External market disruptions and carbon pricing

How the Russian gas ban tested the resilience of the European Emissions Trading System

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Abstract

Emissions trading systems (ETSs) have become a cornerstone of climate change mitigation policies because of their ability to achieve cost-effective emissions reductions and support sustainable development goals. If coupled with market stabilizing mechanisms, they can maintain decarbonization targets through economic turbulence.

The armed conflict between Russia and Ukraine led to the imposition of a European Union (EU)-wide ban on Russian gas, spurring unprecedented gas price increases across the EU. Research has shown that gas and carbon prices are often associated with one another, but carbon prices in the EU ETS have remained stable.

Using a mixed-method analysis, this thesis compares changes in carbon and gas prices in the EU ETS and the California Cap and Trade (CCAT) associated with the ban on Russian gas imports into the EU - two distinct ETSs where only one (EU ETS) experienced an external market shock.

This study finds a statistically significant association between gas and carbon prices in both the EU ($p=0.0007$) and Californian markets ($p=0.0000$) *before* MSR deployment in the EU. The association disappears in the EU post-MSR deployment, which supported by the literature suggests the MSR was likely responsible for the EU's carbon price stabilization. This is an important consideration for policymakers who want to ensure they can achieve emissions reductions through turbulent economic conditions.

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Abbreviations

- California Cap and Trade (CCAT)
- Emissions trading systems (ETSs)
- European Union (EU)
- Greenhouse gas (GHG)
- Intergovernmental Panel on Climate Change (IPCC)
- Market Stability Reserve (MSR)
- Market stabilization mechanisms (MSMs)

Chapter 1: Introduction

Policymakers have proposed many strategies aimed at mitigating the global threat of climate change, which stems from anthropogenic fossil fuel combustion (Allen 2018). These strategies are responses to the latest climate research which calls for urgent action to avoid catastrophic impacts like ecosystem and food system disruptions (Allen 2018). Theoretically, these impacts can be abated with policy actions that neutralize carbon equivalent emissions before 2050 (Allen 2018).

One strategy that has been widely embraced is the emissions trading system (ETS) which is a carbon market mechanism that allows bodies (like governments or corporations) to buy and sell emissions permits which gradually decrease in quantity over a scheduled period (International Emissions Trading Association 2019). The ETS has been embraced as a promising tool by both public and private sectors for its perceived ability to achieve widespread emissions reductions in a cost-effective manner (International Emissions Trading Association 2019). These qualities explain why the Paris Agreement includes plans for an international ETS that will work alongside other mitigation efforts (The World Bank 2022b). Even so, recent developments have put the resiliency of ETSs into question.

The armed conflict between Russia and Ukraine led to the imposition of a European Union (EU)-wide ban on almost all Russian gas imports leading to a drastic reduction in gas deliveries to the EU (European Commission 2022a). Among the many adverse impacts on the EU, rising energy prices was one of the most prominent. Gas prices increased by as much as 1,900 percent between March 2021 and November 2022, a timespan that includes the build-up and anticipation of conflict, both of which likely generated price volatility (Trading Economics 2022b).

As gas prices continued to burden EU residents, many nations decided to accelerate their clean energy transitions in an effort to cut economic ties with Russia while also distancing themselves from the volatile gas industry (Zaretskaya and Wilczewski 2022). These accelerated transitions coupled with the EU-wide ban on Russian gas imports had cascading effects on other markets, including the European Union ETS (EU ETS).

Carbon allowance prices in the EU ETS experienced unprecedented price fluctuations of as much as 192 percent between March 2021 and November 2022 (Trading Economics 2022a). During the same period, European gas prices fluctuated at a much higher rate. Some experts believe the market stability reserve (MSR) helped to avoid higher rates of fluctuation (Burtraw et al. 2021). For context, an MSR is a rule-based adjustment to the supply of emission allowances that either increases or decreases the total amount of allowances in circulation (Burtraw et al. 2021). Accordingly, MSR was deployed in an attempt to stabilize allowance prices after the Russian gas ban (Trading Economics 2022a; California Air Resources Board 2023).

Although ETSs have proven to be effective at reducing emissions (International Energy Agency 2020), limited research exists on how capable ETSs are at withstanding external market disruptions. The Russian gas ban in the EU provides a unique opportunity to explore the resiliency of ETSs and their stabilizing mechanisms in the face of volatile external market conditions, which is the focus of my thesis. My goal is to discover how the EU ETS managed to keep price movements under control despite the unexpected disruption of gas supply. By determining this association, policymakers will be able to deploy stabilizing mechanisms that will allow other ETSs to remain effective at reducing emissions in as many market conditions as possible.

Chapter 2: Methods

The unprecedented energy crisis in Europe caused by the Russian gas ban provides a unique opportunity to see how effective the EU ETS MSR was at stabilizing the price of carbon allowances. This can be done by comparing how the EU ETSs allowance price has changed throughout the build-up of the Russian invasion of Ukraine and mapping out a timeline of events that led us to price stabilization. To aid with this analysis, I also compare price movements and stabilization deployment in the California Cap and Trade (CCAT): a carbon market that is not directly impacted by the Russian invasion or gas ban because California does not import Russian gas. Since the invasion is ongoing, the full extent of the fallout will not be known for potentially many years – so these methods intend to address the short-term impacts through the end of 2022. Therefore, the methods of this thesis intend to explore the following question:

- ***How effective has the EU ETS MSR been at stabilizing short-term carbon allowance prices after the Russian invasion and gas ban?***

These methods compare how two separate ETSs reacted to unanticipated gas price fluctuations – the EU ETS and the CCAT. The purpose is to assess what mechanisms are effective at ensuring that carbon markets remain effective through uncertainty. ETSs have the potential to lead global decarbonization efforts, so it is important that regulating bodies develop methods to monitor and respond to disturbances that could destabilize their carbon markets. To support my research, I will also explore the following questions:

- ***What can the CCAT teach us about carbon price movements outside of the EU?***
- ***How do price movements in the EU ETS compare to the CCAT's?***
- ***Which stabilizing mechanisms make ETSs more resilient?***

These questions will expand my understanding of the unique impacts the Russian gas ban had on the EU ETS by exploring a market that was not directly impacted by the conflict. The CCAT ranks among the largest ETSs in the world and also contains its own stabilizing mechanisms. Comparing the two markets will provide insight into the relationship between gas and carbon markets, the undisturbed pattern of price movements in matured carbon markets, and lessons on effective policy structures that allow for ETSs to generate revenue and mitigate carbon emissions. The lessons learned from this comparative analysis will guide the conclusions and policy implications from this study.

Part I: Literature Review

I first conducted a comprehensive literature review on the current state of climate change relying on modern science-based research referenced by the IPCC's latest climate assessment. This set the stage by confirming the importance of climate change mitigation efforts that include both private and public sectors. Subsequently, I summarized the Paris Agreement's efforts to support global emissions reductions which include the establishment of an international trading scheme with the structure of an ETS. This was followed by a description of carbon markets – specifically ETSs – and the latest research on how effective they are at achieving GHG reductions. Similarly, I review the importance of market stabilizing mechanisms and the structures that have been observed to be effective price stabilizers.

I then provided a thorough description of the EU ETS and traced back its development into a leading carbon pricing scheme that has supported GHG reductions – while emphasizing the controversy over its effectiveness. The same can be said about the EU ETS MSR which I also provide a description of along with some of the contentious opinions about its effectiveness as a price stabilizer. These subsections provided necessary framing before I dove into the conflict that inspired this thesis topic.

I conducted a cogent re-tracing of the events leading up to and following the Russian invasion of Ukraine. This was done to provide evidence that price fluctuations in both gas and carbon markets may have begun far before the actual invasion began. I also detailed all of Russia's and the EU's economic sanctions pertaining to gas deliveries, which served as the entry point for my qualitative data analysis. To visualize the impact of these sanctions, I graphed both carbon and gas price movements in a few time series that included all major dates from the invasion up to the end of 2022. These visualizations helped to illustrate the connections between the Russian gas ban and carbon/gas price movements in the EU.

I followed this with a description of the CCAT and its relevance as a good reference point for comparison: that being its position as a large and matured ETS that operates in a market not directly tied to the Russian gas network. Although it is likely that other factors may have impacted carbon and gas prices in California, the immediate shock of pulling an important fuel source was not felt in the state. Additionally, the market provided an opportunity to compare the relationship between carbon and gas markets in two different regions of the world. Insights from that comparison can be used to determine if the gas-carbon decoupling was unique to the EU ETS. I also provided a brief description of the CCAT's stabilization mechanisms and how they compare to the MSR. I paired these findings with carbon price visualizations to show how the stabilization implementation differs from the MSR.

I reviewed a wide range of documents including hundreds of intergovernmental policies, peer reviewed economic and environmental journals, reputable news articles on the Russian invasion, carbon/gas price databases, and legislative documents. In total, I included no less than 67 reputable sources in the final deliverable. Some of these resources are listed below:

Paris Agreement's articles on carbon markets; official EU ETS Commission documents and announcements; CCAT Commission documents and announcements; carbon and gas price databases from Trading Economics and the World Bank; recent (from the last 4 years) peer-reviewed literature, media, and government documents on carbon markets; the latest IPCC reports on climate change; and reports on the Ukrainian invasion along with other documents that will support each case study.

Part II: Data Analysis

Qualitative Analysis

I included a portion of my qualitative analysis in the literature review because it was helpful to illustrate the timeline of the major events involved in the Russian gas ban. Part II served as an expansion of my literature review to explore my research sub-questions in more detail. My goal was to see if I could deduce any associations between key dates and price trends in all the markets I reviewed (California and the EU). The qualitative analysis included visualizations of the events leading up to, during, and after deployment of the MSR and a similar recounting for European gas prices. This involved first mapping key events collected during my literature review of the Russian invasion. I then used daily carbon and gas price data collected from Trading Economics and other sources and tied those key dates to their corresponding points on a timeline of price movements. These points included the publicized build-up of Russian armed forces along Ukraine's border, the first day of invasion, the beginning of sanctions against Russian exports, the Russian gas ban in the EU, and deployment of MSR to stabilize carbon prices. I then tracked how prices changed at each of these junctures for both markets and compared observations between the two with the goal of showing exactly when and how the MSR managed to stabilize prices in the EU ETS. A similar analysis can be found for CCAT allowance prices. California gas prices were graphed against EU gas prices to visualize the immense difference in market conditions in the two regions. This laid the groundwork for the analysis of CCAT carbon prices and a recounting of events that may have led to the price trends since early 2020. The purpose was to show how these markets differed in their reactions to the Russian gas ban, but also show how undisturbed carbon prices move in relation to gas prices. This comparison shed light onto the effects of market stabilization mechanisms in the EU ETS and carbon markets generally.

Quantitative Analysis

To support these qualitative observations, I conducted Spearman and Pearson correlation analyses of gas price vs carbon price movements in each region (CCAT vs EU ETS) to show how the price movements began to differ before and after the MSR was deployed in the EU ETS. I chose both correlation methods because they each provide insight on the connection between the two markets, with Spearman ranked correlation providing a more robust comparison. Pearson correlations only measure a linear relationship between the two variables, whereas Spearman measures the degree of association between two sets of variables based on their ranks. I also looked at key dates throughout the invasion to assess when gas and carbon prices "decoupled" and how that illustrates the unique price impact of the MSR. CCAT correlations were used to show how unique the EU ETS's decoupling was and help in understanding the extent to which the MSR is uniquely accountable for the price stabilization. This analysis was accompanied by graphical representations with labels for all key dates and correlation test results.

In addition, I analyzed the exponential relationship between carbon and gas prices by graphing a scatterplot of prices in both markets. An exponential trendline was fitted to the scatterplot to visualize the statistically significant relationship between the two markets that became insignificant as gas prices increased due to MSR deployment. Given the amount of pre-MSR deployment datapoints, the trendline will suggest an association between the two markets despite the increased noise at higher gas price points.

This mixed method approach using a literature review paired with qualitative and quantitative data provided a comprehensive review of the MSR's effectiveness at price stabilization. Additionally, the information was used to assess whether the MSR mechanism has performed in its intended purpose. The CCAT served as a comparison case to see how a carbon market outside of Russia's immediate influence has performed during the same period.

Purpose of the Comparative Analysis

The CCAT and EU ETS were chosen for this comparative analysis because of their scope, independence from each other (Californian and European markets operate separately, including how they source energy), and data availability. The CCAT is a large carbon market, although not as big as the EU ETS. Despite this, they cover similar sectors and involve similar decarbonization pathways. They also have unique market stabilization mechanisms that provide insight on different stabilization applications. Along with these factors, CCAT and EU ETS both have publicly accessible databases that provide information on prices and allocations.

Tracking the movements of the CCAT in relation to Californian gas prices served to confirm what the literature concludes – that a relationship exists between the price movements of carbon and gas markets. Correlation tests can reveal the extent of this relationship and serve as an example of carbon price movements in relation to gas prices in a relatively stable market (compared to the EU). As the data showed, California did not experience a gas price spike in response to the Russian gas ban. So, if the ban did impact the Californian markets, it was not reflected in the form of a market disruption.

A correlation analysis can serve to identify what exactly caused the EU ETS to decouple from European gas prices. This will help to assess how effective the EU ETS MSR was at stabilizing carbon prices. Theoretically, the change in correlation post-MSR deployment will only be detected in the EU ETS while the CCAT associations will remain consistent.

Considerations were also made for a comparison between two separate ETSs that experienced the Russian gas ban destabilization – one with a stabilization mechanism and one without – because it would also serve as an effective method to tease out the impact of the MSR. Unfortunately, there were limited ETSs with publicly available data and no good example of an ETS in the EU without a stabilizing mechanism. Carbon market pricing and market stabilization data availability is generally difficult to access. This made the prospect of using California's intuitive CCAT database more appealing given data and time constraints.

Although comparing markets exposed to destabilization is useful, there is value in comparing markets that are separate from each other because of the insight that can be drawn from their price trends. For example, comparing the CCAT and EU ETS allows us to explore what we can learn from the relationship between gas and carbon markets. It also serves as an example of the interconnections between ETSs worldwide and how each one offers lessons on what an effective ETS should look like.

Part III: Discussion and Policy Implications

Both the literature review and data analysis will help policymakers derive a better understanding of the risks ETSs face from external market disruptions and how to properly combat them. That way, ETSs can be structured to maximize carbon reductions while ensuring they don't lose their influence during economically turbulent periods. Using these guidelines, I discussed my findings from the literature review to summarize the latest research on ETSs and MSMs. I paired these findings with a discussion about my data analysis and literature to provide conclusions about the associations between gas and carbon prices in the EU and California, and how the EU ETS MSR may have impacted that relationship. I then summarize my conclusions on effective MSM implementation techniques and how they connect to a broader discussion about effective ETSs and sustainable development.

Following this, I presented a series of policy recommendations pertaining to the use of ETSs as a GHG reduction tool that helps to ensure resilience through market instability. I pair these with a series of alternative market or non-market solutions that should be implemented alongside ETSs to address as many sustainable development goals as possible while reducing emissions. These recommendations extend to the implementation of stabilization mechanisms guided by a combination of literature and observations from my analysis.

Chapter 3: Literature Review

Emissions Trading Systems and their Role in GHG Reduction

The projected impacts of climate change have motivated both private and public entities to propose decarbonization / climate change mitigation efforts that are both cost effective and time efficient (Allen 2018). These efforts stem from the scientific consensus that carbon dioxide (CO_2) emissions from anthropogenic fossil fuel combustion are primarily responsible for the rapid change in Earth's ecosystems, and a significant reduction in these emissions are needed to prevent global average temperatures from breaching 1.5 degrees Celsius (Allen 2018). If successful, preventing this temperature increase will prevent irreversible climate change and ecosystem degradation on a global scale. Climate science is an important consideration to frame ETSs because science should inform how they are structured, from emission reduction timelines to scope and everything in between. The mission should be to support rapid and effective emissions reduction along with generating incentives for clean technology development.

The Intergovernmental Panel on Climate Change (IPCC) – the leading organization created to provide policymakers with up-to-date climate assessments and mitigation options – recently published their sixth assessment report where they are unequivocal about the need for large-scale climate change mitigation efforts. They call for all governments to systematically reduce their CO_2 emissions by at least 45 percent by 2030 with the goal of achieving net zero greenhouse gas (GHG) emissions across all sectors by 2050 (Allen 2018). The IPCC has promoted several market and non-market tools that can reduce global emissions if broadly adopted and implemented with haste. To ensure these tools are effective at meeting the science-based targets, they should support these reduction targets across as many sectors as possible.

One of these tools - an emissions trading system (ETS) – is a type of carbon market solution that can achieve cross-sector emissions reductions efficiently. An ETS is a market tool that creates a gradually decreasing cap on the total amount of permissible GHG emissions by distributing emission allowances (also known as permits, vouchers, or carbon credits) to qualified organizations (Pineda 2021). These allowances represent a consistent quantity of carbon-equivalent emissions and can be bought by and sold to other qualified organizations in the market based on their individual emission levels (Pineda 2021). ETSs can:

1) Achieve cross-sector emissions reductions and generate government revenue through a unified/centralized system.

2) Have low administrative costs compared to non-ETS solutions.

3) Have low cost of compliance (Narassimhan et al. 2018).

As such, it is common for carbon-intensive organizations to buy larger quantities of allowances and more energy-efficient ones to sell theirs. This system incentivizes high-emitting organizations to invest in decarbonizing technologies that reduce their cost of compliance along with carbon emissions. ETSs will often include a scheduled decrease in the quantity of allowances which artificially drives their price up as less become available for purchase, thus increasing demand. This price increase will “unlock” clean technologies with higher marginal costs by making their deployment cost competitive compared to the cost of allowances. Progressively, an ETS will make net-zero operations financially feasible for all qualified organizations by a fixed date (usually 2050) (Pineda 2021). If an ETS is comprehensive enough, it can support each country’s efforts to reduce emissions according to the IPCC’s recommended schedule.

ETSs have been lauded as the most cost/labor efficient method of reducing carbon emissions because of their low cost of operation (compared to a carbon tax) and scalability (He and Song 2022; Hu et al. 2022). However, their effectiveness heavily depends on policy structure, how comprehensive the region's emissions data is, and how accurately emissions are reported. Additionally, different allowance allocation methods can impact an ETS's efficiency if the cost of entry creates a barrier for organizations to comply (He and Song 2022; Hu et al. 2022). For example, some ETSs allow for large emitters to collect free initial allocations to incentivize cooperation by reducing the cost of entry. There remains a lot of debate around allocation strategies, cap setting, stabilization methods, and which sectors to qualify/exempt and many economists continue to monitor the pilot studies. Nonetheless, the conclusion from an extensive number of pilot studies as well as matured markets is that an ETS is capable of combating climate change by reducing emissions (Hu et al. 2022).

The first globally recognized ETS was established during the 1997 Kyoto Protocol on Climate Change, but ETSs have gone through substantial evolutions since that first attempt (Morgan 2006). Modern renditions often include more sectors, take advantage of better emissions tracking, and include more aggressive emissions caps (He and Song 2022; International Emissions Trading Association 2019). As of 2023, there are roughly 70 carbon pricing initiatives implemented worldwide, including 32 ETSs and 36 carbon tax systems, both of which are different types of carbon markets that look to price emissions and internalize an externality (The World Bank 2022a). Carbon taxes differ from ETSs in that they target consumer goods by adding a tax based on a calculated external cost – which guarantees a certain tax revenue but creates uncertainty around emission reduction (Sun 2021). Carbon taxes are as common as ETSs worldwide, but are less capable of ensuring guaranteed emissions reductions

(Sun 2021). This occurs because the underlying incentive in a carbon tax is reducing tax costs by reducing emissions - therein producing certainty about the revenue generation and uncertainty around the exact amount of resulting emissions reductions. It is unclear who will cut emissions and who will instead opt to pay the tax, so it is theoretically possible for some entities to continue emitting (Sun 2021). Alternatively, ETS's place a hard cap on emissions and let the market decide how much it will cost to comply. If participation is mandatory, it is unlikely that an entity will emit more than the permitted level. That being said, the two markets are effective in different ways, so it is not uncommon to see the two operating in the same market.

ETSs have a wide variety of structures, with some being regional and others national or international (The World Bank 2022a). Pricing varies widely by market depending on which sectors are covered, how matured the market is, and which stabilizing mechanisms are used (such as price floors/ceilings or stability reserves). Therefore, the effectiveness of each ETS varies substantially (Zhu, Long, and Gong 2022). For example, China's government has been experimenting with ETSs for many years and is home to several pilot ETSs across many regions of the country. Their goal is to eventually combine these pilot systems into one national trading system that will aid in their emission reduction targets (Hu et al. 2022). China's ETSs have been studied extensively with researchers developing new methods of assessing their effectiveness at emissions reductions like specialized difference-in-differences (DID) analyses (Aihua, Miglietta, and Toma 2022). The DID approach allowed researchers to conclusively determine that ETSs are capable of carbon emission reductions, and that surrounding policies/conditions can have a major impact on how capable they are.

Of the studies reviewed for this analysis, there was a consensus around the importance of an ETS for efficient decarbonization, but that implementation methods can have a major impact on specific levels of efficiency (He and Song 2022; Hu et al. 2022). That is because an ETS is a contraction approach to emission reduction, meaning they often include an emission reduction target (usually a net zero GHG emission target) across all included sectors by a specified date (Pineda 2021). The tool places an absolute cap on total emissions that decreases annually by reducing the number of allowances available for purchase. This system can theoretically scale to a global level through a unified international carbon trading network that could work to artificially reduce emissions on a wider scale than we have ever seen in history (Narassimhan et al. 2018). The system requires a regulating body – usually a government – to provide emissions allowances that represent a certain unit of CO_2 emissions to participating organizations either through an auction or free initial allocation (Narassimhan et al. 2018). After allocations, organizations have certain “compliance periods” where they are free to buy and sell allowances at a market-determined price (Narassimhan et al. 2018). If a regulated entity concludes the year with a surplus of allowances, they can be sold to entities that exceeded their cap for a market-determined value (Narassimhan et al. 2018). All of these stages act as potential fault points that can result in lower reductions than anticipated.

The entities that participate in an ETS can also impact reduction rates. Some require most high emitting entities to participate (such as the EU ETS), while others are regulated by industry (i.e. manufacturing, power, etc.), which is common in less matured “pilot” systems that are seen in the United States or China (He and Song 2022). Regardless of the structure, an ETS aims to reduce emissions by controlling the total amount of allocated allowances while simultaneously increasing the value of each allowance either artificially or through market demand (Narassimhan et al. 2018). ETSs are likely the most cost-effective method of emissions reductions because of their market-based structure that allows supply and demand to determine the cost of abatement. Non-market based environmental policies often include a large amount of "overhead" costs (such as administrative or speculated costs) that create bigger cost barriers. To be clear, just because ETSs can be cost effective does not mean they are necessarily the "best" solution, just that it will result in (likely) the lowest abatement cost per unit of emissions (Narassimhan et al. 2018).

It must be emphasized that an ETS cannot solve the climate crisis on its own. They usually operate in tandem with other mitigation efforts (like carbon taxes or renewable incentives) that work together to reduce emissions across all sectors (The World Bank 2022a). Although carbon market solutions can achieve significant emissions reductions, they are far from the only important factor in sustainable development, which is ultimately the larger goal of climate change mitigation policies. Rather, the emission reduction from an ETS is one important piece of a sustainable world that includes eradicating poverty, delivering clean and affordable energy, eliminating world hunger, and reducing inequalities among other important goals (United Nations 2022).

As mentioned, ETSs are far from the only method being used to reduce emissions, and in many cases the same governing body will deploy several market and non-market solutions simultaneously (International Emissions Trading Association 2019). Along with carbon taxes, there are carbon offsets which in theory would allow some sources of emissions to persist if the equivalent amount of emissions are captured and paired with renewable energy investments whenever possible (The World Bank 2022b). There are also several non-market solutions like creating legislation that provides equitable access to sustainable technologies by ensuring they are deployed in environmental justice communities. There are also more policies aimed at poverty, disease, and food injustice eradication which require legislative action but are just as critical to limiting the disproportionate impacts of climate change (Allen 2018). If implemented correctly, these solutions are capable of mitigating the worst impacts of climate change while raising the quality of life for all those who may be affected (United Nations 2022). With an ETS at the helm of the market solutions, we can also ensure that private sector organizations follow suit while remaining economically viable (Allen 2018).

This was cemented as a leading global strategy during the 2021 United Nations Climate Change Conference (COP26) where 120 nations gathered to expand the Paris Agreement so it conforms with newfound research on our rapidly depleting carbon budgets (United Nations 2021). During this conference, all nations agreed to accelerate their transitions away from fossil fuels, provide support to developing nations in their transitions, and finally establish norms for a carbon markets (United Nations 2021). The carbon markets component of the agreement was detailed in Article 6 of the revised Paris Agreement and includes rules for carbon market mechanisms like ETSs and carbon taxes (The World Bank 2022b). Article 6 also paves the groundwork for pilot programs so that developing nations can experiment with their own regional pilots at a lower cost. The ETS described in Article 6 also allows countries to transfer allowances with one another in a global emissions trading scheme under one centralized allowance verification system. The new agreement supports the deployment of ETS pilot studies to learn how emissions reductions can be achieved in the most cost-effective manner (The World Bank 2022b). Eventually, these markets could all consolidate into one that allows for any country signed into the Paris Agreement to buy or sell emission allowances in a global effort to reduce emissions. However many of these systems today remain local with only a handful extending beyond a single nation.

The European Emissions Trading System (EU ETS)

The European Emissions Trading System (EU ETS) was established in 2005 by the European Commission. It is one of the largest ETSs and is widely accepted as the most matured carbon market in the world (The World Bank 2022a). Although other ETSs like China's have seen extensive growth over the last decade, the EU ETS is unique in that it extends across all nations in the EU (plus Norway, Iceland, and Liechtenstein) and covers multiple sectors (power, industry/manufacturing, and aviation) (European Commission 2021b). The system encompasses 31 national jurisdictions and 4,001 mega-tonnes of CO_2-equivalent ($MtCO_2e$) emissions with its allowances, or just over three percent of global GHG emissions (Hintermayer 2020; The World Bank 2022a). This jurisdiction also covers roughly 40 percent of the EU's GHG emissions and requires participation from most power, manufacturing, and aviation-based organizations in the EU with some exceptions based on size (ex. small businesses may be exempt). As of 2023, there are around 1.5 billion allowances circulating in the EU ETS but that number can fluctuate depending on market conditions (more detail in the "Market Stability Mechanisms and the EU ETS MSR" section) (European Commission 2021b). The annual reduction of allowances is set at 43 million per year in order to keep pace with the EU Commission's goal of a 55 percent net reduction in GHG emissions from 1990 levels by 2030 and "climate neutrality" by 2050 (International Carbon Action Partnership 2022). Allowances trade at an average price per allowance around €80/tCO_2e bringing the total market value to €120 billion (The World Bank 2022a). Since its implementation Europe has seen an average annual emissions reduction of 3.5 percent which can be partially attributed to their ETS (The World Bank 2022a).

Allowance allocation methods have evolved over the lifetime of the ETS. For example prior to 2012, all allowances were distributed for free across the eight member states that were involved (International Carbon Action Partnership 2022). Then between 2012 and 2020, around half were auctioned and the remainder were allocated for free based on emission benchmarks as the primary focus was on developing methods to prevent carbon leakage (a.k.a. emitted carbon that was not accounted for through the allocations). As of 2021, the breakdown is the following (International Carbon Action Partnership 2022):

- **Power**: 100 percent of power sector allowances are auctioned (with exceptions for low-income member states).
- **Industry/manufacturing**: allocations are based on the average emissions intensity of the 10% most efficient installations within each subsector – adjusted annually for technological progress along with a fixed annual reduction rate (0.2-1.6 percent).
- **Aviation**: 15 percent are auctioned, 82 percent are allocated for free, and 3 percent are reserved for new entrants in the growing industry.
- **Sectors with high carbon leakage risk**: Free allocation along with a safeguard buffer of additional allowances to compensate for emission uncertainty. This category is scheduled to be discontinued by 2030 (aside from district heating).
- **New entrants reserve (NER)**: 200 million residual allowances are reserved for new entrants into the regulated markets.

Some high-emitting entities receive free initial allocation to reduce cost barriers for entering the market. Other entities may need to buy their way into the market, while the smallest emitters are usually exempt from participation (The World Bank 2022a). For context, “small” emitters are installations with less than 25,000 tCO_2e of emissions and a thermal output below 35 megawatts for a three year period before submission for exemption (European Parliament 2003). The EU ETS does not allow the use of carbon offsets to acquire additional permits. Instead, the use of offsets results in the forfeiture of an equivalent number of allowances. However it does include market stabilization mechanisms (MSMs) which are covered in more detail in the next section. It should be noted that entities are responsible for annual compliance with reporting and participation regulations, as the EU ETS is not a voluntary market contrary to many ETSs (The World Bank 2022a). Regulated entities must pay a penalty of €100 for each tonne of CO_2 emitted for which no allowance was surrendered, and also must buy the equivalent number of allowances (International Carbon Action Partnership 2022). A list of noncompliant entities is made available to the public. With this structure, it will always be cheaper to comply with the regulations than to pay the penalty which serves as an incentive to not only comply but reduce emissions over time.

The EU ETS has gone through four reform phases since 2005, beginning with a “learning by doing” phase (Phase 1) where a small-scale operation covering generation and manufacturing was implemented for research purposes (European Commission 2020). This phase provided insight on carbon pricing and necessary infrastructure for emissions monitoring and verification. Phase 2 and 3 worked to expand the system by covering more EU nations, more sectors, and experimenting with a reduced cap (European Commission 2020). These phases proved their system’s ability to reduce emissions while also providing insight on carbon leakage and effective allocation techniques.

Phase 4 commenced in 2021 and blended the system’s emission reduction targets with the EU’s climate neutrality by 2050 target along with an intermediate goal of a 55 percent net reduction in GHG emissions by 2030 (European Commission 2021b). This latest phase also increased the pace of emissions cuts to 4.2 percent annually and introduced the Market Stability Reserve (MSR) as a mechanism to control the price movements resulting from behaviors of the participants in the market. The MSR immediately began to shape the supply of carbon allowances by providing greater price stability during the COVID-19 pandemic (The World Bank 2022a). All of these phases contributed to a bank of research and development which many other ETSs used to develop their own carbon pricing mechanisms (He and Song 2022). The current allocation price of around €80 per ton of CO_2e is among the highest in the world (The World Bank 2022a). There are currently over 9,600 stationary entities and 349 aircraft operators in the EU ETS (International Carbon Action Partnership 2022).

Market Stability Mechanisms and the EU ETS MSR

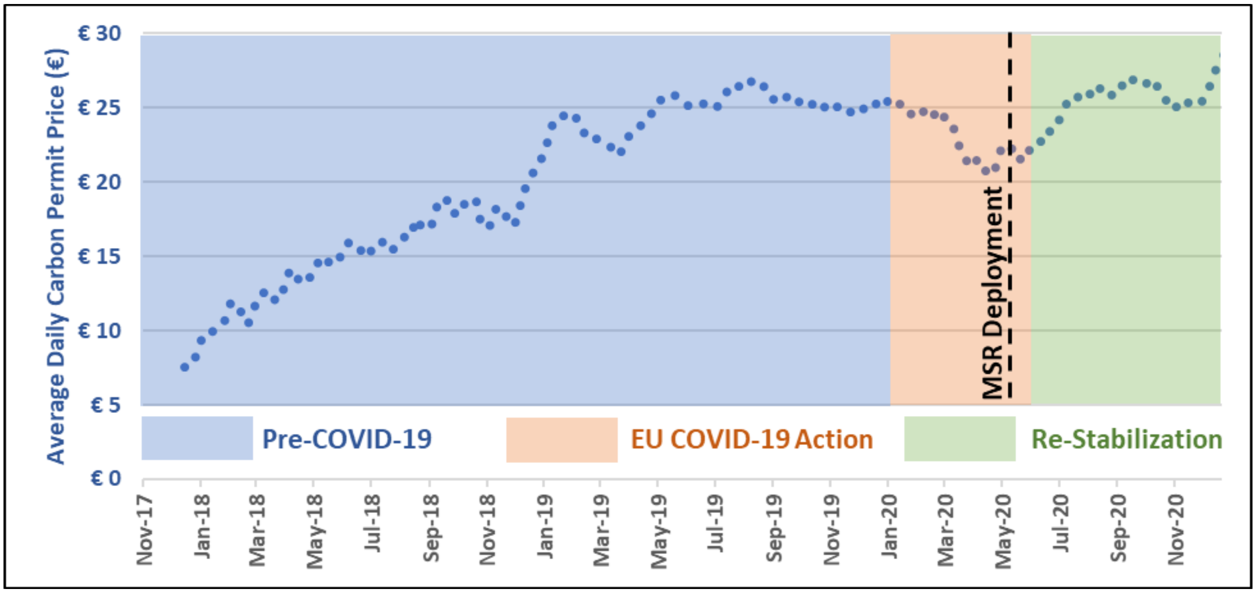
Unlike most commodity markets, ETSs have a regulated quantity of allowances in circulation that can be increased or reduced by a governing body (Acworth, Schambil, and Bernstein 2020). This structure makes price movements far more predictable in ETSs than in other markets because of the scheduled decrease in allowances that is designed to gradually increase price (International Energy Agency 2020). Without intervention, these factors create an incentive for participants to hold their allowances in anticipation of a higher sell point. Or alternatively, it can motivate participants to sell off permits if they anticipate a disruption-driven reduction in demand for permits (like during the COVID-19 pandemic). They can increase the likelihood of both internal and exogenous demand shocks that drive price volatility, and as such, many of the active ETSs have established some form of MSM that aims to dissuade behaviors that can stray an ETS away from its intended purposes: reduce emissions and incentivize investments in carbon reduction technologies (Acworth, Schambil, and Bernstein 2020). There are many unique scenarios where an MSM can stabilize allowance prices. For example, smaller and less matured ETSs who are more concerned with keeping allowance prices high (to incentivize low-carbon technology investments) will use MSMs to remove allowance oversupply (Acworth, Schambil, and Bernstein 2020). Alternatively, an ETS may experience a sudden external disruption that reduces demand for carbon-intensive products/services - an MSM would remove those excess allowances. The intention is to disincentivize emitting entities from purchasing cheap allowances instead of reducing their emissions; and to improve system resilience to major shocks (Acworth, Schambil, and Bernstein 2020).

For these reasons, the EU Commission decided to implement their own MSM which they call the Market Stability Reserve (MSR) at the beginning of phase 4 (European Commission 2021c). The MSR operates by publishing the total number of allowances in circulation in May of each year and using that number to determine how many allowances are being auctioned according to pre-defined rules (EU Commission Staff 2021). These rules work to keep the total number of allowances below a certain threshold by eliminating excess allowances which keeps prices from deflating (Marcu et al. 2022). These excess allowances are then placed into a reserve where they can be released without impacting the emissions cap.

Although very little research has been conducted on the MSR, experts have expressed concern over price volatility that may be caused by the reserve. For instance, cancelling allowances reinforces allowance scarcity which may trigger price spikes resulting from short-term volatility (Marcu et al. 2022). Experts have also expressed concern about removing allowances because it may create uncertainty around the future cap on emissions, but the MSR does not affect the cap – rather it works within the cap to eliminate unallocated allowances (EU Commission Staff 2015). Therefore, the MSR improves the functioning of the EU ETS without affecting the EU's emission reduction targets.

A good example of an allowance surplus was seen during phase 3 of the EU ETS in 2020. The economic recession brought on by the COVID pandemic shut down or severely limited many industrial and power sector operations for several months (European Union 2022). These shutdowns resulted in lower emissions than the European Commission anticipated when it allocated carbon credits at the beginning of the year, thus resulting in an oversupply of allowances and subsequent crash from around €25 to €16 within a week (European Commission 2021c; Trading Economics 2022a).

FIGURE 1: AVERAGE DAILY EU ETS ALLOWANCE PRICES PRE-AND-DURING THE COVID-19 PANDEMIC.



Data Sources: (EU Commission Staff 2021; European Commission 2022b; Trading Economics 2022a)

As Figure 1 shows, the price of allowances began to drop rapidly as the EU implemented several measures to combat the spread of COVID-19. These measures indirectly resulted in a reduction in demand for carbon-intensive activity which reduced demand for allowances. In May of 2020, the EU Commission identified a surplus of allowances and decided to cut the total number by nearly 400 million (EU Commission Staff 2021). This brought the total number of allowances to 1.5 billion and almost immediately brought allowance prices back to pre-COVID levels. Although the EU ETS MSR was only recently implemented at this point, the mechanism responded as intended by preventing further price drops. This justified the Commission's push for more responsive stabilizing mechanisms in phase 4 (The World Bank 2022a).

Despite its effectiveness during the pandemic, some experts still doubt the MSR's (and MSMs in general) capability to produce price stability. Policy makers have emphasized the purported strengths of MSRs while economists have identified several shortcomings. These include the possibility of increased price volatility, reversal of climate mitigation, and vulnerability to speculation – all of which have the potential to prevent ETSs from achieving their intended purposes (Perino et al. 2022).

These shortcomings were observed in the EU ETSs MSR which uses a fixed emissions cap to adjust prices (Marcu et al. 2022). This scheme essentially adjusts the emissions cap by increasing or decreasing the number of allowances in the market (Perino et al. 2022). The tradeoff between less price volatility in return for (potentially) less climate benefits is the primary source of criticism about MSMs - if they introduce more allowances into the market, it essentially permits more emissions. Additionally, the EU ETSs MSR adjusts allowance supply based on number of allowances in circulation, meaning the Commission can withhold and cancel allowances when they exceed a price threshold (European Commission 2021c). Although this cap structure can reduce emissions, it can theoretically lead to potential speculative efforts from market participants to anticipate these price movements. For example, if market participants observe a rapid carbon price increase, they may sell their allocations in anticipation of the MSR being deployed which would bring carbon prices back down.

For these reasons, some economists believe fixed cap systems can be less efficient than price-based mechanisms which use cost and emission containment reserves to regulate volatility – as seen in California's Cap and Trade ETS (Perino et al. 2022). Despite these opinions, research has shown that MSRs are effective at:

1) stabilizing prices in the face of unanticipated demand shocks – as seen in the EU ETS MSR's successful deployment during the COVID-19 pandemic;

2) reducing surplus/unallocated allowances; and

3) minimizing negative impacts on competitiveness (Perino et al. 2022; Directorate-General for Climate Action and Vivid Economics 2021).

A large source of concern from private vendors was negative impacts that an MSR would have on their long-term performance (Directorate-General for Climate Action and Vivid Economics 2021). Their concern stemmed from carbon leakage – which occurs when firms move their production to jurisdictions where carbon costs are lower – in this case areas outside of the EU's scope. For example, a firm that produces carbon-intensive goods may move their production and facilities to an Asian or African country that does not price their carbon emissions. Some EU firms were concerned that carbon leakage would price the EU out of the global economy. Additionally, European firms that rely on a global sales network were concerned about internalizing the burden of compliance costs without being able to pass those costs onto customers. International markets often have many substitute goods leading to less price elasticity compared to local markets. All these potential impacts could also have cascading effects on business growth and jobs within the EU.

In response to these concerns, the European Commission conducted a meta-analysis of studies on the MSR's impact on competitiveness in its 2021 review of the MSR (Directorate-General for Climate Action and Vivid Economics 2021). Their study found that carbon pricing can motivate firms to change their conduct to benefit their competitiveness – in this case reducing system emissions. There was some evidence that the first two phases of the EU ETS supported moderate levels of innovation and investment in low-carbon technologies. For instance, ETS regulated manufacturing in France reduced emissions significantly. The studies reviewed also found that negative competitiveness impacts can be alleviated through a "well-designed policy package" that protects jobs and economic growth – which circles back to the importance of pairing ETSs with policy-based solutions. In the French example, the same study found that employment in regulated manufacturing was reduced by 7 percent, although exact impact on widespread employment is not conclusive. Most importantly, literature on the EU ETS has found limited evidence of carbon leakage in the initial ETS phases.

Regarding MSRs specifically, its impact will vary by facility and industry, but generally the impact on competitiveness is minimal (Directorate-General for Climate Action and Vivid Economics 2021). Entities that purchased their allowances are likely to see the biggest benefit from an MSR that artificially controls prices by ensuring a return on their purchase. Alternatively, entities with free allocations who then have to purchase those allowances in the future will see heightened costs. In all, the EU ETS's MSR has had a positive impact on market stability with minimal impact on competitiveness.

Even so, changing market and policy conditions bring a lot of uncertainty. This is because entities may store their allowances in anticipation of a shock that increases demand for them. To combat this, the Commission is proposing additional legislation that would give them authority to remove these banked allowances from circulation in the case of a price shock (Perino et al. 2022). This would remove the total number of allowances in circulation as the primary indicator of scarcity for those involved in the market. Allowances removed would be temporarily stored in the MSR and free to be released by the Commission if deemed necessary – for instance in the case of a price spike to increase supply.

The Commission continues to tinker with the MSR to see how it can help stabilize the EU ETS through current market conditions. Dynamic market conditions suggest that regular reviews of the MSR are necessary to ensure its effectiveness (Directorate-General for Climate Action and Vivid Economics 2021). For example, the EU coal phase-out plans will see the majority of coal plants shuttered by 2030, which will add 2 billion allowances to the oversupply through 2030 (European Commission 2021a). To prevent a price crash from oversupply, the MSR needs to be bolstered so it can eliminate allowances from circulation completely when high emitting industries are phased out (Stoefs 2022). However, as it stands, the coal phase out (and similar phase outs of high emission products) threatens to create an allowance oversupply.

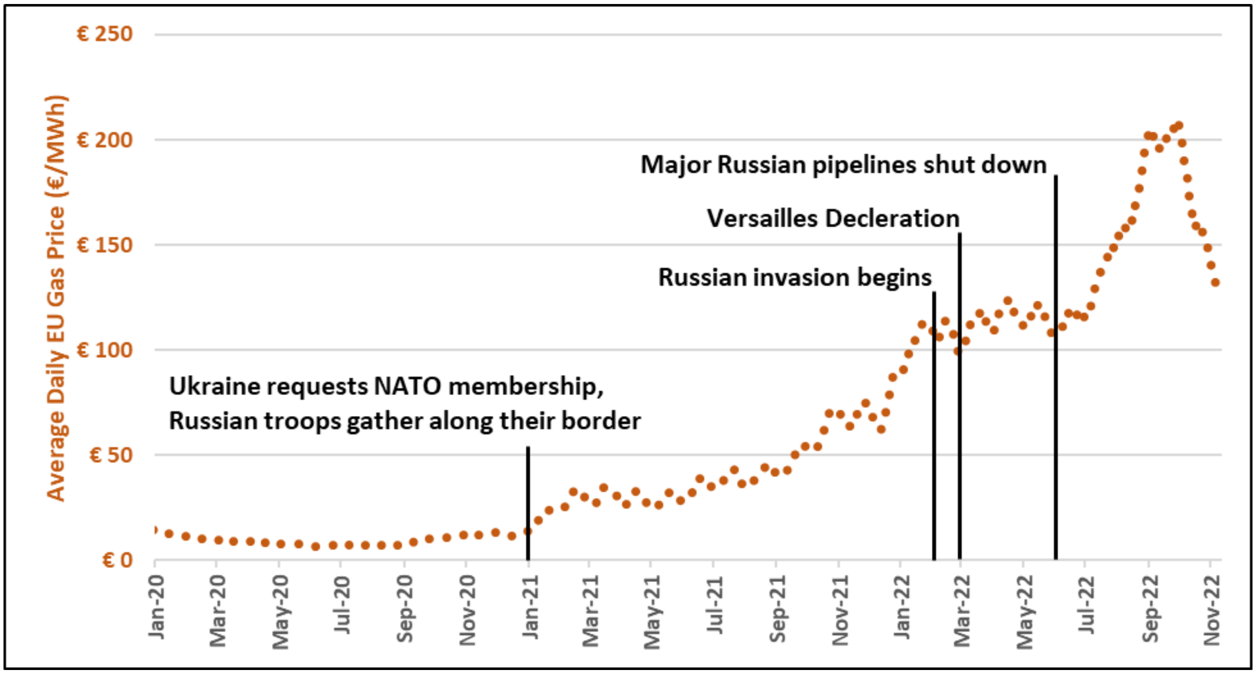
The Russian Invasion of Ukraine and its Impact on EU Markets

In early 2021, Russia began massing troops near Ukraine's borders in response to Ukraine's request to join the North Atlantic Treaty Organization – a coalition of western nations (Reuters 2022). Russia continued to mobilize armed forces for the next year in spite of warnings from many regarding economic sanctions if they were to cross into Ukrainian territory (Reuters 2022). Despite this, on February 24, 2022, they launched a large-scale invasion of Ukraine leading to a conflict that continues today and has led to thousands of casualties and alleged war crimes by Russian forces (Borrell 2023; Reuters 2022). These events triggered sanctions from several western nations on goods going into and coming out of Russia with the intention of economically isolating the country from the west (Reuters 2022). This led to an economic pseudo-war as both sides announced sanctions aimed at weakening their respective economies - which had major implications on gas prices in the EU as Russia was a major exporter (Borrell 2023). The Russian government weaponized their control over European gas by increasing tariffs and delivery costs to western nations that were aiding Ukraine in an effort to counter the economic damage being done to their country while also attempting to dissuade nations from providing support to Ukraine (Borrell 2023).

In response to Russia's decision to suspend gas deliveries to several EU member nations, the European Commission signed the Versailles Declaration which established the plan to phase out the EU's dependence on Russian fossil fuels including gas (European Commission 2022a). The European Council agreed to ban 90 percent of all Russian gas imports by the end of 2022 with a plan to eventually replace all Russian gas imports with western gas deliveries coupled with an acceleration of renewable energy deployment (European Commission 2022a). Russian gas imports dropped from 40% of total supply in 2021 to around 17% by August 2022, and that number is continuously dropping (Horton and Palumbo 2021). The sanctions also led to a decoupling of Russian gas prices which began to drop at a much faster rate compared to EU's Brent price. This means Russia was losing out on up to €140 million a day in gas exports due to sanctions (Horton and Palumbo 2021).

These sanctions handicapped Russia financially and triggered a short-term energy crisis across the EU as many nations struggled to source affordable alternatives to Russian gas. Along with the sanctions, many hydroelectricity plants were facing climate change-related operational issues forcing them to shut down for longer-than-expected periods (Borrell 2023). Additionally, the many nuclear power plants across Europe were not capable of handling peak energy demand. These factors contributed to a gas price explosion in the EU reaching levels up to eight times higher than the 10-year average during Fall of 2022, as seen in Figure 2 (Neufeld 2022).

FIGURE 2: TIMELINE OF GAS PRICE MOVEMENTS DURING MAJOR EVENTS IN UKRAINE ALONG WITH EU SANCTIONS.

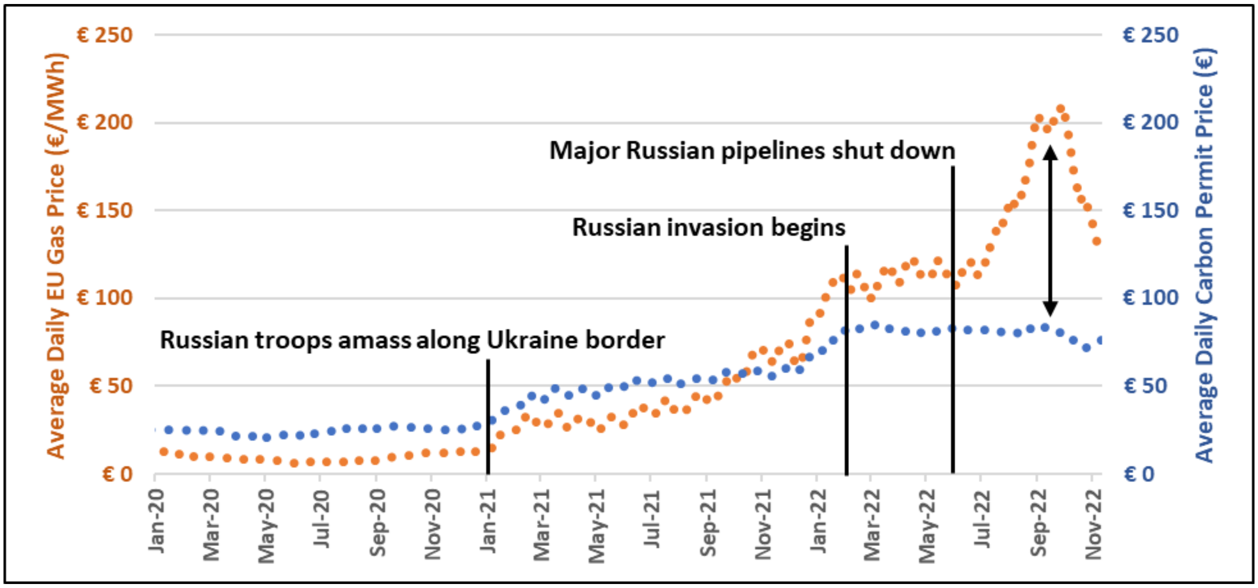


Data sources: (Reuters 2022; European Commission 2022a; Trading Economics 2022b)

In response, European nations accumulated over $246 billion in funding for subsidies and initiatives aimed at stabilizing the cost of living for residents (Neufeld 2022). Much of the funding went to the procurement of alternative energy sources that could replace Russian gas, primarily from liquid natural gas (LNG) imports from American and Qatari ships and increased coal-fueled power generation (Zaretskaya and Wilczewski 2022; Reuters 2023). Both of these energy sources have significantly higher emissions compared to the pipeline gas they were receiving from Russia – leaving many concerns about the short-term impacts on emissions and allowance prices (Horton and Palumbo 2021; Shaton, Hervik, and Hjelle 2019).

The Russian gas ban had a very nuanced effect on allowance prices in the EU ETS. For context, before the invasion, carbon prices generally moved alongside energy prices – especially gas as seen in Figure 3 (Fjellheim 2022). However, the gas ban caused the two prices to "decouple", with both markets experiencing extreme price volatility at differing rates, something that had never been seen at this scale in the EU ETS. Allowance prices dropped from nearly €95 to €55 within a week (Trading Economics 2022a; Fjellheim 2022). But when average weekly prices are taken, it is shown that carbon prices increased in anticipation of conflict and stayed relatively level with a slight drop through the end of 2022.

Figure 3: Timeline of major events in Ukraine along with EU sanctions against EU gas and carbon allowance prices depicting the "decoupling" caused by the Russian gas ban.



Data sources: (Trading Economics 2022a; 2022b; Reuters 2022; European Commission 2022a)

Analysts believe the initial cause of this price volatility was a liquidation of allowances by holders to cover energy price increases (Fjellheim 2022; Trading Economics 2022b). As seen in Figure 3, this sell-off did not impact prices nearly as much as they should have. Instead, they remained relatively level, as if the EU ETS's stabilization mechanism managed to minimize the Russian gas ban's impact on the carbon market.

Trends in the California Cap and Trade ETS

To assess the EU ETS MSR's price stabilization, I reviewed a matured market that is not (and has never been) connected to the Russian gas network. Comparing the two markets' price movements will provide insight into how the EU ETS managed to get prices back on the expected track, allowing for future ETSs to be structured in a way that ensures emission reduction. The two markets also create an ideal environment to assess how MSRs can control prices in different market conditions. As mentioned in the methods, two big contributors to selecting these markets were data availability and scope/maturity. There is also a valid case for comparing two different MSM's in the same market because that would allow for easier isolation of impacts. Data availability makes that difficult, so comparing two separate systems was more realistic and can still provide valuable insight on localized market impacts.

As such, this section provides an overview of the California Cap and Trade (CCAT) ETS, its stabilizing mechanisms, and its price movements over the same period reviewed for the EU ETS. This review is intended to describe the similarities (and differences) between the CCAT and EU ETS along with how CCAT allowance prices shifted in a market that did not experience the external market shock caused by the Russian gas ban. This paired with an overview of California gas price movements will set the stage for an analysis of price movements in both markets.

The state of California has been making substantial efforts to combat climate change with wide ranging market and non-market solutions that are not seen in many states. These efforts contribute to California's reputation as one of the most environmentally progressive states among the United States (Green 2023). Its latest efforts in 2020 came in the form of a series of executive orders from Governor Gavin Newsom calling for an accelerated decarbonization timeline, increased wildfire suppression/prevention funding, and a revamped expenditure plan for their CCAT revenue spending (Newsom 2020a; 2020b; CalEPA 2022). Given how much of a pressing issue wildfire suppression/forest resilience & restoration is, this portion of the plan received a significant amount of funding. The Governor also laid out a transition plan to zero-emission vehicles by 2035 which would also be partially supported by CCAT revenues. The state plans to dedicate over $2.5 billion to these efforts, with some of the funding (around $325 million) dedicated to communities with disproportionate exposure to pollution (CalEPA 2022).

As for the CCAT, the system was established in 2012 to aid with the state's goal of reducing emissions to 1990 levels by 2020 and an 80 percent reduction by 2050 – targets that have since become more stringent (The World Bank 2022a). Over the last 11 years, the CCAT has developed into a mature ETS carbon market with the potential to create significant carbon reductions for the state. The system covers almost all GHG emissions from industry, industrial processes, power, transport, and buildings sectors amounting to an annually decreasing emissions cap of 308 $MtCO2_e$ – an amount that covers 74 percent of emissions from included jurisdictions (The World Bank 2022a). Although this coverage is much smaller than the EU ETS (over 4 thousand $MtCO_2e$), it is still one of the biggest markets in the world, bringing in almost $4 billion in government revenues (as of 2022) from California's globally dominant economy (The World Bank 2022a). Additionally, there are similarities to the EU ETS in that it covers similar sectors and utilizes its own unique MSM. As of the fourth quarter of 2022, allowance prices are hovering around $28 (California Air Resources Board 2023).

The market currently allocates around 56 million allowances and also allows for trading in an advance allowance auction market (California Air Resources Board 2023). Allowance allocations are distributed through a combination of free allocation and auctioning to provide transition assistance and to prevent carbon leakage (The World Bank 2022a):

- **Industrial facilities (>25,000 $tCO2_e$):** Free allowances according to benchmarks and production volumes.

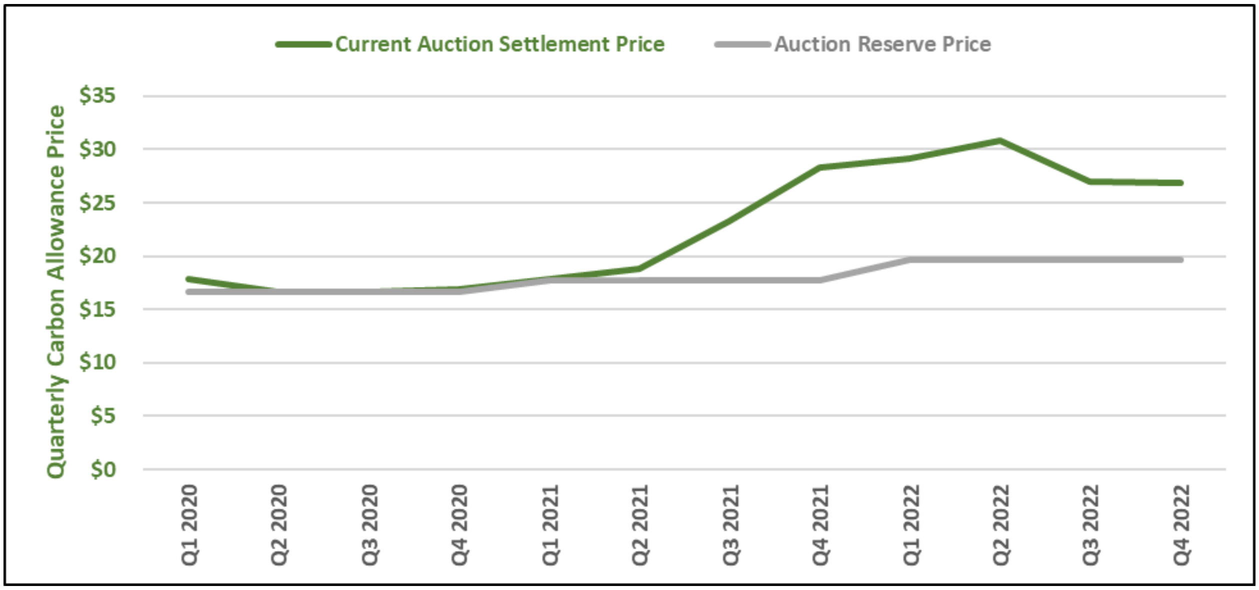
- **Electricity distributors/natural gas suppliers:** cosigned allowances, meaning they are paid by ratepayers and must be used to benefit ratepayers or to support emissions reduction measures.
- **Other:** Auctioned allowances unless identified as a high risk of carbon leakage.

Much like the EU ETS, the CCAT's mission is designed to provide covered entities the flexibility to seek out and implement the lowest cost options to reduce emissions (Sahota 2015). The goal is to use the market to reduce emissions by an increasing percentage each year, and so it is important the market is capable of withstanding market turmoil. The CCAT contains MSMs designed to stabilize prices and have been effective at keeping allowance prices high throughout the development of the market. It manages to do so through an auction reserve price that is set at \$17.71/$tCO2_e$ which increases by 5 percent plus inflation annually (The World Bank 2022a). There is also an allowance containment reserve that is being slowly built up for deployment in the case of allowance prices exceeding a price threshold – a scenario the market has yet to experience.

The CCAT's MSM, as opposed to the EU ETSs fixed cap scheme, uses a price-based flexibility mechanism which relies on cost and emission containment reserves that adjust allowance supply based on the price – a system that may be more cost efficient compared with a fixed-cap scheme or a carbon tax (Perino et al. 2022). Although there does exist disagreement about which system is better, as fixed-cap schemes (if regulated effectively with declining limits) are better at guaranteeing emission reductions (Wang et al. 2022). Also unique to the CCAT is the ability to use carbon offsets for up to 8 percent of each organization's compliance obligations, however this allowance is set to reduce to 6 percent in 2030 and eventually phase out entirely (The World Bank 2022a).

The CCAT experienced a major overhaul in 2022 to reflect recent Executive orders N-79-20 and N-82-20 which accelerate the path to carbon neutrality by 2045 and provide additional coastal land protections (Newsom 2020a; 2020b; CalEPA 2022). This overhaul was partially responsible for allowance prices separating from the auction reserve price for the first time in a significant way, as seen in Figure 4.

Figure 4: CCAT Allowance price trends (USD).



Data source: (California Air Resources Board 2023)

Once the CCAT expanded into the transportation sector, the marketplace experienced an unprecedented uptick in allowance prices beyond the reserve price. Most of these additional funds directly contributed to the state's Greenhouse Gas Reduction Fund - a stream of investment capital that is invested into a wide range of emission-reducing efforts including: food waste prevention and materials recycling, air monitoring, low-carbon transportation development, climate adaptation research, and many other decarbonization efforts receiving roughly $1.6 billion in annual funding (Morgenstern and Adler 2022; California Air Resources Board 2022).

Although these investments are promising and could advance clean energy technological development, some research shows the CCAT only having modest impacts on GHG reductions (Morgenstern and Adler 2022; Wang et al. 2022). This is in part due to compliance issues, litigation from fierce industry opposition that led to less stringent emissions caps, and a massive allowance surplus from free allocations that has devalued their permits (Wang et al. 2022). In all, the CCAT represents a series of compromises with private industry that has ultimately put its effectiveness into question.

It is important to understand that the CCAT's shortcomings are not a byproduct of a flawed carbon market concept. Much of the research discussed earlier in the literature review showed that ETSs are capable of producing significant emissions reductions if structured appropriately, and there are lessons that can be taken from many of the global pilot efforts that were undertaken, which include (Wang et al. 2022):

1. Tightening benchmarks and improved monitoring/updating regulations, operations, and coverage.
2. Mass-based caps with declining limits.
3. Reduce free allocations.
4. Pair with policy-driven incentives for fuel-switching and research.

The CCAT is proving that it can be an effective carbon market that can generate revenue for important climate change mitigation efforts, but still has a long way to go before it is as comprehensive as the EU ETS. Despite this, the CCAT's price movements show that it also experienced a similar price increase at the beginning of 2021 as the EU ETS – although that was likely attributed to the structural changes that reduced the number of allowances in circulation. Importantly, the CCAT did not deploy any MSMs in 2022, so that market's price movements were entirely determined by existing supply and demand. Contrast this to the EU ETS which deployed their MSR in May and – like the CCAT – remained stable through the end of 2022.

These findings support the stabilizing capabilities of the EU ETS MSR because its price movements remained as stable as a separate market that was not directly impacted by the Russian gas ban. Both markets experienced price increases after 2021, but they were largely due to policy changes – which further supports the importance of policy structure in the effectiveness of a carbon pricing scheme. It is also worth noting that both the EU and California deploy an array of climate change mitigation efforts – both market and non-market based – which contribute to a wholistic mitigation effort that aims to create socially, environmentally, and economically sustainable communities.

Chapter 4: Data Analysis

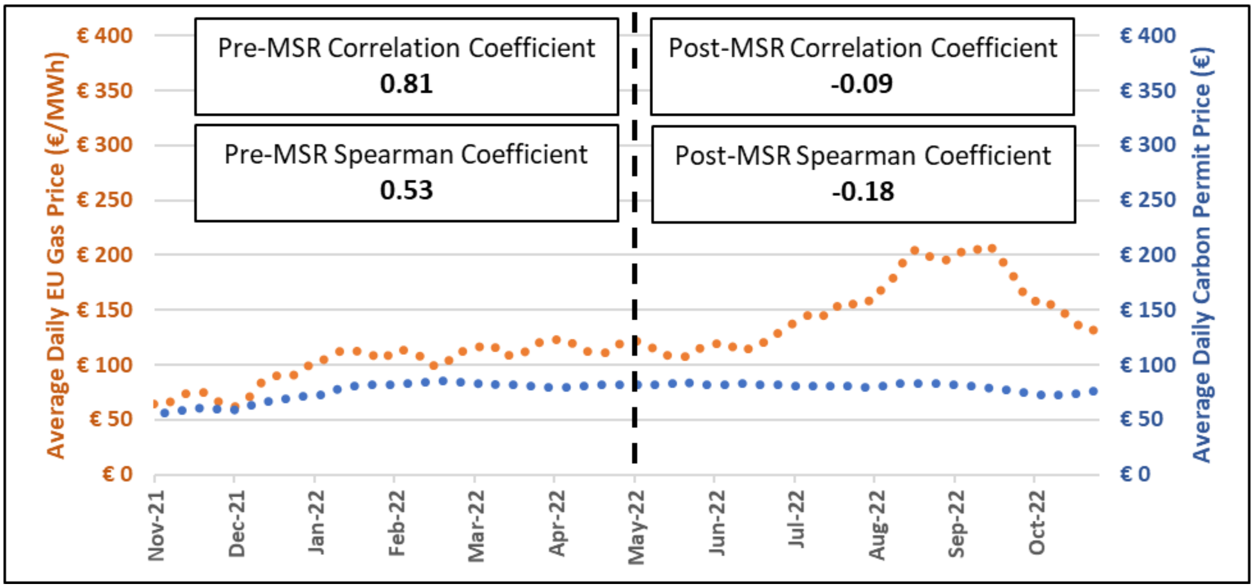
Associations Between Gas Prices and Carbon Prices

Literature on carbon markets support that allowance prices often closely follow the price of popular sources of high-emission fuels like gas. This is because many ETSs – including the EU ETS – have most of their allowances tied to fossil fuel industries including gas operators (Horton and Palumbo 2021). However, the relationship between the two prices could theoretically change if one or the other markets becomes price controlled. This would theoretically result in a decoupling of the two markets where the price controlled market remains far more stable than the non-price controlled one.

In the case of the EU ETS, the MSR was developed to prevent prices from getting too high or too low by deploying an allowance reserve that does not impact the overall emissions cap. Beginning in May of 2022, the MSR was deployed in response to irregular carbon trading behavior from market participants who were unsure of the fallout that would result from the Russian gas ban (Fjellheim 2022). Allowance prices began to lose their upward momentum that had been building since early 2021 – when phase 4 commenced. So, the European Commission pulled additional allowances that weren't being traded into the reserve.

This information can be used to assess the extent to which a MSM has controlled prices by comparing the correlation between the two prices before and after its deployment. Figure 5 contains the price movements of gas and EU ETS carbon prices before and after the MSR was deployed to stabilize prices in anticipation of instability resulting from the Russian gas ban. The Pearson correlation (0.81) suggests a relationship exists between the two prices dating back to 2017. The Spearman ranked correlation (0.53) is not as strong, but still suggests an association given its low error and high statistical significance ($p=0.0007$). These findings support the claim that gas and carbon prices are associated with one another. Importantly, there is a clear difference in the correlation between the two values before and after MSR deployment, with a significant positive relationship pre-MSR deployment and insignificant negative relationship after. This would suggest the MSR impacted the association between the gas and carbon markets in the EU.

FIGURE 5: CORRELATION BETWEEN CARBON AND GAS PRICES BEFORE AND AFTER MSR DEPLOYMENT.



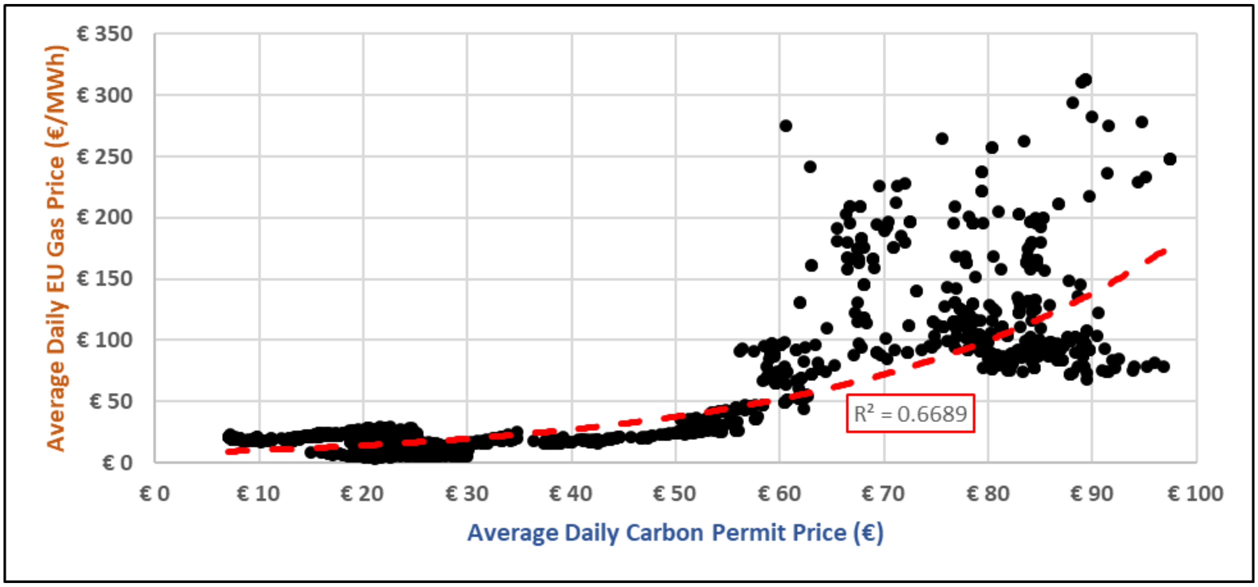
Data sources: (Directorate-General for Climate Action and Vivid Economics 2021; Trading Economics 2022a; 2022b; Taylor 1990)

Historic data on European gas and carbon prices show highly correlated movements between the two markets – which is expected given what is understood about the relationship between complementary markets (Trading Economics 2022a; 2022b). The findings in this analysis of price destabilization further strengthen that theory as permit prices in the EU ETS and gas prices in the EU have a statistically significant Spearman correlation - suggesting a positive relationship exists between the markets (Taylor 1990). This means any external disruption in one market is likely to moderately affect the other. Despite the moderate relationship, an important takeaway is the difference in both Spearman and Pearson correlations once an MSM is deployed to regulate carbon prices. This exact situation occurred in the EU ETS when the MSR was deployed in May of 2022 in response to price volatility caused by the Russian gas ban. Reserve permits were deployed to keep prices level while gas prices continued to surge unchecked. As a result, almost all the Spearman correlation between gas and carbon prices was lost (-0.18) after the MSR was deployed, and as Figure 5 shows, carbon prices managed to remain much more stable over that period.

Another way to illustrate this separation is by looking at the exponential relationship between increasing gas and carbon prices in the two markets. The lower gas price points represent pre-gas ban prices. Here there is less noise in the scattered points, meaning gas and carbon prices in the EU are more closely associated with one another at lower prices. The exponential trendline shows an R^2 of 0.67 suggesting a relationship exists between the price movements, which is shown by the red line in Figure 6. However, it is difficult to provide context to the R^2 without statistical significance, so the trendline is only used to visualize the shifting association at different price points.

The two prices have very little noise when prices in both markets are low, and there are very few (if any) outliers that fall beyond the trendline. Prices in both markets were relatively low before the Russian invasion/gas ban so the price movements were much more closely related. This all changed once prices began to spike and the MSR was deployed. Gas prices began to rise at a much higher rate, leading to a significantly more scattered array of prices – which reflects the loss of correlation shown at the higher price points in Figure 5. The relationship became much more obvious as prices increased in the gas market because carbon prices were stabilized during the recent gas price spike.

Figure 6: Relationship between the price movement of EU gas and EU ETS carbon permit prices.



Data sources: (Trading Economics 2022a; 2022b)

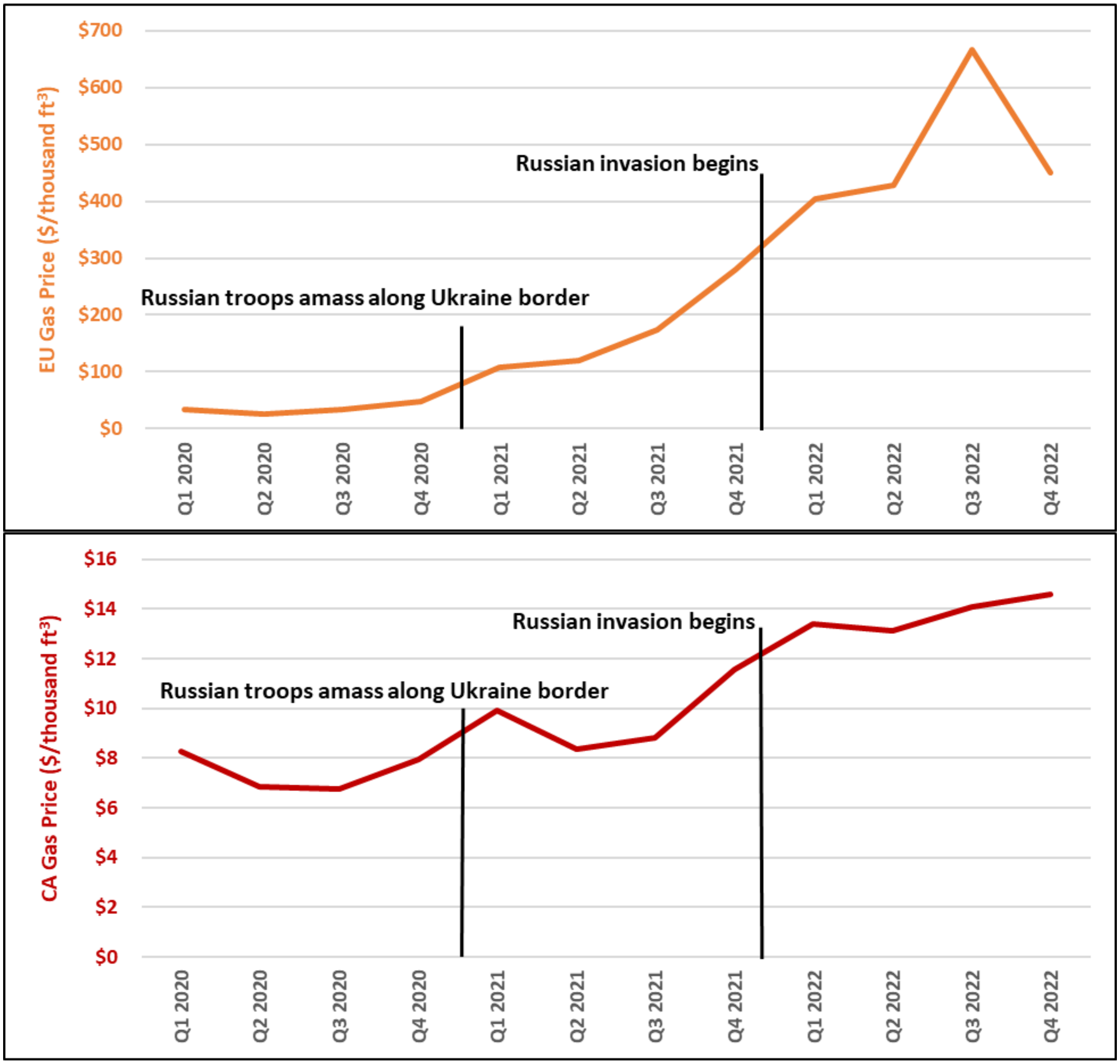
After the Russian gas ban, prices in both markets experienced volatility, but the relationship became significantly more scattered because gas prices increased at a much higher rate than carbon prices. These observations along with the relatively correlated historic prices further support the theory that MSR deployment contributed to a decoupling of the two markets.

The significance of this decoupling is that it goes against what the literature says about the relationship between gas and carbon markets. Historically, the two markets have moved in the same general direction even though many climate and gas-related legislation has been passed, including several updates to the EU's decarbonization pathway (European Commission 2021b). The MSR was the biggest change factor introduced to the EU ETS in May 2020, meaning it stands as the likely source of the EU ETS's price stabilization while facing Russian gas ban – a stabilization that was not seen in the gas market (uncontrolled).

Comparison of Price Movements in Europe and California

The CCAT can be used as an example to further illustrate the existence of a relationship between carbon and gas prices. California does not import any of its gas from Russia, and so was not directly impacted by the Russian gas ban. This is important to note because the Russian conflict and political response were big contributors to the price spike experienced in the EU. As such, Californian gas prices increased significantly less than the European market, as shown in Figure 7.

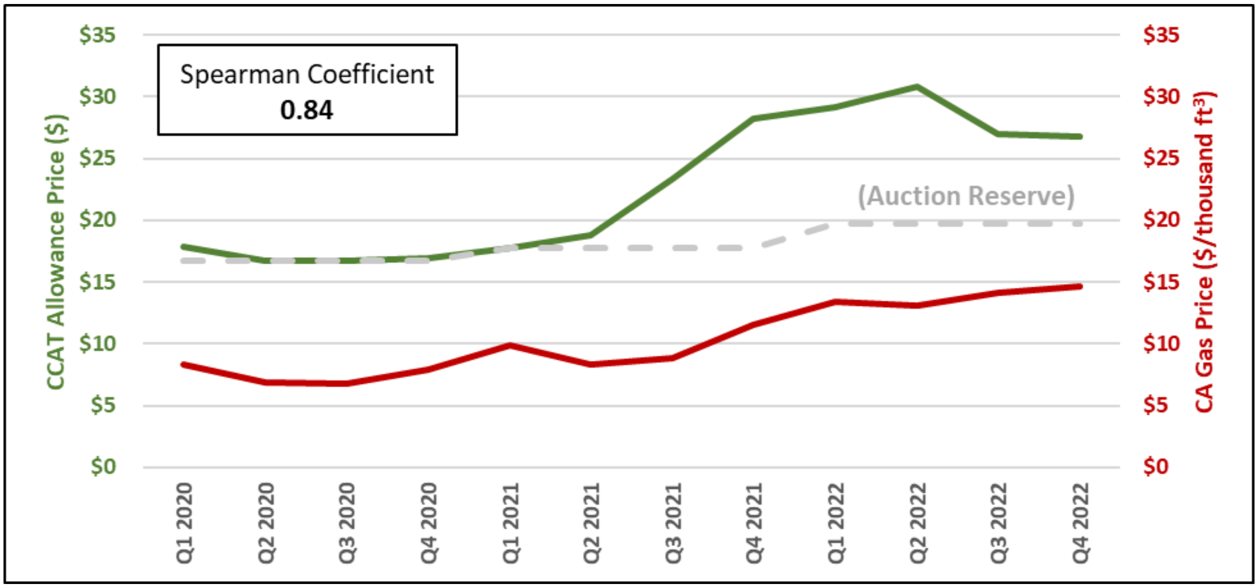
FIGURE 7: COMPARISON BETWEEN THE GAS PRICES IN CALIFORNIA AND THE EU.



Data sources: (Reuters 2022; Trading Economics 2022b; U.S. Energy Information Administration 2023)

This figure visualizes the drastically different market conditions experienced in the two regions. Despite the different market conditions, Californian gas prices still went up during that period, and carbon prices appeared to follow even after allowance prices separated from the reserve price. As shown in Figure 8, the Spearman correlation between the two prices is positive (0.84).

Figure 8: Comparison between California gas and CCAT allowance.



Data sources: (California Air Resources Board 2023; U.S. Energy Information Administration 2023)

CCAT allowance price information is only released quarterly, so there are not enough data points to conduct a more robust correlation test. Still, the Spearman coefficient coupled with an empirical look at the price movements show that a relationship exists between the markets despite fewer data points. This assessment was done using the same timeframe where EU carbon prices began to decouple from gas prices. A stronger Spearman correlation exists between the CCAT and gas markets compared to the EU ETS and European gas – likely due to the smaller scale of the CCAT and larger proportional share of allocations going to the gas industry.

These findings show that in uncontrolled market conditions, both CCAT and EU ETS prices have some form of a relationship to gas prices. The only instance where the relationship ceased to exist was in the EU ETS after MSR deployment. As a result, it becomes increasingly likely that an external factor – likely the EU ETS MSR- performed its intended purpose to make the ETS more resilient to external market disruptions by significantly reducing price fluctuations.

The data collected on both gas and carbon markets verify findings from the literature that have found a relationship between carbon prices and gas prices. The data also shows where the MSR was successful in controlling allowance prices.

Chapter 5: Discussion and Policy Implications

Discussion

An ETS can come in many different forms, but the behaviors of its market participants, complementary markets, and policy decisions have a large impact on whether they are effective at reducing carbon emissions at the rate that is needed to prevent catastrophic climate change. Luckily many regions across the world are experimenting with their own market variations which provides countless opportunities for research and optimization. The defining characteristic of ETSs worldwide is they are all open to change. Most are treated as pilot studies where economists, policymakers, and participants work together to ensure the market brings positive climate benefits without introducing too much risk to participants. Other markets suffer from implementation issues, usually stemming from entities that are concerned about the impact carbon markets will have on their bottom line. Therefore, in structuring an ETS, it is important to anticipate these concerns and address them through policy implementation. For example, coupling an ETS with comprehensive non-market policies that create jobs and protect industries can minimize the competitive impact of an ETS on an industry. Additionally, it is critical to tailor the use of ETS revenues so they address local climate impacts, and so need to be coupled with up-to-date research on localized climate change impacts. The CCAT is a good example as they use much of the revenue for wildfire prevention.

Additionally, my analysis teased out the likelihood that the MSR was effective at stabilizing carbon prices in the EU ETS. This is an important finding for policymakers to consider because market volatility is often a large source of concern for private sector entities. MSMs include price floors that ensure their allowances don’t crash below a certain threshold and reserves that can be deployed or refilled to stabilize price increases. They also include structures that hand out free allocations to incentivize participation. All of these mechanisms can make an ETS much more appealing to participants and potentially reduce pushback. The less pushback that's received, the more likely they are to contribute significant emissions reductions and clean technology innovation.

Policy Implications

The structure of an ETS is often best discovered through several iterative phases where policymakers and stakeholders can make observations about what does and does not work for the specific region. Many mature markets have developed strategies that have proven effective at ensuring the effectiveness of an ETS through periods of instability – the primary one being MSMs. Based on my literature review and data analysis, I offer the following ETS policy implications for all ETSs to consider in their carbon market structures:

- If structured correctly, ETSs are resilient to external market shocks and capable of operating as expected even in turbulent conditions.
- ETSs across the globe would benefit from adopting more comprehensive price based MSMs that minimize the effect of price volatility on carbon pricing schemes.
- MSMs need to include the authority to delete allowances when market participants (such as coal plants) get phased out.
- Stabilizing mechanisms can impact short-term emissions allowances and so should only be used in times of crisis and market shock. This ensures that stabilizing actions don't drastically delay GHG reduction timelines or are abused due to participant pressures.
- IPCC should update Article 6 to emphasize the importance of MSMs in ETSs.

Chapter 6: Conclusion

The Russian occupation of Ukraine has been horrible for human rights and sheds light on the influence that dangerous actors have on the globalized economy. Russia weaponized its gas exports to destabilize the entire European economy. This served as a wake-up call to the EU and the rest of the world who relies on gas from just a handful of nations with questionable human rights track records. This series of events further emboldened the argument to move away from fossil fuel dependency and move towards a sustainable and renewable energy industry that is less extractive and cheaper in the long-term.

The invasion and cascading market impacts have also been a proving ground for the EU ETS to see how resilient it is to external market disruptions. Although ETSs are not without faults, they can play an integral role in emissions reduction while remaining stable in turbulent economic conditions.

The literature on climate change is conclusive about the potential dangers humans face if climate action is not taken, and market disruptions do not delay that urgency. MSRs can ensure that climate targets are maintained even in times of volatility, and so should be included in an ETS to ensure its long-term effectiveness.

Limitations

Researching the fallout of an ongoing crisis introduces several limitations in what can and cannot be researched. For example, the Russian gas ban may have introduced a gas price shock that decoupled gas and carbon prices, the long-term impact is yet to be fully understood. There remain questions about how the relationship between the two markets will develop as carbon markets begin to encompass more sectors beyond just energy. MSMs will also likely lead carbon prices to develop in a unique manner – both factors that cannot be researched yet.

Additionally, data on carbon price movements is not easily accessible. Of the largest active carbon markets, only the CCAT and EU ETS provide publicly available price movements – and the EU ETS was the only market with a large database of daily prices. This limited the selection of markets with enough data to perform a price analysis. These limitations lead the quantitative conclusions to be suggestive and reliant on support from the literature review.

The quantitative data was further limited by daily EU gas price data that was missing datapoints for certain days where prices were not recorded. As a result, 27 daily prices were assumed to be the same as the previous day's price to ensure a price point for every day in comparison to carbon prices. This introduces more uncertainty in the results.

The CCAT dataset included its own limitations because the State of California only releases quarterly carbon prices. Seeing as though the test period is 3 years, this led to an issue around available datapoints for a statistical test. The correlation coefficients should be considered with hesitancy due to this limitation.

Future Research

As of writing this thesis, the Russian invasion of Ukraine is ongoing and continues to be unpredictable. The newly implemented sanctions had short term effects, but the long-term impacts are yet to be seen and should continue to be observed. As such, a follow-up analysis should be done after the conflict is resolved to see where gas and carbon prices have moved. Additionally, ETSs continue to expand worldwide, so if more pricing data is made publicly available, it would be worth analyzing several ETSs with and without MSMs to compare their stability and price movements.

The newfound EU decarbonization pathway will lead to a large renewable energy build-out and gas retirements, so carbon markets should be monitored to see how those unhoused allocations impact prices.

Although there is evidence that the MSR stabilized carbon prices, other legislative factors like residential energy subsidies may have impacted both markets. These other factors should be studied to assess the extent of their impact on carbon prices in both regions.

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Appendix A: Glossary of Terms

Carbon (or emissions) allowance: A permit, voucher, or carbon credit that allows an entity participating in an emissions trading system to emit a specific quantity of carbon dioxide equivalent.
Carbon market: A broad category of economic solutions to incentivize private entities to address externalities relating to carbon-intensive activities by establishing a cost for emissions.
Contraction emissions reduction: A method of emissions reduction were all entities work to collectively reduce their emissions intensity, as seen in emissions trading systems with a hard cap on carbon emissions.
Decarbonization: The process of reducing carbon equivalent emissions and increasing carbon-free or carbon-uptake efforts to ensure that less (or an equal amount of) carbon is emitted than is sequestered artificially. The primary cost-effective driver of decarbonization is the replacement of fossil-fuels with electrification powered by renewable energy paired with battery storage.
Emissions Trading System (ETS): A carbon market variation that establishes a decreasing cap on total emissions. Emission reduction is achieved by distributing carbon allowances that can be bought and sold at a value that can be controlled by market stabilizers but is also influenced by participant demand, which theoretically increases as fewer allowances become available, leading to a greater incentive to decarbonize operations.
External market disruption: A situation wherein markets cease to function in a stable manner due to factors that are tangentially related to the market itself without being directly involved.
Fixed cap scheme: An ETS structure that regulates the total amount of carbon emissions. This total decreases on a predetermined schedule and cannot be adjusted by market factors.
Market Stabilizing Mechanism (MSM): A subset of tools that can be used in ETSs to drive prices in a desired direction, or to stabilize prices during periods of instability. Usually, this is done through price ceilings/floors (reserve prices) or a pool of permit reserves that can be deployed or filled depending on market conditions.
Market Stability Reserve (MSR): The EU ETS's market stabilization mechanism that collects unallocated carbon allowances to balance supply and demand and make the system more resilient to future demand shocks.
Price-based flexibility mechanisms: A type of ETS that allows for flexibility in the total cap on emissions as a form of market stabilization. This mechanism trades off emissions reduction for price stability.