Central banks' Integration of Climate Change Issues into an Increased Taylor Rule in the Mediterranean Region: An Analysis based on the System The Generalized Method of Moments (GMM)

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Abstract: Climate change could have significant consequences such as rising sea levels, intensified storms, floods, droughts and forest fires. These effects could lead to forced migration, ecosystem degradation and extinction of many species. In addition, they could also affect the ability of central banks to maintain price stability. This research proposes an innovative method to integrate CO2 emissions into a Taylor rule, considering a risk premium related to climate change. This risk premium is determined by the CO2 emission gap. The model is evaluated over a period from 2002 to 2022 for 14 countries in the Mediterranean region, using the two step system Generalized Method of Moments (GMM). The results show that the coefficient associated with the CO2 emission gap is both positive and statistically significant at a level of 5%. This means that a 1% increase in this gap leads the Central Bank to increase its policy rate by 2.64%.

Key-Words: Central Bank; Climate change; CO2 emissions; Taylor's Rule; System Generalized Method of Moments (GMM); Mediterranean region.

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1 Introduction

Central banks around the world are paying increasing attention to climate change, recognizing that it could undermine their ability to achieve their monetary and financial stability goals. In addition, climate change poses major economic and social challenges, requiring a central role for the financial system in managing climate risks and financing the transition to a low carbon economy. Climate change can influence monetary policy in several ways. First, the physical and transitional risks associated with climate change can affect macroeconomics and inflation forecasts. Second, climate change can indirectly influence monetary policy by changing the expectations of households and businesses about future economic performance, [1]. Climate risks also directly affect central bank balance sheets. Thus, central bank risk managers need to integrate these risks into their day to day operations.

An effective approach is to establish climate risk management principles, which provide the basis for the identification, assessment, mitigation and disclosure of climate risks.These principles should also detail the tools used by the central bank at each stage of this climate risk management process. In November 2020, the ECB published a Guide on Climate and Environmental Risks,[2], setting out its supervisory expectations for the management and communication of climate risks. Although the guide is not formally binding, it sets out the standards that banks should comply with. It covers several areas such as strategy, governance, organization, measurement and risk management, as well as non financial reporting.

As part of its supervision, the ECB launched its first climate stress test, involving 104 major euro area banks, [3]. The main objective was to assess banks' ability to perform internal stress analyses related to climate risks. This included their ability to develop a framework for climate risk analysis, assess different climate risk factors and project climate risk into the future.

At the heart of monetary policy is Taylor's famous rule, [4]. This rule proposes that the EDF's interest rate policy should follow a simple pattern: respond to differences between inflation and the inflation target, as well as between real output and potential output. Since then, many econometric studies, such as, [5], [6], [7], [8], [9], [10], have estimated Taylor's rule for various countries and economic contexts. This research examined the central principle that a central bank reacts when real macroeconomic performance diverges from its objectives. For example, if inflation exceeds its target and/or real output exceeds potential, a central bank must raise its key interest rates. Taylor's rule has become a central tool in the teaching of monetary policy, as noted by Waters in 2021.

Our analysis extends the application of the Taylor rule by considering the gap between CO2 emissions and their target, as a key factor influencing changes in interest rates. The most polluting economies should bear higher interest rates to reflect their increased level of polluting emissions. This proposal introduces a premium, called the climate change premium, which must be integrated into central bank decision making. The new model of Taylor's rule is examined in the Mediterranean region using the system method GMM. Our work aims to answer the following research question: how can central banks in the Mediterranean region adapt their monetary policy to incorporate CO2 emissions into an augmented Taylor rule, in the face of the challenges posed by climate change?

To address this issue in a systematic way, our study is structured along two main lines. The first is a review of the literature on climate change and the role of central banks. The second axis is dedicated to the application of an augmented Taylor rule, integrating CO2 emissions, using the GMM system method, and to the analysis of the results obtained.

2 Climate Change and the Role of Central Banks

The main thrust of this proposal is that central banks should incorporate climate change issues into their decision making processes. We plan to analyse the origins and impacts of climate change and then examine the role that banks can play in combating this phenomenon.

2.1 Climate Change

The industrial revolution was propelled by the intensive use of fossil fuels, mainly coal, which, once burned, released carbon dioxide into the atmosphere, contributing to global warming. Watt's steam engines and most of the means of transport at the time operated with coal. During the 20th century, oil became crucial to fuel vehicles, aircraft and ships. The agricultural revolution has also played a role in climate change due to the use of nitrogen fertilizers, which emit powerful greenhouse gases. The expansion of agricultural land to meet growing demand has led to massive deforestation, releasing carbon stored in trees, while livestock emit methane during digestion. These revolutions have led to remarkable economic growth, significantly reducing poverty and hunger in many parts of the world. However, this growth has also led to an unprecedented increase in greenhouse gas emissions, causing man made climate change. The correlation between real GDP growth and the increase in global CO2 emissions is not accidental, but demonstrates a causal relationship, as illustrated in Figure 1 and Figure 2. Climate change represents an unprecedented challenge for humanity, capable of profoundly altering the biosphere and raising

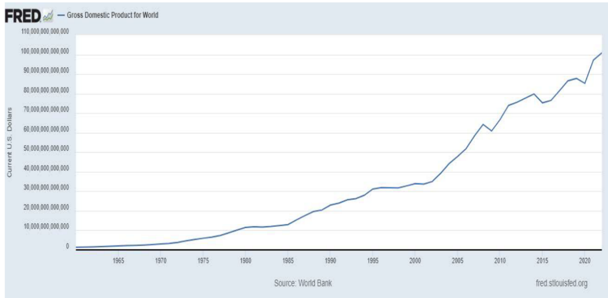

Fig. 1: Global GDP, Source: Federal Reserve Economic Data

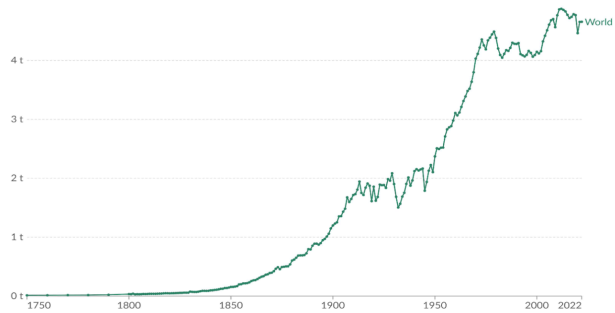

Fig. 2: Increase in CO2 concentration, Source: Our World in Data

awareness of the global ecological impact of human development. The current era, described by some as the "Anthropocene", bears witness to the fact that humanity is now a threat to itself. In this section, we examine the causes and consequences of climate change.

2.2 The Causes of Climate Change

Industrialized nations are generally identified as the main contributors to climate change, while the countries of the South are seen as having less responsibility for climate change. Much research has been done to understand the reasons for the difference in pollution between certain countries. Most of these studies have shown a positive correlation between economic growth and greenhouse gas emissions, [11]. Another factor contributing to the increase in greenhouse gas emissions is population growth. According to United Nations projections, the world population is expected to reach about 9 billion by 2050. This population growth is mainly concentrated in the countries of the South: Africa and Asia have the highest growth rates, while the European population is declining. By 2050, it is estimated that 60 per cent of the world's population will reside in Asia and 20 per cent in Africa.

OECD countries account for only about 12% of the world's population, underscoring the need for more involvement of other nations in emission reduction efforts, particularly major economies such as China, India or Brazil, [12]. Human activities have contributed significantly to increasing levels of greenhouse gases in the atmosphere.

2.3 The Consequences of Climate Change

Climate change has emerged as one of the major challenges of our time. The impacts of global warming are now evident, as shown by the changes in adverse global climate events illustrated in Figure 3.

Existing research on the relationship between climate and the economy highlights several mechanisms by which progressive global warming could curb the potential for economic growth. First, it could lead to a decline in the effective supply of labour in the economy due to lower labour productivity caused by physical and cognitive changes in human capital. In addition, extreme heat waves could also reduce this supply by increasing mortality and morbidity, promoting the spread of diseases such as malaria, [13]. For example, [14] observed a decrease in productivity of about 1.7% for each 1◦C increase in daily average temperature above 15◦C, based on variations between U.S. counties over a 40 year period. Similarly, [15] found that higher temperatures have a negative impact on a more comprehensive indicator of human well being, as measured by the Human Development Index. Another possible consequence of global warming could be a reduction in the rate of accumulation of productive capital, either by permanent damage or by an increase in the rate of depreciation of capital, [13]. There is a strong link between agriculture and climate change, where changes in environmental conditions affect crop production and productivity, contributing to global food insecurity, [16], [17], [18], [19]. The rise in global temperature leads to an increase in the water pressure deficit, resulting in a reduction in crop productivity. To cope with this, agriculture adopts adaptation strategies such as changing crop cycles and selecting more resistant seeds, such as wheat varieties adapted to heat and requiring less sunlight. Other agricultural production methods are expanding, such as organic farming, agro ecology, permaculture and urban agriculture.

2.4 The Role of the Central Bank in the Fight against Climate Change

Central banks are institutions responsible for overseeing the financial system and implementing a country's monetary policy. In many countries, they are public entities with institutional independence from government. Unlike commercial banks, central banks do not function as deposit taking institutions

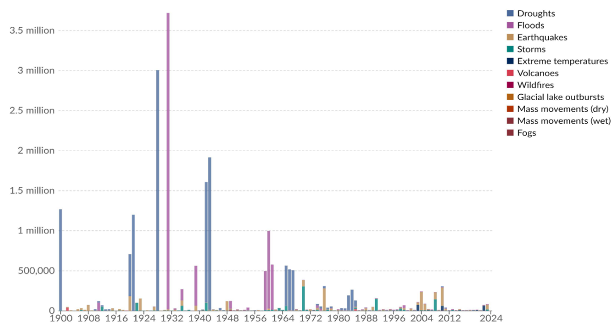

Fig. 3: Number of deaths from natural disasters worldwide, Source: Our World in Data

open to the general public; it is generally impossible for an individual to open an account or apply for a loan. The evolution of the role of central banks has been marked by a great diversity throughout history, however, contemporary central banks are generally assigned two main functions:

• Monetary policy: Its role involves the issuance of notes and coins, while developing monetary guidelines aimed at ensuring price stability and confidence in the currency. In many countries, an inflation target is defined, and it is up to the central bank to achieve it. Therefore, determining "key interest rates" is the main measure used by central banks to implement their monetary policy;

• Financial stability: It takes place through the supervision of the financial system, where central banks use their regulatory and supervisory authority to ensure the stability of financial institutions, prevent bank crises and discourage reckless or fraudulent banking practices. In times of financial crisis, they also act as "lenders of last resort" for the banking sector.

Central banks must take climate change risks into account because of their potentially significant implications for the economy and the financial system. Climate change can cause disruptions at different levels of the economy, both through natural disasters and transition shocks, making it a potential source of price and financial instability, [20]. Since climate risks can directly affect the traditional responsibilities of central banks, all institutions should integrate climate related physical and transition risks into their strategies to maintain financial stability.

2.5 Physical Risks and Their Impact on Monetary Policy

Physical hazards include damage caused by weather events such as floods, droughts, fires, heat waves, sea level rise, and damage to ecosystems and the services they provide. These risks can be immediate, as in floods, or prolonged, such as changes in precipitation patterns or rising temperatures. Since tightening monetary policy could aggravate the economic consequences of weather disasters, a flexible approach to the inflation target would allow a central bank to exercise discretion in mitigating these adverse effects. Central banks should carefully examine the impact on supply and demand as well as on the output gap, especially because of the increased difficulty in forecasting potential output during unforeseen shocks such as climate events. The destruction of the capital stock following natural disasters reduces overall supply, while reconstruction efforts could stimulate aggregate demand. If a natural disaster leads to an increase in surplus output and inflationary pressure, a central bank may consider tightening its monetary policy, [21]. However, a natural disaster could also have a significant and lasting negative impact on demand, creating a production deficit, if it damages the balance sheets of households and businesses in the affected areas, leading to a decrease in consumption and investment. In addition, a natural disaster could undermine business confidence, trigger a large sale in financial markets, increasing the cost of financing new investments and reducing investment demand. According to, [22], storms lead to a temporary increase in food price inflation, although this effect fades during the year. Similarly, floods generally have a temporary effect on inflation. [23] also notes that exogenous shocks affecting food prices have a significant impact on consumer prices, contributing on average to 25-30% of inflation volatility. Thus, climate change could increase the volatility of overall inflation by increasing the volatility of food price inflation rates. [24] points out that climate change has long lasting stag flationary effects that central banks cannot effectively cope with. The main channels through which these impacts are transmitted to the traditional risks of banking are as follows, [25]:

• Credit risk: Physical and transition risks increase a bank's credit risk by compromising a borrower's ability to repay and service its debt, or by impeding the bank's ability to recover the value of a loan in the event of default.

• Market risk: Climate risk factors can have a significant influence on the value of financial assets. Physical and transition risks may alter or reveal new prospects for future economic conditions or for the value of real or financial assets, leading to downward price shocks and increased volatility in the markets for traded assets. In addition, climate risk could disrupt asset to asset correlations, reducing the effectiveness strategies and undermining banks' ability to actively manage their risks. However, early consideration of climate risk could mitigate the potential for unforeseen price movements.

• Liquidity risk: Climate risk factors can also influence banks' liquidity risk, both in terms of their ability to raise funds and indirectly through additional liquidity outflows from customers and/or reductions value of assets used as collateral. It has been noted that a natural disaster may constitute a potential liquidity outflow factor.

• Operational and reputational risk: Within the framework of the Basel Capital Agreement, operational risk is defined as the possibility of suffering losses due to faulty internal processes, human errors, systemic failures or external events, including legal risk but excluding strategic and reputational risk. However, the operational risk management of banks should, if necessary, take into account the latter. Physical risks can directly impact banks as operational risks. Although public research on these risks related to physical risk factors is limited, similarities with other natural disasters can be established. For example, physical disruptions to transport and telecommunications infrastructure can reduce the operational capacity of banks. Companies, as well as banks, may also face an increased risk of non compliance with laws and regulations, as well as costs related to litigation and civil liabilities resulting from climate sensitive investments and activities.

2.6 Transition Risks and Their Impact on Monetary Policy

Regulatory changes represent the most significant transformation risk, as they can alter overnight returns on investments. Figure 4 highlights transition risks and summarizes how these risks are spreading across the financial system. The risks associated with the transition to a low carbon or zero carbon economy can be examined using the Kaya identity model, [26]. This model provides an analytical framework by breaking down global variations in greenhouse gas emissions into fundamental factors:

$$\text{CO}_2 \text{ emissions} = \text{population} \times \frac{\text{GDP}}{\text{population}} \times \frac{\text{Energy}}{\text{GDP}} \times \frac{\text{CO}_2 \text{ emissions}}{\text{Energy}}$$

Kaya's identity breaks down CO2 emissions into four basic elements: population, GDP per capita (GDP/population), energy intensity of GDP (Energy/GDP), and CO2 intensity of energy (CO2/energy). This formulation implies that to specifically reduce carbon emissions, action must be taken on two fronts: on the one hand, to reduce energy intensity by reducing the energy used per unit of GDP, and on the other, to reduce the carbon intensity of energy by adopting cleaner energy sources. According to, [27], growth accounting assesses the impact of emission reductions, including

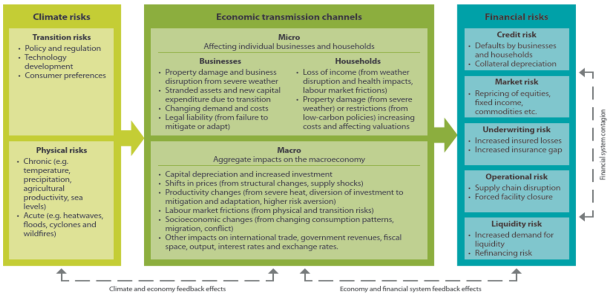

Fig. 4: Channels of Climate Risk to Financial Risk
Source: NGFS Climate Scenarios for Central Banks and Supervisors, 2020

reductions in energy consumption, on economic growth. In a competitive economy, the elasticity of energy in relation to production corresponds to the share of energy costs in production, which is generally low on a global scale. Thus, an approximate 10% reduction in energy consumption could lead to a decrease in production of up to 1%.

The main threat to macroeconomics associated with the transition from climate change comes from climate policies. Some of these policies, such as those based on pricing mechanisms such as carbon taxes or regulations, can lead to economic constraints. Compliance with these environmental regulations may force companies to reduce production or allocate part of their resources to reduce emissions, which may have negative effects on profitability, productivity, employment and, ultimately, GDP. From a monetary policy perspective, the carbon pricing approach can be interpreted as a negative supply side shock. By imposing a price on carbon, the authorities seek to discourage the production and consumption of emissions intensive goods. Disturbances in macroeconomic and financial markets caused by climate change and transition policies could undermine the effectiveness of monetary policy and the ability of the Central Bank to achieve its objective of price stability through various channels, including interest rates, credit, asset valuation, exchange rates and expectations. These disruptions could result in particular from the depreciation of assets and the subsequent weakening of the banking sector, thus hampering the transmission of monetary policy. In addition, climate change and the transition to a low carbon economy are changing the value and risk profile of assets held in the central bank's balance sheet, which could accumulate climate related financial risks. [28] identifies three ways climate change could affect price stability:

• Initially, the impacts of climate change could disrupt the transmission of monetary policy measures from central banks to the financing conditions available to households and businesses, thus influencing consumption and investment.

• Secondly, climate change could further restrict the policy space of traditional monetary policy by lowering the real equilibrium interest rate, which balances savings and investment. For example, rising temperatures could lead to lower labour productivity or higher disease and mortality rates. This could lead to the diversion of productive resources to adaptation financing, while climate uncertainty could encourage precautionary savings and discourage investment.

• Thirdly, climate change and efforts to mitigate its effects can directly influence inflation dynamics. Recent events have shown that an increase in the frequency of physical risks can lead to short term fluctuations in output and inflation, exacerbating long term macroeconomic instability (see figure 4).

2.7 Rethinking the Integration of Climate Risks into Macroeconomic Models

The economic impact of climate change and mitigation measures requires careful assessment through macroeconomic models, given the fundamental uncertainty surrounding this phenomenon. Conventional approaches to financial risk management may be insufficient in the face of this uncertainty, [29], [30]. Greenhouse gases accumulating in the atmosphere and its implications for future temperatures remain uncertain despite efforts to reduce emissions. This uncertainty includes not only the average temperature rise, but also their spatial and temporal variability. For example, identifying and assessing climate risks requires alternative approaches, [31], [32].

[33] developed a network based climate stress testing method applied to major euro area banks through "green" and "brown" scenarios. Their results underline the importance of timing in the implementation of climate policies, with differentiated impacts on the valuation of assets according to the early and stable political framework. An early and stable climate policy would allow gradual adjustments, while a delay or abrupt change could lead to negative systemic consequences. A study by, [34], assessing the potential impact of a disruptive energy transition on financial stability in the Netherlands suggests that financial institutions could face significant but manageable losses. These losses could be mitigated by considering the risks associated with the energy transition. Policymakers have a crucial role to play in putting in place timely, reliable and effective climate policies to avoid unnecessary financial losses. In 2020, the Bank of France launched a pilot stress test involving French banks and insurance companies to assess

their exposure to transition and physical risks, while raising awareness of climate issues, [35].

For many years, economists have been using Integrated Assessment Models (IAM) to study the impact of climate change. These models make it possible to anticipate the future implications of global warming on the Gross Domestic Product (GDP) by examining the complex interactions between the physical and economic aspects of the phenomenon. For example, they are used to estimate the ”social cost of carbon”, which helps to define an optimal trajectory for the carbon price. However, Integrated Valuation Models often rely on damage functions that can be unreliable, thus limiting their usefulness for monetary policy development. Among these models, the Integrated Dynamics of Climate and the Economy (DICE). [36], is widely considered to be the most influential, taking into account CO2 emissions, climate impacts and associated economic losses. [37] estimated the social cost of carbon at 31$.

Per tonne of CO2 for the year 2015, with an annual increase of 3% until 2050. In parallel, [38] analyzed a dynamic stochastic general equilibrium model (DSGE) integrating an externality linked to climate change due to the use of fossil energy. Their study revealed that coal, due to its abundance, represents a major threat to economic well being, unlike oil.

3 Modeling Tests of the Taylor Rule Augmented with CO2 Emissions in the Mediterranean Region

3.1 Description of the Variables

Our analysis covers 14 countries in the Mediterranean region over the period 2002 to 2022. The descriptive data of the variables are presented in Table 1. On average, GDP per capita in the Mediterranean region is estimated at 17 577.82 with a standard deviation of 12 410.98. The average money market rate is 3.53% with a standard deviation of 4.78%. As regards CO2 emissions, the average is 144 million tonnes with a standard deviation of 148 million tonnes. Domestic credit to the private sector, expressed as a percentage of GDP, has an average of 73.77% with a standard deviation of 46.49%. Figure 5 illustrates a positive correlation between the interest rate and the inflation gap. When inflation exceeds the target, the Central Bank reacts by raising the interest rate.

Figure 6 shows a positive correlation between CO2 emissions and inflation. Figure 7 illustrates a positive correlation between the interest rate and the CO2 emissions gap. It is noted that a 1% increase in this gap leads the Central Bank to increase its policy rate by 4.43%. In the Mediterranean region, the correlation between GDP growth and CO2 emission

Table 1. Description of variables

Variable	Abbreviation	Source	Obs	Mean	Std. Dev.
Money Market Rate	MMR	IMF	294	3.53	4.78
Inflation	INF	Federal Reserve Economic Data	294	3.90	6.10
Constant GDP per capita	GDP	World Bank	294	17577.82	12410.98
Annual CO_2 emissions tonnes	CO_2	Our World in Data	294	1.44e + 08	1.48e + 08
Domestic credit to private sector by banks (% of GDP)	Cred	World Bank	294	73.77	46.49

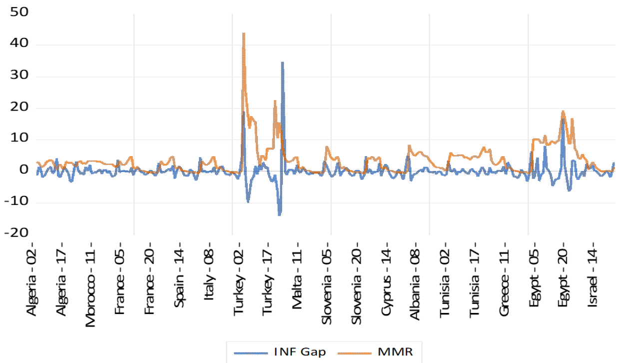

Fig. 5: The relationship between the money market rate and the inflation gap, source: Authors

growth is not an accident; rather, it reflects a causal relationship, as illustrated in figure 8. In the end, figure 9 shows a positive correlation between the interest rate and credit Gap. When the credit exceeds the target, the Central Bank reacts by raising the interest rate.

3.2 Taylor's Original Rule

In 1993, John Taylor enriched the reflection on the objectives of monetary policy by proposing his equation (known as the Taylor equation) to explain the central bank's interest rate policy:

$$i_t = \beta_0 + \beta_1(\pi_t - \pi_t^*) + \beta_2(y_t - y_t^*) \quad (1)$$

With

$$\beta_0 = r_t + \pi_t \quad (2)$$

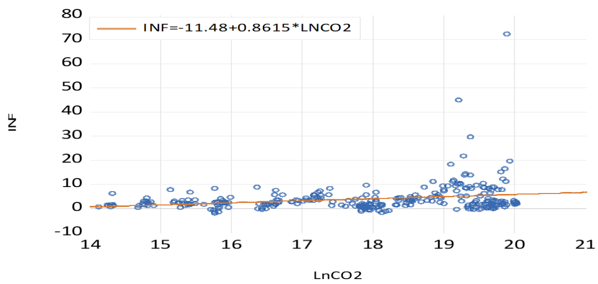

Fig. 6: The regression of Inflation (INF) on CO2

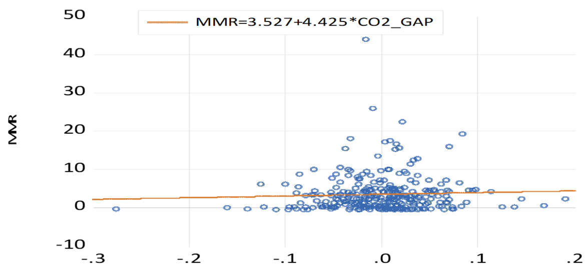

Fig. 7: The regression of MMR on CO2 Gap

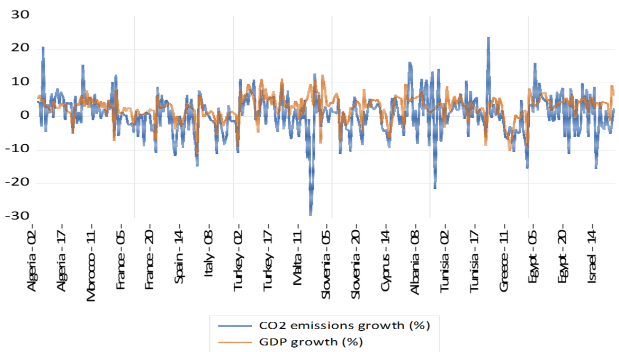

Fig. 8: The relationship between CO2 growth and GDP growth

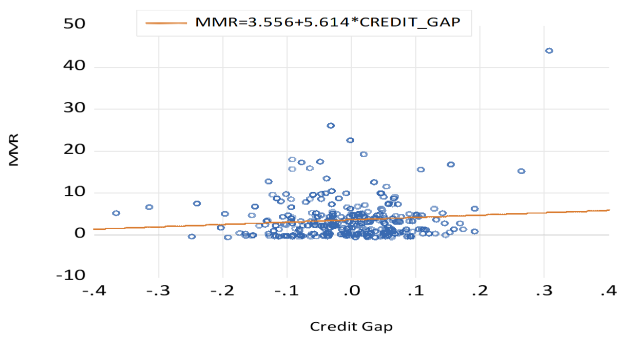

Fig. 9: The regression of MMR on Credit Gap

Where i is the short term interest rate targeted by monetary authorities, $r$is the real equilibrium interest rate, π is inflation, π^* is the inflation target, y is real GDP, y^* is potential GDP, and β_1 and β_2 are positive coefficients. The real equilibrium interest rate is generally estimated either by taking the difference between the average of short term interest rates and the average of inflation rates over a period, or by using the potential growth rate of the GDP. The Taylor rule with its own parameters becomes, [4]:

$$i_t = 2\% + \pi_t + 0.5(\pi_t - 2\%) + 0.5(y_t - y_t^*) \quad (3)$$

The rule suggests a tighter monetary policy when inflation exceeds its target and production exceeds its potential, and vice versa. [4] and [39] put forward the idea that a simple interest rate rule, reacting systematically to inflation and trend production, can, with the appropriate coefficients, represent the evolution of the federal funds rate during the Greenspan era. Empirical evidence of the constancy of this Taylor rule over time and in various countries is presented, [5], [40], [8]. [41] evaluated rules with seven different models. These rules include the Taylor Rule, a "balanced approach" rule, a difference rule that responds to growth rather than inflation and unemployment levels, as well as two rules that take into account periods with federal funds rates close to zero in particular by implementing a promise of future guidance to compensate for periods of lower zero bound with a later looser policy.

3.3 System GMM Estimation

In this study, the empirical analysis of the augmented Taylor's rule, which integrates CO2 emissions in the Mediterranean region, is carried out using the generalized moment method estimator (GMM) proposed by, [42], [43]. We use the generalized moment (GMM) system method rather than standard panel OLS or intra group estimates, as the latter produce biased and inconsistent estimates, [42], [43], [44], [45]. Firstly, level OLS estimates are biased and inconsistent because they neglect country specific effects, which are unobserved and time invariant. The estimator of the coefficient of the lagged dependent variable remains biased upwards, and the estimated coefficients of the exogenous variables are biased downwards, [46]. Using the standard within group estimator for dynamic models with fixed individual effects leads to estimates that become inconsistent when the number of "individuals" increases indefinitely, while the number of periods remains constant, [47]. The GMM system estimator corrects the bias associated with these two approaches. Secondly, the system GMM

estimator offers efficient and consistent parameter estimates in a regression where the explanatory variables are not strictly exogenous. This means they are correlated with past and present errors, and/or there is heteroskedasticity and auto correlation within individuals, [48].
Third, the estimator GMM solves the problem of endogeneity by using instruments for the delayed dependent variable and/or any other endogenous variable. These instruments are selected to be unrelated to fixed effects, [47]. Finally, compared to the estimator GMM in differences, introduced by, [49], the estimator GMM in system proves more effective by adding an additional hypothesis that the first differences of the instruments are not correlated with the fixed effects, allowing the use of more instruments, [48]. [49] suggested using delayed differences of the dependent variable as instruments for the level equation and delayed levels of the dependent variable as instruments for the first difference equation. It is well known in econometrics that instrumental variable instrument performance decreases when we have "too many instruments", [48] and [50] introduced a statistical test to assess the validity of over identified restrictions in instrumental variables. Hansen then extended this Sargan test to apply to the GMM method. The null hypothesis of the Sargan/Hansen J tests states that the over identified restrictions are valid. In this situation, we prefer that our restrictions be appropriate. Therefore, we do not wish to reject the null hypothesis, so higher p values are preferable. [51] has shown that the J test is weakened by many instruments. More worryingly, when the number of instruments equals the number of panels, it is even possible to obtain a false $p = 1$, [48]. We search a test capable of assessing the validity of our instruments, because the results of GMM depend on it. However, this test becomes ineffective if too many instruments are used. [48] recommends that a p value slightly above 0.05 be sought, but little more. P values above 0.25 could indicate that the many instruments compromised the validity of the test. [49] proposed to verify the presence of auto correlated errors by examining the auto correlation in the residues of the estimated differentiated equation. A first order auto correlation in these residues is to be expected. However, we encounter a problem if we find auto correlated residues in the second differences. The null hypothesis for this test is that there is no auto correlation. Thus, if we obtain a small p value, we can reject the null hypothesis of the absence of auto correlation; on the contrary, we have proofs of auto correlation. Therefore, we should look for p values greater than, say, 0.05 for $AR(1)$ in the first differences and p values greater than 0.05 for $AR(2)$.

3.4 Discussion of the Results

The Taylor rule approach can be increased to consider the difference between actual and potential CO2 emissions. In the same way as for variables such as inflation and production, a positive coefficient should be included for CO2 emissions. This reasoning stems from the fact that exceeding the desired CO2 emissions leads to externalities that need to be addressed through higher borrowing costs, which reduces the demand for credit and ultimately the level of economic activity. The dynamic version of Taylor's rule is expressed:

$$MMR_{i,t} = \beta_0 + \beta_1 MMR_{i,t-1} + \beta_2 \left(INF_{i,t} - INF^*_{i,t}\right) + \beta_3 \left(GDP_{i,t} - GDP^*_{i,t}\right)$$

$$+\beta_4 \left(CO2_{i,t} - CO2_{i,t}{}^*\right) + \beta_5 \left(\text{InterINFCO2}_{\,i,t}\right) + \beta_6 \left(\text{Cred-Cred}^*\right) + \epsilon_{i,t} \qquad (4)$$

where : $\beta_0 = r_{i,t} + INF_{i,t}$ The estimated values of INF*, GDP $*$, Cred * and CO2* are obtained by using a HodrickPrescott filter:

- r_t is the real equilibrium interest rate.
- InterINFCO2 is the interaction between Gap inflation and Gap CO2 emissions.
- $\epsilon_{i,t}$ means an error term.

Table 2 shows that the coefficients are statistically significant. The coefficients associated with the output gap and the inflation gap are positive and significant at the 5% threshold. Therefore, the Central Bank should increase its policy rate, as inflation exceeds the target and output exceeds its potential. The Central Banks of the Mediterranean countries attach particular importance to inflation and output gap. This suggests these countries are concerned with both price stability and the stability of economic activity. The coefficient associated with a time lag in interest rates is positive and significant at the 5% threshold. We also find that the coefficient associated with the CO2 emission gap is positive and significant at the 5% threshold. An increase of 1% in this gap leads to a reaction from the Central Bank, which increases its interest rate by 2.64%. According to a study conducted by, [52], using the Global Vector Auto regressive (GVAR) methodology, a restrictive monetary policy in a country has been associated with a reduction in national CO2 emissions, both in the short and long term. The coefficient associated with the interaction between the inflation gap and the CO2 gap is positive and significant at the 5% threshold. Droughts, heat waves and frequent floods can lead to higher commodity and food prices, increasing inflation, [53]. In response, the Central Bank must increase its policy rate by 2.29%.
The coefficient associated with the credit gap granted to the private sector is positive and significant at the 5% threshold. This means that an increase of this 1% gap leads to a reaction from the central

Table 2. The estimation of the Taylor rule increased by the system method GMM

Dynamic panel-data estimation, two-step system GMM

Group variable: id country
Time variable : years
Number of instruments = 13
Wald chi2(6) = 8546.77
Prob > chi2 = 0.000

Number of obs = 280
Number of groups = 14
Obs per group: min = 20
avg = 20.00
max = 20

MMR	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
MMR						
L1.	.485065	.0202194	23.99	0.000	.4454357	.5246944
INFGap	.0217339	.0083322	2.61	0.009	.0054031	.0380646
CO2Gap	2.643534	.5759439	4.59	0.000	1.514705	3.772363
c.INFGap#c.CO2Gap	2.292855	.2094083	10.95	0.000	1.882422	2.703288
GDPGap	13.68066	1.115987	12.26	0.000	11.49336	15.86795
CreditGap	3.108306	.9475035	3.28	0.001	1.251233	4.965378
_cons	1.481025	.1165948	12.70	0.000	1.252504	1.709547

Arellano-Bond test for AR(1) in first differences: z = -1.03 Pr > z = 0.302
Arellano-Bond test for AR(2) in first differences: z = 0.66 Pr > z = 0.509

Sargan test of overid. restrictions: chi2(6) = 11.21 Prob > chi2 = 0.082
(Not robust, but not weakened by many instruments.)
Hansen test of overid. restrictions: chi2(6) = 9.28 Prob > chi2 = 0.159
(Robust, but weakened by many instruments.)

Difference-in-Hansen tests of exogeneity of instrument subsets:
GMM instruments for levels
Hansen test excluding group: chi2(4) = 5.27 Prob > chi2 = 0.261
Difference (null H = exogenous): chi2(2) = 4.01 Prob > chi2 = 0.135
iv(INFGap CO2Gap c.INFGap#c.CO2Gap GDPGap)
Hansen test excluding group: chi2(2) = 3.37 Prob > chi2 = 0.185
Difference (null H = exogenous): chi2(4) = 5.90 Prob > chi2 = 0.207

bank, which increases its policy rate by 3.11%. Second tier banks adjust the rates they apply to their customers based on changes in key rates, whether they increase or decrease. Higher policy rates tend to slow down economic activity, while lower rates stimulate economic activity.
The equation of the augmented Taylor rule is as follows:

$$\text{MMR}_{i,t} = 1.48 + 0.49MMR_{i,t-1} + 0.02\left(INF_{i,t} - INF_{i,t}{}^{*}\right)$$
$$+13.68\left(GDP_{i,t} - GDP_{i,t}{}^{*}\right) + 2.64\left(CO2_{i,t} - CO2^{*}_{i,t}\right)$$
$$+2.29(InterINFCO2_{i,t}) + 3.11(\text{Cred-Cred}^{*}) + \epsilon_{i,t} \quad (5)$$

Table 2 shows that the tests $AR(1)$ and $AR(2)$ show the absence of auto correlation in the residues, since the values of p are greater than 0.05.
The results of the Sargan and Hansen over identification tests support the legitimacy of the instruments used. In this context, a value of p greater than 0.05 is generally considered satisfactory, but an excessively high value, ([48] suggested that 0.25 was too high), suggests an excess of instruments. Therefore, the p values of 0.08 and 0.16 that we obtained are encouraging.

4 Conclusion

Climate change is influencing the financial sector through two types of risks: physical risks and transition risks. The increased public awareness of these risks underlines the importance of the role of central banks in managing environmental risks and supporting the development of green finance. Traditionally, central banks use three monetary policy levers to regulate the money supply in the economy: key interest rates, minimum reserves and open market operations. These traditional tools can be enriched by environmental considerations, thus allowing monetary policy to contribute to environmental protection. Key interest rates are a monetary policy instrument commonly used by central banks to regulate the money supply. As part of initiatives to integrate ecological considerations, central banks can integrate environmental elements into the determination of interest rates. For example, a central bank could introduce differentiated interest rates for banking institutions according to their ecological commitment. Thus, banks fully committed to ecological initiatives could benefit from lower interest rates, while those with little or no ecological commitment could be charged higher rates.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process
The authors wrote, reviewed and edited the content as needed and They have not utilised artificial intelligence (AI) tools. The authors take full responsibility for the content of the publication.

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