Undergraduate Research Fellowship Working Paper Series

Title:

"Assessing the Economic Impact of Climate Policies A Comparative Study of GDP Growth in Selected Nations (US, UK, GERMANY, FRANCE)"

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Abstract

This research compares the GDP growth paths of four major nations—the US, UK, GERMANY, FRANCE—to examine the economic impact of climate policy. Time series analysis is used to track long-term economic and environmental developments from 1990 to 2022. The study explores the shifting relationship between climate policy interventions and economic indicators, concentrating on GDP growth and CO2 emissions. During the research period, all four nations spotted significant economic growth and variable degrees of CO2 emission reduction. The United Kingdom and France have achieved significant economic growth and pollution reductions, demonstrating effective climate policies and cleaner energy transitions. Due to its focus on renewable energy and sustainability, Germany has strong economic development and low emissions. Despite economic growth, the US has only marginally reduced CO2 emissions, highlighting the need for stronger climate measures. The study emphasises policy formulation, institutional frameworks, and supportive measures in determining climate policy economic consequences. Policymakers, stakeholders, and scholars may use its empirical findings to understand the complicated link between climate action and economic performance. The research adds to climate policy efficacy and sustainable economic growth by explaining the economic aspects of climate policies and comparing them.

Introduction

Climate change is a significant and serious issue of the 21st century, having wide-ranging effects on global economies, cultures, and ecosystems. As a reaction, countries globally have undertaken many climate policy efforts with the goal of reducing greenhouse gas emissions, adjusting to evolving environmental circumstances, and promoting resilience. As policymakers strive to find a balance between environmental goals and economic growth, there has been a growing focus on comprehending the economic consequences of climate policies.

This research aims to evaluate the economic consequences of climate policy by comparing the GDP growth paths of four significant nations: the United States, the United Kingdom, Germany, and France. Although there is increasing agreement on the need for immediate action to address climate change, there is a significant lack of research on the lasting economic impacts of climate policy, particularly when analysed using rigorous quantitative methods like time series analysis. Although many studies have examined the environmental and social aspects of climate change, there are fewer that have thoroughly examined how climate policies influence economic performance over time, especially when comparing different contexts.

This research is important because it has the ability to fill a gap by offering factual insights into how climate policies affect GDP growth. This may help decision-makers at both national and international levels make informed choices based on facts. This study aims to use a time series analytic technique to examine the relationship between climate policy initiatives and economic indicators. By doing so, it aims to get a detailed knowledge of the intricate

causal mechanisms involved. The project seeks to use comparative analysis to discover similarities and differences in the economic effects of climate policy in various national contexts. This will provide insights into effective strategies, obstacles, and opportunities for enhancement.

Moreover, as countries endeavour to attain the lofty objectives outlined in global accords like the Paris Agreement, comprehending the economic ramifications of climate policy becomes of utmost importance. This research aims to provide significant insights into the continuing discussion on the success of climate policies, delivering practical assistance to policymakers, stakeholders, and scholars. This research aims to clarify the economic aspects of climate action in order to promote informed discussions and support the creation of comprehensive, sustainable policy frameworks that successfully balance environmental preservation and economic growth.

Literature review

The foundation of this literature review is a comprehensive analysis of the financial effects of climate policy, with a focus on studies conducted in the US, UK, Germany, and France. The efficiency of climate policy, its impact on GDP growth, sectoral dynamics, and the broader lessons from past research are all significant subjects.

Much of the previously published research has focused on the effectiveness of climate policy in reducing carbon emissions and achieving environmental goals. Studies by Pizer (2019) and Stavins (2018) show how carbon pricing and incentives for renewable energy may effectively reduce emissions without obstructing economic development, highlighting the potential synergy between environmental and economic objectives (Stavins, 2019).

By examining the relationship between GDP growth and climate policy, Acemoglu et al. and Barrett et al. contribute to the conversation. While a number of studies show a positive relationship between environmentally friendly policies and economic growth, other research emphasizes the role that market processes and policy formulation have in lowering economic risks.

As the sectoral consequences of climate policy are examined, research on renewable energy transitions reveals both good aspects, such as job creation and economic diversification, and negative ramifications, especially in carbon-dependent sectors. This nuanced viewpoint highlights the need for specific tactics to address a variety of economic fallout.

Case studies, such as Germany's Energiewende and the UK's shift to a low-carbon economy, provide valuable insights into successful policy frameworks that other nations may use as a template (The German Energiewende – History, Targets, Policies and Challenges on JSTOR, n.d.). These examples demonstrate how important good and adaptable policy design is to achieving long-term goals.
The significance of obtaining public endorsement for climate efforts is underscored by studies on stakeholder participation and public sentiment. It is acknowledged that swaying

public opinion and ensuring the efficacy of climate policy need excellent communication and participatory decision-making processes (Corner et al., 2014).

The literature also looks at how national climate policy will be affected globally by multilateral accords like the Paris Agreement. A review of the benefits and drawbacks of international collaboration in climate change mitigation by Victor (2011) and Bodansky (2016) makes clear.

An historical perspective on global efforts to address climate change may be gained by examining previous international agreements, including the Kyoto Protocol (1997), the Paris Agreement (2015), and the Copenhagen Accord (2009). These agreements mark important sea changes in the history of international cooperation and climate management.

Examining the national climate policies of the United States, Germany, France, and the United Kingdom reveals a variety of approaches and commitments. Resolving to achieve net-zero emissions by 2050 and the UK Climate Change Act from 2008 show a strong commitment to sustainability. Changes in U.S. policy, such the Clean Power Plan and the shift in positions from administration to administration, emphasize the dynamic nature of climate policy. Germany's Energiewende, which emphasizes renewable energy and increased energy efficiency, exemplifies a comprehensive energy transformation. France has recently become more reliant on renewable energy sources after previously being reliant on nuclear energy.

The literature also addresses the concerns of the present and the path forward, emphasizing the need for technical improvement, international cooperation, and adaptable legal frameworks. Among the difficulties include the need for continuous innovation in sustainable technology, the complexity of securing fair burden-sharing in international discussions, and the changing nature of national and international climate policy (Sebi, C., & Vernay, A. L., 2020).

A review of previous studies on the connection between climate policy and economic growth is presented, with a focus on noteworthy instances that demonstrate the harmonious coexistence of environmental and economic goals. It is concluded that carbon pricing plans are necessary to reduce greenhouse gas emissions without negatively impacting economic expansion, highlighting the need for well-considered legislation. Stern's study highlights the potential financial benefits of transitioning to a low-carbon economy in addition to the financial costs of doing nothing (Stern, N., & Xie, C., 2023).

Identified Gaps in the Literature

Despite the large number of studies, there are still gaps in the literature. The economic effects of climate policies on various sectors are not well known, which contributes to the lack of knowledge about the sectoral consequences of these policies. Moreover, studies can ignore the nuances of policymaking in favor of general impacts, raising questions about the diverse outcomes of different regulatory regimes.
Particularly in large, varied countries, there is little attention paid to regional differences within countries. It is necessary to comprehend how different areas are impacted by climate

policy in order to create inclusive and effective policies that take regional variations into account.

The lack of research on the long-term effects of climate policy on economic growth highlights the need for studies examining the mechanisms behind these effects. Public engagement and buy-in are not sufficiently explored in the literature that is presently available for publication, which calls for further study and is necessary for the successful implementation of policies.

These research gaps need to be overcome in order to provide insightful information on the intricate relationship between economic growth and climate policy. With this knowledge, policymakers may better negotiate the complexities of sustainable development and guarantee the implementation of inclusive climate policies that support both environmental resilience and economic success.

Theoretical Background

Introduction to Climate Policies and Economic Impact

Climate policies include a variety of initiatives aimed at reducing greenhouse gas emissions, adapting to climate change consequences, and promoting sustainable development. These policies might include regulatory frameworks, economic tools, technology incentives, and international agreements targeted at lowering carbon emissions and increasing resilience.

The economic impact assessment process entails assessing the consequences of climate policy on a variety of economic metrics, including GDP growth, employment, income distribution, consumer pricing, and global competitiveness. Understanding these implications is critical for politicians to make educated decisions that balance environmental goals with economic concerns.

Key Indicators for Assessing Impact

GDP Growth

An important measure of economic health, GDP growth is affected by a number of variables, one of which is climate policy. To measure how climate policies affect GDP growth, one must take into account both the direct and indirect effects on energy, as well as on innovation, consumer behavior, and productivity.

Consumption-based emissions

Consumption-based emissions are national or regional emissions that have been adjusted for trade. They are calculated as domestic (or ‘production-based’ emissions) emissions minus the emissions generated in the production of goods and services that are exported to other countries or regions, plus emissions from the production of goods and services that are imported.

Fossil emissions (CO2 emissions)

Fossil emissions measure the quantity of carbon dioxide (CO_2) emitted from the burning of fossil fuels, and directly from industrial processes such as cement and steel production. Fossil CO_2 includes emissions from coal, oil, gas, flaring, cement, steel, and other industrial processes. Fossil emissions do not include land use change, deforestation, soils, or vegetation.

Other Economic Indicators

In addition to GDP growth, measures such as employment levels, productivity changes, investment patterns, and income distribution can give useful information on the economic impact of climate policy.

What Empirics Say?

Different empirical studies on the economic effects of climate policies have come up with different outcomes, which shows how complicated this issue is. Numerous studies that have looked at the connection between GDP growth and climate policies in various nations have shed light on the possible impacts of these policies on economic performance.

There is conflicting empirical data about the economic effects of climate initiatives in the United States. A carbon tax or cap-and-trade system, for example, might encourage economic efficiency and innovation while lowering greenhouse gas emissions, according to research by Aldy et al. (2010). However, the implementation of comprehensive climate policy at the federal level has been hampered by political obstacles and regulatory ambiguities, which has limited the field of empirical study on this issue.

According to research by Stern (2007), effective climate policies may promote investment in clean technology and innovation in the UK, which will boost economic development. Furthermore, by boosting productivity and generating new employment opportunities in low-carbon industries, the UK Committee on Climate Change (CCC, 2019) determined that enacting ambitious climate policies might support long-term economic growth.

On the other hand, certain research has brought attention to possible immediate financial consequences linked to strict climate regulations. For example, a meta-analysis conducted in 2019 by Van den Bergh et al. shows that although climate measures can cause a brief decline in GDP growth, the long-term advantages—like averted climatic harm and enhanced public health—far exceed these short-term expenses.

Research conducted in Germany has demonstrated how climate regulations have a favourable economic impact, especially in the field of renewable energy. Schmidt et al. (2017) found that Germany's Energiewende (energy transition) has boosted economic development and environmental sustainability by fostering innovation, creating employment, and reducing reliance on fossil fuels.
Similarly, empirical data from France indicates that, when combined with supporting policies, climate legislation may have a beneficial economic impact. For instance, Bovet and Audinet's (2020) research discovered that France's shift to renewable energy sources has

boosted economic activity in areas like energy efficiency, green mobility, and the generation of renewable energy.

Overall, empirical studies on how climate policies affect the economy highlight how crucial institutional frameworks, supportive policies, and policy design are to deciding the results of these policies. A shift to a low-carbon economy has long-term economic advantages, but some studies also point to possible short-term costs, especially in the lack of sufficient legislative support. Furthermore, this thesis's comparative research will provide insightful information on the many ways that nations have implemented climate policy and achieved sustainable economic development.

Methodology

Our methodology for evaluating the economic effects of climate policy employs a comprehensive approach that combines data gathering, analysis, and interpretation. We depend on trusted databases, such as the World Bank's World Development Indicators, to acquire comprehensive and trustworthy data that covers a broad time frame from 1990 to 2022. The long duration of this era enables us to accurately observe and analyze economic and environmental patterns over a lengthy period, ensuring a strong and reliable basis for our study.

The data obtained from trustworthy sources, as described in the approach, will be used for analysis. The tables in the appendix, which provide time series data for GDP and CO2 emissions of the selected nations, will be used as the basis for the charts and the in-depth analysis. This methodology guarantees transparency, reproducibility, and precision in analyzing the economic consequences of climate policy in the United States, the United Kingdom, Germany, and France.

Our investigation focuses on identifying carbon dioxide emissions as a crucial factor. The core of the research is centred around time series analysis, which investigates the correlation between GDP growth and CO2 emissions for each country within the chosen time frame. Carbon dioxide emissions are important indications of a country's role in causing climate change and its influence on the environment. Our objective is to analyze the emissions data for the United States, the United Kingdom, Germany, and France throughout the stated time in order to identify patterns, trends, and changes in each country's environmental impact. This technique allows us to obtain valuable information about the efficacy of climate policies and efforts adopted by these countries over a period of time.

The investigation will employ models, as outlined in this work (Friedlingstein et al., 2023). The selection of these models is based on their appropriateness in portraying the dynamic interactions and possible causal linkages between GDP growth and CO2 emissions over a period of time.

Calculating adjusted GDP growth rates entails factoring in the environmental expenses linked to carbon dioxide emissions. These costs include a range of issues, such as harm to ecosystems, health implications, and spending for remediation. By integrating these

environmental expenses into our research, our objective is to provide a comprehensive viewpoint on economic development that takes into account both economic and environmental aspects.

Results

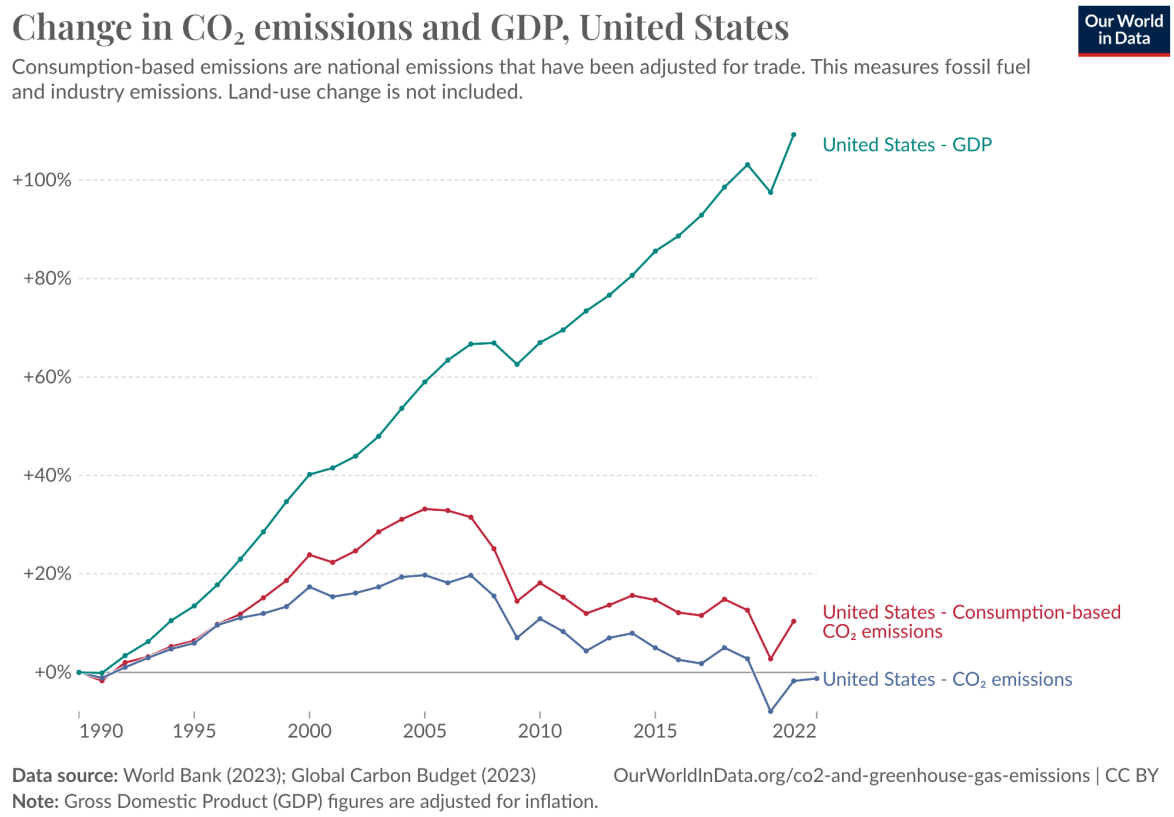

Fig 1: Change in CO_2 emissions and GDP, United States

When analyzing the green line that represents the change in GDP, we see that it has been steadily increasing, with a sharp rise until around 2007, followed by a dip during the global financial crisis, and then a continued upward trend with some fluctuations. The red line depicts the change in consumption-based CO2 emissions, which have been relatively stable, with some fluctuations over the years, but showing a decreasing trend in recent years. While the blue line shows the change in CO2 emissions, which follows a similar trend to the consumption-based emissions, with a more pronounced decrease in recent years. The graph suggests that the United States has been able to decouple its economic growth from CO2 emissions to some extent, with emissions remaining relatively stable or decreasing while the GDP continues to grow, particularly in recent years.

Over the given time, the United States saw significant economic development, with its Gross Domestic Product (GDP) rising from $10.10 trillion in 1990 to $21.13 trillion by 2022. This translates to an excellent absolute gain of nearly $11.03 trillion and a tremendous relative growth of 109%. However, in terms of carbon dioxide (CO2) emissions, the United States

saw a small decline, with emissions falling from 5.12 billion metric tons in 1990 to 5.06 billion in 2022. This is a moderate absolute reduction of around 63.65 million metric tons, with a tiny relative decline of 1%. Despite the economic expansion, the marginal reduction in CO2 emissions highlights the need for more robust climate policies and measures to decouple economic growth from carbon emissions, such as increased renewable energy adoption, improved energy efficiency standards, and stronger regulatory frameworks.

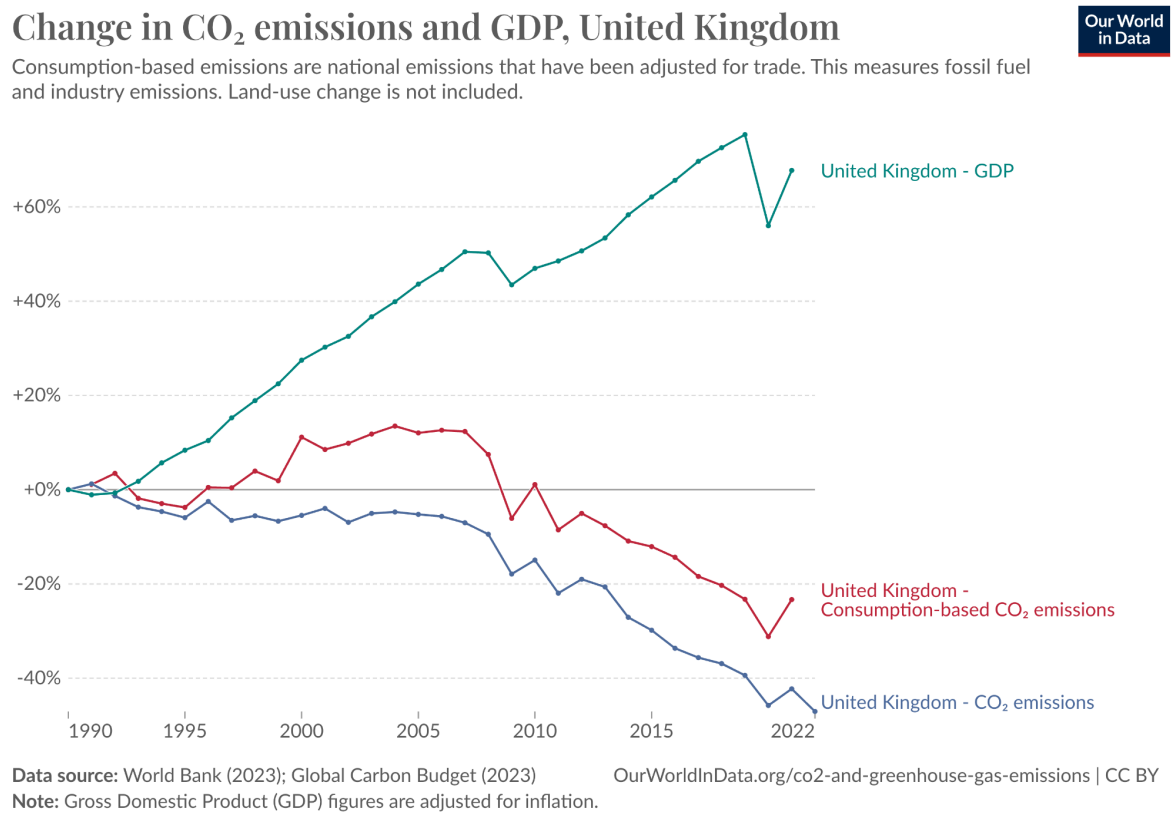

Fig 2: Change in CO_2 emissions and GDP, United Kingdom

When looking at the green line that represents the change in GDP, which has been steadily increasing, with a sharp rise until around 2007, followed by a dip during the global financial crisis, and then a continued upward trend with some fluctuations. The red line depicts the change in consumption-based CO2 emissions, which have been decreasing overall, with a sharp decline in the early 2000s and a more gradual decline in recent years. While the blue line shows the change in CO2 emissions, which follows a similar trend to the consumption-based emissions, with a sharper decline in the early 2000s and a more gradual decline thereafter. The graph highlights the decoupling of economic growth, as measured by GDP, from CO2 emissions in the United Kingdom, with emissions decreasing while the economy continues to grow, particularly in recent years.

With a GDP that increased from $1.81 trillion in 1990 to $3.03 trillion in 2022, the United Kingdom showcased remarkable economic growth throughout the defined time. This is an impressive 68% relative gain and an absolute increase of almost $1.22 trillion. In the same vein, the United Kingdom was able to significantly cut its CO2 emissions, which fell from 601.95 million metric tons in 1990 to 318.65 million metric tons in 2022. This translates to a substantial relative drop of 47% and an absolute drop of about 283.29 million metric tons.

These tendencies highlight the fact that the United Kingdom has been successful in promoting economic growth and enacting effective climate policies to reduce emissions, maybe through programs like carbon pricing, energy efficiency upgrades, and the integration of renewable energy sources.

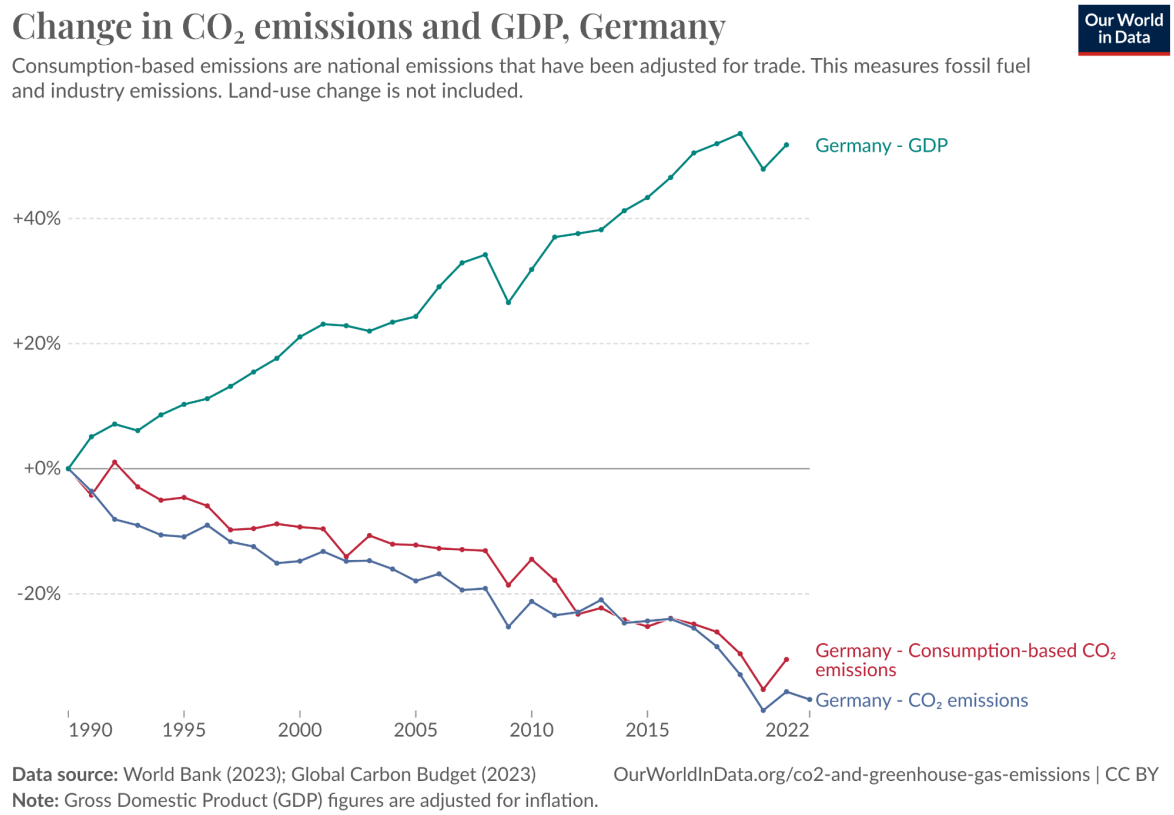

Fig 3: Change in CO_2 emissions and GDP, Germany

The green change in GDP line has been steadily rising over the time period, with a sharp rise until around 2008, followed by a dip during the global financial crisis, and then a continued upward trend with some fluctuations. The red line depicts the change in consumption-based CO2 emissions, which have been decreasing overall, with some fluctuations over the years. While the blue line that is illustrating the change in CO2 emissions, follows a similar trend to the consumption-based emissions, with a more pronounced decrease in recent years. The graph highlights the decoupling of economic growth, as measured by GDP, from CO2 emissions in Germany, with emissions decreasing while the economy continues to grow, particularly in recent years.

From 1990 to 2022, Germany's Gross Domestic Product (GDP) increased from $2.92 trillion to $4.42 trillion, demonstrating significant economic expansion. A relative change of 52% and an absolute change of about $1.51 trillion are shown by this. Emissions of carbon dioxide (CO2) from Germany fell sharply from 1.05 billion metric tons in 1990 to 665.60 million metric tons in 2022, a decline of substantially. A relative drop of 37% and an absolute drop of 389.14 million metric tons are shown in this. The considerable focus on renewable energy, energy efficiency, and sustainable development policies in Germany is likely

responsible for these developments, which indicate a successful decoupling of economic growth from carbon emissions.

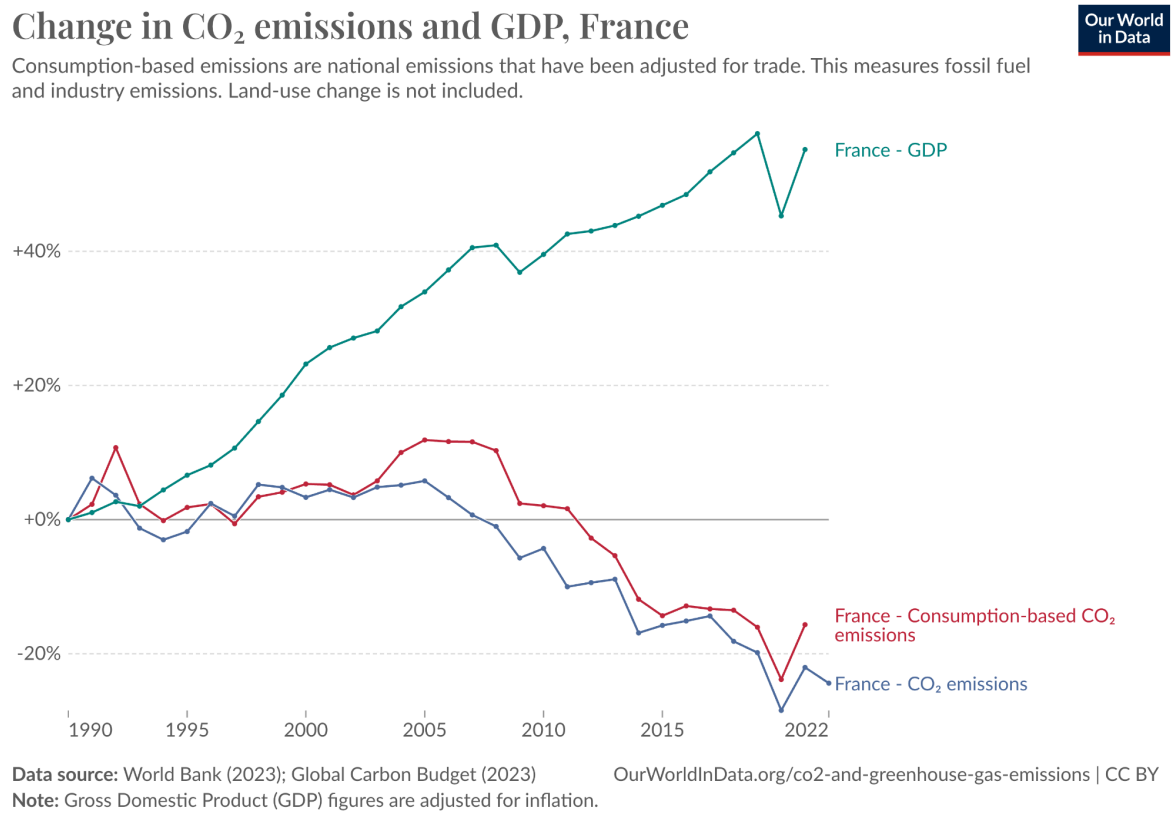

Fig 4: Change in CO_2 emissions and GDP, France

The green line representing the change in GDP has been steadily increasing over the time period, with a sharp rise until around 2008, followed by a dip during the global financial crisis, and then a continued upward trend with some fluctuations. The red line depicting the change in consumption-based CO2 emissions has been relatively stable, with some fluctuations over the years, but showing a decreasing trend in recent years. The blue line shows the change in CO2 emissions, which follows a similar trend to the consumption-based emissions, with a more pronounced decrease in recent years. The graph suggests that France has been able to decouple its economic growth from CO2 emissions to some extent, with emissions remaining relatively stable or decreasing while the GDP continues to grow, particularly in recent years.

During the time under consideration, France saw substantial economic expansion, as its Gross Domestic Product (GDP) rose from $1.96 trillion in 1990 to $3.05 trillion in 2022. This is an absolute increase of almost $1.08 trillion and a relative increase of 55%. Simultaneously, France effectively reduced its CO2 emissions, lowering them from 393.43 million metric tons in 1990 to 297.53 million metric tons in 2022. This signifies a total reduction of around 95.90 million metric tons and a proportional drop of 24%. These patterns indicate a strong economic growth together with successful environmental regulations, which may include a transition towards cleaner energy sources and improved efficiency measures.

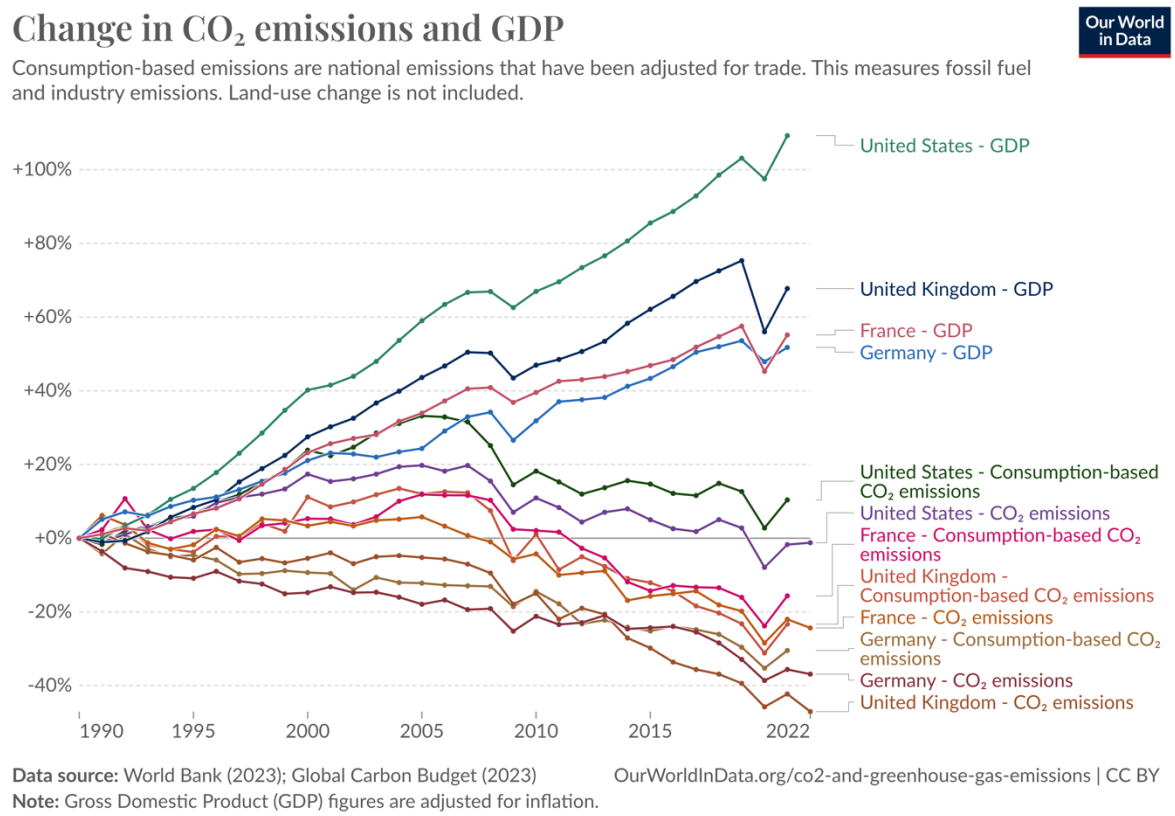

Fig 5: Change in CO_2 emissions and GDP for US, UK, Germany and France

The comprehensive examination of GDP growth trends and CO2 emissions across the United Kingdom, the United States, Germany, and France exhibits distinct patterns of decoupling economic activity from carbon emissions.

The United Kingdom and France exhibit a notable divergence, with their GDP rising at a faster rate than consumption-based emissions after around 2000, indicating greater progress in decoupling economic growth from emissions growth. Germany's emissions lines remain relatively flat after the 2008 recession, despite continued GDP expansion, suggesting improved decoupling efforts. In contrast, the United States displays a closer coupling between its GDP and emissions lines, implying less substantial decoupling over this period compared to its European counterparts. These divergent trends underscore the varying degrees to which these major economies have succeeded in transitioning towards low-carbon development pathways while sustaining economic progress, a critical challenge in mitigating climate change impacts.

Limitations

The use of already-collected data for GDP growth and CO_2 emissions is a limitation of this study. Such data might be inconsistent or of low quality, which can introduce bias into the research, especially when compared between countries and across time. In addition, there may be a lack of complete information on the monetary effects of climate policies due to data

inconsistencies or gaps, and subtle differences in data-collecting methods or reporting standards could make it hard to see the connection between policy actions and monetary results. Therefore, although the study aims to shed light on the financial consequences of climate policy, it is important to recognize the constraints caused by the data's quality and availability.

Assessing the link between climate policy and GDP growth is complicated, which is another major restriction. It is difficult to demonstrate a precise causal relationship, but time series analysis can reveal correlations between policy actions and economic indices. It is difficult to determine the exact effect of policy interventions because of the many confounding elements that could affect both climate policies and economic performance, such as socio-economic issues and geopolitical dynamics. Further clouding the causative processes are nation-specific contextual subtleties including institutional frameworks, political stability, and technology breakthroughs. Therefore, although this study adds to our understanding of the monetary effects of climate policy, we must proceed with care in interpreting the results and must acknowledge the difficulties of drawing causal conclusions from these types of studies.

Conclusion

The comparative analysis of GDP growth trajectories and CO2 emissions in the United Kingdom, the United States, Germany, and France reveals valuable insights into the economic impact of climate policies over the past three decades. Across all four nations, significant economic growth occurred alongside varying degrees of CO2 emissions reduction, highlighting the potential for decoupling economic expansion from carbon emissions.

The United Kingdom demonstrated remarkable economic expansion of 68% while achieving a significant reduction in CO2 emissions by 47%. This indicates the UK's success in fostering economic prosperity while concurrently implementing effective climate policies, possibly through initiatives such as renewable energy integration and carbon pricing mechanisms.

Germany experienced substantial economic growth of 52% during the same period, alongside a remarkable decrease in CO2 emissions by 37%. The successful decoupling of economic growth from carbon emissions underscores Germany's emphasis on renewable energy adoption and sustainable development policies.

France exhibited robust economic growth of 55% from 1990 to 2022, coupled with a notable reduction in CO2 emissions by 24%. This suggests effective environmental policies contributing to economic prosperity, possibly driven by shifts towards cleaner energy sources and enhanced efficiency measures.

In contrast, the United States witnessed impressive economic growth of 109%, albeit with only a marginal decrease in CO2 emissions by 1%. This suggests a need for more robust

climate policies and measures to decouple economic growth from carbon emissions effectively.

The comparative analysis underscores the importance of well-designed climate policies in achieving sustainable economic development. The findings suggest that effective climate policies can stimulate economic growth while concurrently reducing greenhouse gas emissions, highlighting the potential for synergies between environmental and economic objectives. However, continued efforts are needed to strengthen climate policies and accelerate the transition to a low-carbon economy, ensuring a sustainable future for generations to come.

References

Burns, C., Eckersley, P., & Tobin, P. (2020). *EU environmental policy in times of crisis. Journal of European Public Policy*, 27(1), 1-19. https://www.tandfonline.com/doi/full/10.1080/13501763.2018.1561741

Corner, A., Markowitz, E. M., & Pidgeon, N. F. (2014). Public engagement with climate change: The role of human values. *WIREs Climate Change*. https://doi.org/10.1002/wcc.269

Friedlingstein, P., O'Sullivan, M., Jones, M. W., Andrew, R. M., Bakker, D. C. E., Hauck, J., Landschützer, P., Le Quéré, C., Luijkx, I. T., Peters, G. P., Peters, W., Pongratz, J., Schwingshackl, C., Sitch, S., Canadell, J. G., Ciais, P., Jackson, R. B., Alin, S. R., Anthoni, P., ... Zheng, B. (2023). Global Carbon Budget 2023. *Earth System Science Data*, 15(12), 5301–5369. https://doi.org/10.5194/essd-15-5301-2023

Grafakos, S., Viero, G., Reckien, D., Trigg, K., Viguie, V., Sudmant, A., ... & Dawson, R. (2020). Integration of mitigation and adaptation in urban climate change action plans in Europe: A systematic assessment. Renewable and Sustainable Energy Reviews, 121, 109623. https://www.sciencedirect.com/science/article/abs/pii/S1364032119308305

Klemeš, J. J., Van Fan, Y., Tan, R. R., & Jiang, P. (2020). Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19. Renewable and Sustainable Energy Reviews, 127, 109883. https://www.sciencedirect.com/science/article/pii/S1364032120301763

Our World in Data. (2023). Change in CO2 emissions and GDP. https://ourworldindata.org/grapher/co2-emissions-and-gdp?facet=none&showSelectionOnlyInTable=1&country=FRA~USA~DEU~GBR

Rye, C. D., & Jackson, T. (2020). Using critical slowing down indicators to understand economic growth rate variability and secular stagnation. *Scientific Reports*, 10(1), 10481. https://www.nature.com/articles/s41598-020-66996-6

Salvatore, D. (2020). Growth and trade in the United States and the world economy: Overview. Journal of Policy Modeling, 42(4), 750-759. https://www.sciencedirect.com/science/article/pii/S0161893820300351

Sebi, C., & Vernay, A. L. (2020). Community renewable energy in France: The state of development and the way forward. *Energy Policy*, 147, 111874. https://www.sciencedirect.com/science/article/pii/S0301421520305905

Stavins, R. N. (2019). The Future of US Carbon-Pricing Policy. National Bureau of Economic Research. https://ideas.repec.org/h/nbr/nberch/14285.html

Stern, N., & Xie, C. (2023). China's new growth story: Linking the 14th Five-Year Plan with the 2060 carbon neutrality pledge. *Journal of Chinese Economic and Business Studies*, 21(1), 5-25. https://www.tandfonline.com/doi/abs/10.1080/14765284.2022.2073172

The German Energiewende – History, Targets, Policies and Challenges on JSTOR. (n.d.). JSTOR. https://www.jstor.org/stable/24324660

Appendix

Table 1: United States GDP and CO2 Emissions (1990-2022)

Year	GDP, PPP (constant 2017 international $)	Annual CO2 emissions	Annual consumption-based CO2 emissions
1990	1.00988E+13	5120957000	5048029700
1991	1.00879E+13	5062956500	4961271300
1992	1.04432E+13	5174227500	5148226000
1993	1.07306E+13	5272850400	5207483000
1994	1.11629E+13	5364279300	5312555500
1995	1.14625E+13	5425259500	5372450000
1996	1.1895E+13	5612983000	5540392400
1997	1.2424E+13	5688142300	5646006300
1998	1.29807E+13	5733281000	5811633700
1999	1.36031E+13	5803918000	5990146600
2000	1.41577E+13	6010135600	6253939700
2001	1.42928E+13	5907739600	6176889300
2002	1.45352E+13	5946308000	6293475000
2003	1.49417E+13	6010145300	6488713000
2004	1.55173E+13	6112655000	6617633000
2005	1.60578E+13	6132183000	6724063700
2006	1.65046E+13	6052686000	6707719700
2007	1.68365E+13	6130123000	6639217000
2008	1.6857E+13	5915118600	6315350500
2009	1.64188E+13	5480725500	5779449000
2010	1.68635E+13	5679715300	5965814000
2011	1.71249E+13	5546116000	5818907600
2012	1.75155E+13	5344086000	5652215000
2013	1.78381E+13	5480156700	5738612700
2014	1.82462E+13	5528681000	5836821000
2015	1.874E+13	5376473000	5790281000
2016	1.90525E+13	5252932000	5660727000
2017	1.94796E+13	5212162000	5631145500
2018	2.00534E+13	5377797000	5798152000
2019	2.05135E+13	5262145000	5685683700
2020	1.99457E+13	4714628000	5186557400
2021	2.11316E+13	5032213000	5572173300
2022		5057303600	

Table 2: United Kingdom GDP and CO2 Emissions (1990-2022)

Year	GDP, PPP (constant 2017 international $)	Annual CO2 emissions	Annual consumption-based CO2 emissions
1990	1.80547E+12	601945100	669606140
1991	1.78555E+12	609412700	676764200
1992	1.79271E+12	593845950	692667650
1993	1.83735E+12	579612540	657332100
1994	1.90801E+12	574016900	649759600
1995	1.95632E+12	566158900	644332500
1996	1.99364E+12	586760700	672855800
1997	2.08069E+12	562708160	672131200
1998	2.14639E+12	568543700	695996600
1999	2.21108E+12	561649600	682163300
2000	2.30157E+12	569033660	744108100
2001	2.35123E+12	577970560	726544600
2002	2.39286E+12	560273200	735419800
2003	2.46759E+12	571618750	748545900
2004	2.52545E+12	573429760	759976700
2005	2.59284E+12	570338370	750134460
2006	2.64886E+12	567845600	754026050
2007	2.71676E+12	559566460	752317900
2008	2.71257E+12	544932400	719616600
2009	2.59022E+12	494107700	628732400
2010	2.65316E+12	511904580	676785600
2011	2.68149E+12	469713300	612430340
2012	2.72033E+12	487476770	635758600
2013	2.76983E+12	477611260	618388860
2014	2.85846E+12	438807070	596451100
2015	2.92687E+12	422460800	588640500
2016	2.99024E+12	399430140	573530940
2017	3.06331E+12	387367140	546267400
2018	3.11554E+12	379729760	533604320
2019	3.16552E+12	364753280	513828030
2020	2.81634E+12	326263200	460805060
2021	3.02826E+12	347465060	513400060
2022		318654370	

Table 3: Germany GDP and CO2 Emissions (1990-2022)

Year	GDP, PPP (constant 2017 international $)	Annual CO2 emissions	Annual consumption-based CO2 emissions
1990	2.91515E+12	1054740600	1194926000
1991	3.06406E+12	1016870300	1144321500
1992	3.12299E+12	969474200	1207437600
1993	3.09248E+12	959367200	1160422500
1994	3.16645E+12	943184830	1134980500
1995	3.21535E+12	939897150	1140018300
1996	3.24126E+12	959653300	1123902600
1997	3.29934E+12	931486900	1078258300
1998	3.36579E+12	923467000	1080494600
1999	3.42931E+12	895402100	1089646500
2000	3.52919E+12	898938050	1083652100
2001	3.58853E+12	915242100	1080182500
2002	3.58143E+12	898834560	1027003140
2003	3.55635E+12	899858370	1067265340
2004	3.59814E+12	885632500	1050723650
2005	3.62447E+12	865470700	1049214900
2006	3.7628E+12	877497660	1042731700
2007	3.8748E+12	850229800	1040366140
2008	3.91199E+12	852857860	1038431800
2009	3.68925E+12	788285800	972580400
2010	3.84345E+12	831129600	1022113100
2011	3.99432E+12	807613950	981790800
2012	4.01103E+12	812815550	917210750
2013	4.02858E+12	833804350	929136500
2014	4.1176E+12	794738500	906148500
2015	4.17903E+12	798084740	893463900
2016	4.27222E+12	801744600	909227100
2017	4.38673E+12	785985860	898094200
2018	4.42977E+12	754811140	883258560
2019	4.47658E+12	707491400	841380200
2020	4.31109E+12	647252300	773277400
2021	4.42434E+12	678798900	830509630
2022		665604700	

Table 4: France GDP and CO2 Emissions (1990-2022)

Year	GDP, PPP (constant 2017 international $)	Annual CO2 emissions	Annual consumption-based CO2 emissions
1990	1.96441E+12	393430700	493079870
1991	1.985E+12	417775000	504327330
1992	2.01675E+12	407717280	545937800
1993	2.00407E+12	388397980	504507140
1994	2.05133E+12	381576320	492354750
1995	2.09454E+12	386456830	502071140
1996	2.12414E+12	402893150	504597700
1997	2.17377E+12	395511900	490037570
1998	2.25178E+12	413964540	509896960
1999	2.32882E+12	412369630	513189000
2000	2.42019E+12	406507520	519230820
2001	2.4682E+12	411016480	518791550
2002	2.49623E+12	406431040	511183000
2003	2.51678E+12	412456700	521593860
2004	2.588E+12	413663400	542455360
2005	2.63104E+12	416151140	551656450
2006	2.69548E+12	406309800	550430200
2007	2.76084E+12	396198180	550306100
2008	2.76788E+12	389427330	543767900
2009	2.68835E+12	370965630	504964220
2010	2.74076E+12	376563900	503268540
2011	2.80085E+12	354089100	501104600
2012	2.80963E+12	356444540	479554240
2013	2.82582E+12	358487460	466584800
2014	2.85284E+12	327009470	434584830
2015	2.88459E+12	331414430	422465020
2016	2.91619E+12	334005060	429594300
2017	2.98301E+12	336895900	427413500
2018	3.03864E+12	322078560	426542900
2019	3.09465E+12	315449730	413963360
2020	2.85374E+12	281539040	375640600
2021	3.04827E+12	306775740	415829570
2022		297533920	