47 – Model summary from DE/LU's model

					Change Statistics					
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**R Square Change**	**F Change**	**df1**	**df2**	**Sig. F Change**	**Durbin-Watson**
6	.949[a]	.900	.900	29.371054268205175	.900	6479.924	3	2157	<.001	.809

Annex 48 – ANOVA tests from DE/LU's model

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
6	Regression	16769891.345	3	5589963.782	6479.924	<.001b
	Residual	1860755.094	2157	862.659		
	Total	18630646.439	2160			

Annex 49 - Coefficients from DE/LU's model

		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
6	(Constant)	68.210	6.351		10.741	<.001	55.756	80.665					
	resepc	-1.356	.040	-.240	-33.807	<.001	-1.435	-1.278	-.293	-.589	-.230	.922	1.085
	cons	1.161E-5	.000	.021	2.897	.004	.000	.000	.059	.062	.020	.924	1.083
	ngprice	1.799	.014	.904	132.568	<.001	1.772	1.825	.916	.944	.902	.995	1.005

Annex 50 – Coefficient correlations from DE/LU's model

Model			ngprice	cons	resepc
6	**Correlations**	ngprice	1.000	.046	.064

	cons	.046	1.000	.275
	resepc	.064	.275	1.000
Covariances	ngprice	.000	2.519E-9	3.462E-5
	cons	2.519E-9	1.607E-11	4.417E-8
	resepc	3.462E-5	4.417E-8	.002

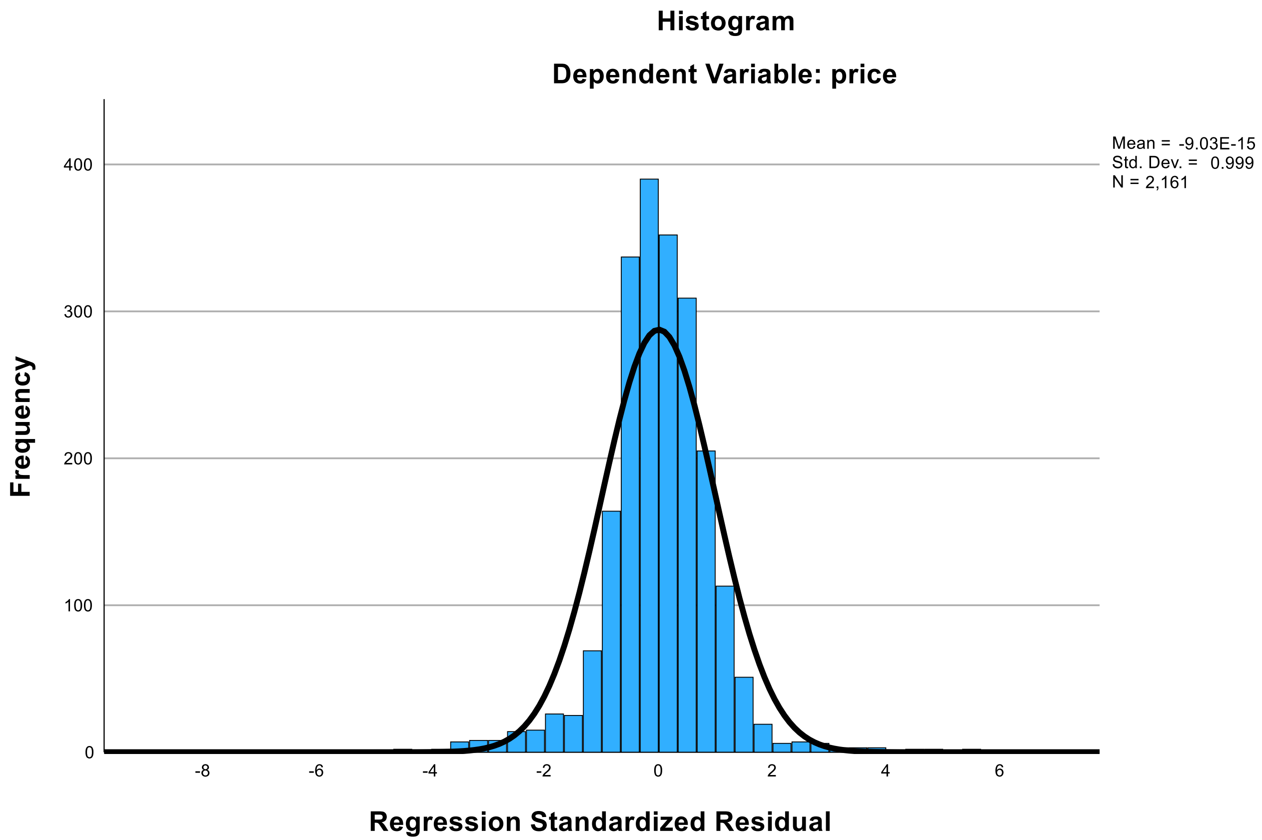
Annex 51 - Collinearity Diagnostics from DE/LU's model

				Variance Proportions			
Model	**Dimension**	**Eigenvalue**	**Condition Index**	**(Constant)**	**resepc**	**cons**	**ngprice**
6	1	3.468	1.000	.00	.01	.00	.03
	2	.453	2.766	.00	.02	.00	.94
	3	.072	6.930	.01	.75	.05	.02
	4	.006	24.392	.99	.23	.95	.01

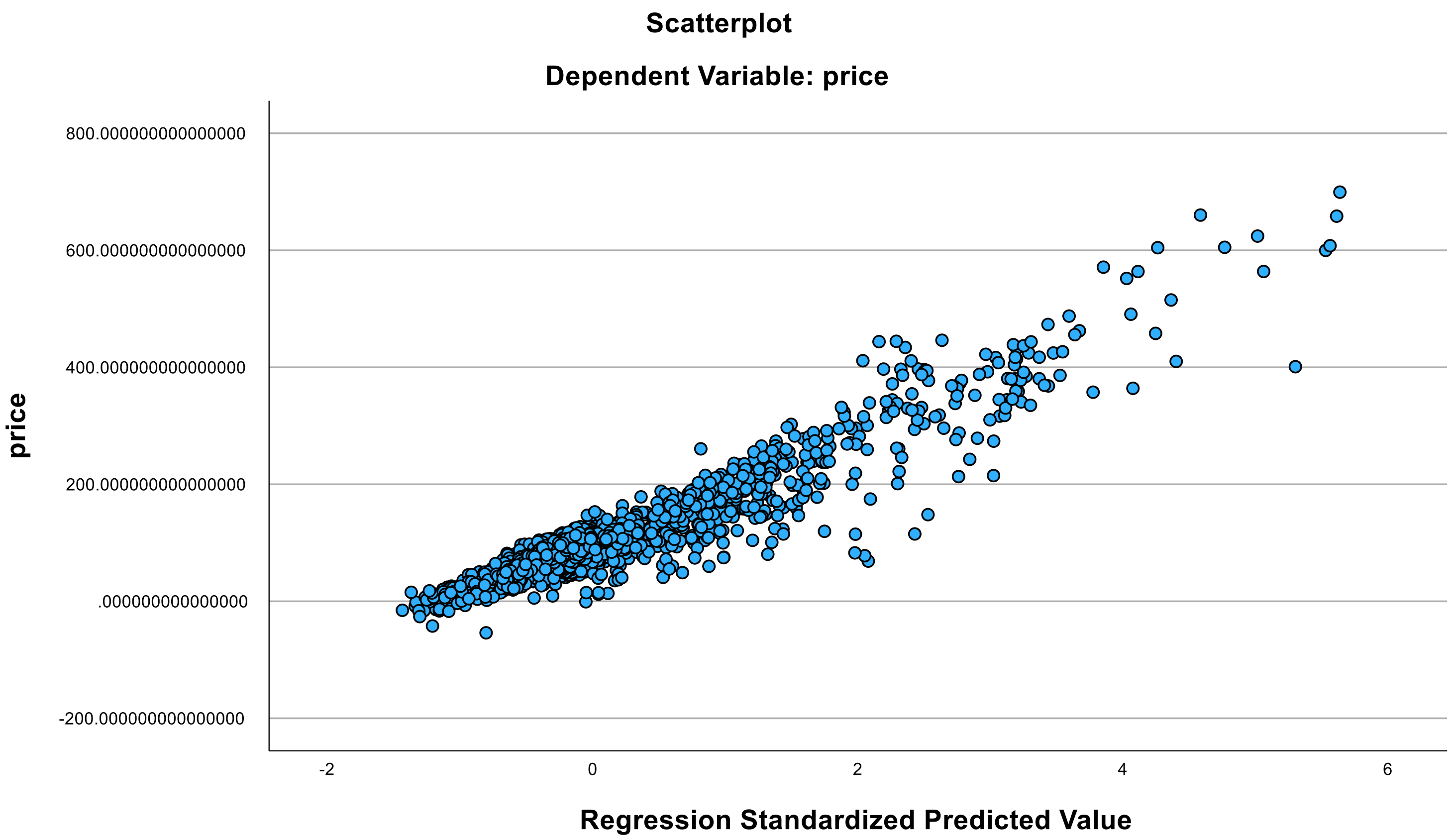
Annex 52 - Residuals Statistics from DE/LU's model

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-32.983638763427734	590.319763183593800	93.776145303100720	88.112647137408930	2161
Std. Predicted Value	-1.439	5.635	.000	1.000	2161
Standard Error of Predicted Value	.637	3.842	1.199	.398	2161
Adjusted Predicted Value	-33.049949645996094	588.568481445312500	93.778777110534720	88.102424821997390	2161
Residual	-207.988540649414030	162.618377685546880	-.000000000000261	29.350650615678695	2161
Std. Residual	-7.081	5.537	.000	.999	2161
Stud. Residual	-7.103	5.566	.000	1.001	2161
Deleted Residual	-209.229553222656250	164.371734619140650	-.002631807434220	29.462222549477946	2161
Stud. Deleted Residual	-7.185	5.606	.000	1.004	2161
Mahal. Distance	.018	35.962	2.999	3.187	2161
Cook's Distance	.000	.131	.001	.005	2161
Centered Leverage Value	.000	.017	.001	.001	2161

Annex 53 – Histogram of Regression Standardized Residuals for *price* from DE/LU's model



Annex 54 - Scatterplot of Actual *price* vs. Predicted *price* from DE/LU's model



Model 7 - Austria

Annex 55 - Correlations from Austria's model

		price	resepc	cons	ngprice
Pearson Correlation	price	1.000	-.249	.125	.948
	resepc	-.249	1.000	-.529	-.216
	cons	.125	-.529	1.000	.018
	ngprice	.948	-.216	.018	1.000
Sig. (1-tailed)	price	.	<.001	<.001	<.001
	resepc	.000	.	.000	.000
	cons	.000	.000	.	.207
	ngprice	.000	.000	.207	.
N	price	2161	2161	2161	2161
	resepc	2161	2161	2161	2161

cons	2161	2161	2161	2161
ngprice	2161	2161	2161	2161

Annex 56 – Model summary from Austria's model

					Change Statistics					
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**R Square Change**	**F Change**	**df1**	**df2**	**Sig. F Change**	**Durbin-Watson**
7	.955[a]	.911	.911	29.620674863875006	.911	7373.633	3	2157	<.001	.694

Annex 57 – ANOVA tests from Austria's model

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
7	Regression	19408531.933	3	6469510.644	7373.633	<.001[b]
	Residual	1892518.106	2157	877.384		
	Total	21301050.039	2160			

Annex 58 - Coefficients from Austria's model

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
7	(Constant)	-79.327	7.451		-10.647	<.001	-93.938	-64.715					
	resepc	.076	.033	.018	2.311	.021	.012	.141	-.249	.050	.015	.677	1.477
	cons	.001	.000	.118	15.482	<.001	.000	.001	.125	.316	.099	.710	1.408
	ngprice	2.024	.014	.950	143.555	<.001	1.997	2.052	.948	.951	.921	.940	1.063

Annex 59 – Coefficient correlations from Austria's model

Model			ngprice	cons	resepc
7	**Correlations**	ngprice	1.000	.117	.244
		cons	.117	1.000	.538
		resepc	.244	.538	1.000

Covariances	ngprice	.000	5.439E-8	.000
	cons	5.439E-8	1.092E-9	5.885E-7
	resepc	.000	5.885E-7	.001

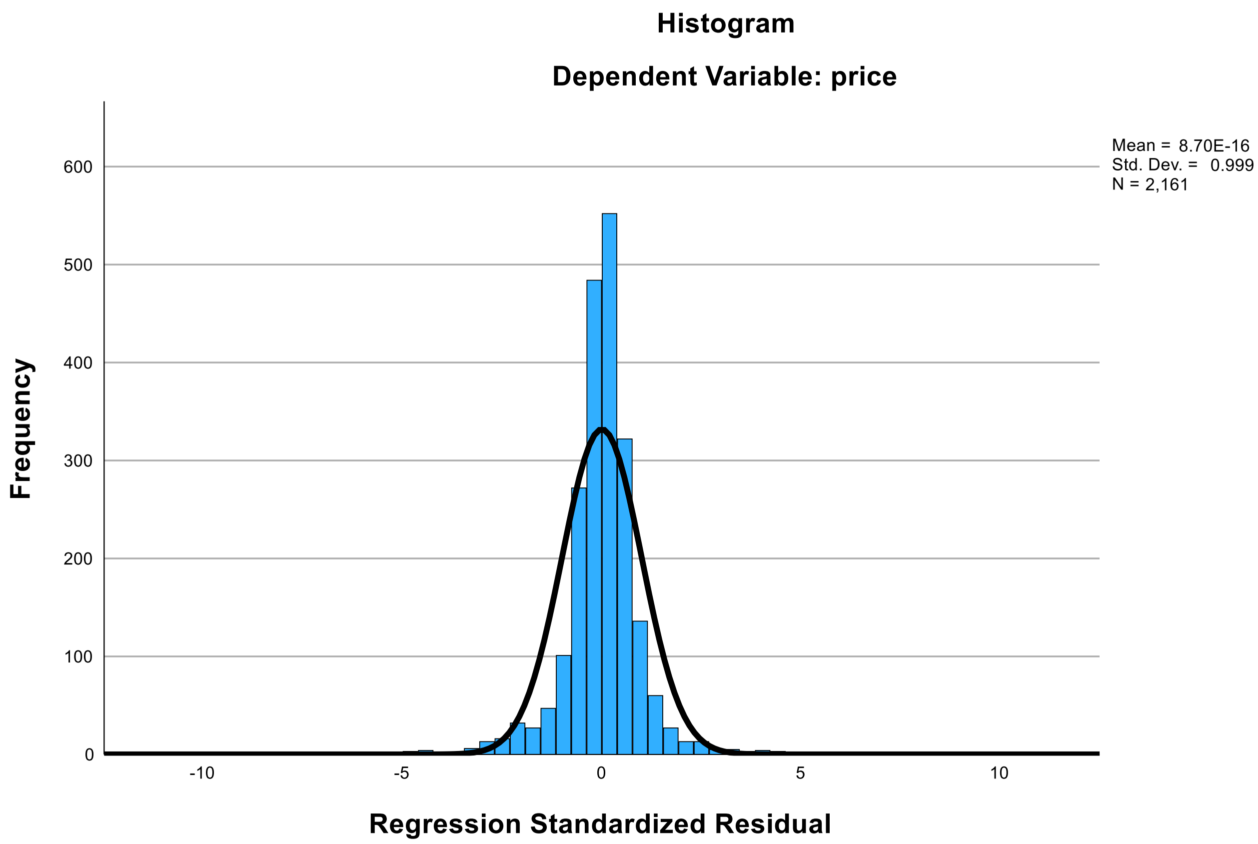
Annex 60 - Collinearity Diagnostics from Austria's model

				Variance Proportions			
Model	**Dimension**	**Eigenvalue**	**Condition Index**	**(Constant)**	**resepc**	**cons**	**ngprice**
7	1	3.457	1.000	.00	.00	.00	.03
	2	.468	2.718	.00	.01	.00	.86
	3	.070	7.014	.01	.45	.07	.07
	4	.005	27.410	.99	.53	.93	.05

Annex 61 - Residuals Statistics from Austria's model

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-2.087898969650268	643.570739746093800	101.966455344747630	94.791515708550960	2161
Std. Predicted Value	-1.098	5.714	.000	1.000	2161
Standard Error of Predicted Value	.640	3.876	1.213	.392	2161
Adjusted Predicted Value	-2.119190692901611	642.936401367187500	101.965913748599890	94.782110303618140	2161
Residual	-230.920379638671880	185.646667480468750	.000000000000025	29.600097803480390	2161
Std. Residual	-7.796	6.267	.000	.999	2161
Stud. Residual	-7.819	6.301	.000	1.001	2161
Deleted Residual	-232.279953002929700	187.651367187500000	.000541596147908	29.699371664571740	2161
Stud. Deleted Residual	-7.930	6.359	.000	1.004	2161
Mahal. Distance	.009	35.987	2.999	3.181	2161
Cook's Distance	.000	.107	.001	.005	2161
Centered Leverage Value	.000	.017	.001	.001	2161

Annex 62 – Histogram of Regression Standardized Residuals for *price* from Austria's model



Annex 63 - Scatterplot of Actual *price* vs. Predicted *price* from Austria's model