CAHIER DE RECHERCHE #2406E
Département de science économique
Faculté des sciences sociales
Université d’Ottawa

WORKING PAPER #2406E
Department of Economics
Faculty of Social Sciences
University of Ottawa

Exploring the Environmental Impact of Monetary Policy

Mamdouh Abdelkader and Lilia Karnizova [*]

November 2024

---

[*] Department of Economics, University of Ottawa, 9053-120 University Private, Ottawa, Ontario, Canada, K1N 6N5; e-mail: lkarnizo@uottawa.ca.

Abstract

As climate change risks escalate, central banks are increasingly called upon to address this global challenge. Yet, estimates of the environmental impact of monetary policy are limited, leaving a significant gap in understanding how monetary policy interacts with climate change. In this paper, we aim to fill this gap by providing new evidence based on U.S. data. We identify monetary policy shocks using the recursiveness assumption and estimate their effects on domestic carbon dioxide emissions. Three key findings emerge from our analysis. First, an unexpected monetary policy tightening produces a persistent yet transitory negative effect on total CO2 emissions. This finding holds consistently across different model specifications, periods, and monetary policy indicators, underscoring its robustness. Second, the effects of monetary policy vary significantly across major polluter types. Emissions in the industrial sector, closely tied to production activities, show the strongest response. In contrast, emissions in the residential and commercial sectors are weakly affected, likely due to the essential nature of energy services. Finally, the contribution of U.S. monetary policy shocks to explaining domestic CO2 emissions fluctuations has been modest. Since central banks have limited capacity to directly influence environmental outcomes, monetary policy should be viewed as complementary to fiscal policy and environmental regulation in addressing climate change.

Key words: *CO2 emissions; Carbon emissions; Monetary policy shocks; Climate change; Environmental policy; Recursive VAR*

JEL Classification: E52, E58, Q50 and Q51.

1 Introduction

In 2015, Mark Carney, then Governor of the Bank of England, delivered a speech highlighting the financial stability risks posed by climate change (Carney, 2015). Since that pivotal moment, climate change considerations have gained growing recognition among central banks.[1] In response, theoretical monetary policy models have been adapted to integrate pollution and environmental policy.[2] Moreover, scholars have advocated for proactive central bank interventions to support desired environmental outcomes.[3] Despite the surge in theoretical literature, empirical research on the environmental impact of monetary policy remains limited, constraining the validation of theoretical models on an environmental dimension. In this paper, we provide new estimates of the impact of U.S. monetary policy on domestic carbon dioxide (CO_2) emissions.

According to the interest rate transmission channel, an unexpected monetary policy tightening raises real borrowing costs, reducing aggregate demand and ultimately leading to a decline in aggregate output and income. Emissions are often characterized as a by-product of production. Given this premise, we expect monetary policy tightening to reduce emissions alongside output via the interest rate channel. This prediction, however, receives mixed empirical support. While Khan et al. (2019) and Attílio et al. (2023) find that contractionary monetary policy actions reduce U.S. emissions, Halkos and Paizanos (2016) suggest that such policies trigger an increase in emissions.[4] These contrasting results motivate us to re-examine the existing evidence.

We build on the extensive literature aimed at estimating exogenous changes in U.S. monetary policy, or monetary policy shocks (e.g., Christiano et al., 1999; Ramey, 2016). Our research centers on conventional interest rate shocks, identified with the recursiveness assumption in vector autoregressive (VAR) models. In addition to standard macroeconomic variables, our VARs include environmental indicators. We use data up to the end of 2005 in our estimation. This cut-off date avoids the zero lower bound periods when the Federal Reserve (the Fed) resorted to unconventional monetary policy tools. Furthermore, environmental regulation can restrict how the economy responds to monetary policy shocks (e.g., Annicchiarico and Di Dio, 2015). Without federal climate change regulation, several U.S. states have implemented CO_2 emissions reduction requirements in the power sector. By ending our sample before these measures took effect, we achieve a more accurate assessment of the environmental impact of monetary policy.

Our baseline model integrates total CO_2 emissions into a monetary VAR. We find that a contractionary monetary policy shock exerts a statistically significant negative impact on total emis-

---

[1] E.g., Rudebusch (2019), Boneva and Ferruci (2022), Hansen (2022), ECB (2024).

[2] E.g., Annicchiarico and Di Dio (2015, 2017), McKibbin et al. (2020), Chan (2020).

[3] E.g., Chan (2020), Böser and Senni (2020), Chen et al. (2021), Ramlall (2023), Ferrari and Nispi Landi (2024).

[4] Halkos and Paizanos (2016) and Khan et al. (2019) report emissions responses to a monetary expansion. However, their empirical models are linear, meaning the responses to a monetary contraction merely invert the signs.

sions. The emissions' response is delayed, persistent but transitory. This result is robust to several modifications, including controlling for weather and energy price changes. In terms of magnitude, the trough response of total emissions to a typical one-standard-deviation contractionary monetary policy shock centers around -0.11% to -0.13% across all monthly specifications, and occurs between five and eighteen months after the shock. For comparison, the standard deviation of the monthly growth rate of total emissions in our full sample is 0.28%. Furthermore, the trough effect of the same contractionary policy shock on industrial production centers around -0.22% to -0.19%. The contribution of the monetary policy shock to the forecast error variance of total emissions is modest. In most specifications, the peak contribution is around 10%.

We extend our analysis to major types of polluters, classified as energy end-use sectors by the U.S. Energy Information Administration (EIA). Together, these sectors encompass CO_2 emissions of the entire U.S. economy. However, these sectors vary in their energy needs and sources, and options for emissions reductions. We find that the environmental impact of monetary policy differs across the polluters. In response to monetary tightening, emissions fall sharply in the industrial sector and moderately in the transportation sector. By contrast, the policy effect on CO_2 emissions in the residential and commercial sectors is minimal.

The observed heterogeneity in sectoral responses helps us understand the dynamics of total emissions. In particular, the muted responses of residential and commercial emissions can explain why total emissions fall by less than aggregate output after a contractionary monetary policy shock. An immediate implication of our findings is the importance of distinguishing between different polluting sectors in both theoretical models and policy analyses. Ignoring sectoral differences may lead to an overestimation of the environmental impact of monetary policy.

Our research broadens the empirical evidence on the link between monetary policy and environmental outcomes. Qingquan et al. (2020) and Chishti et al. (2021) document a negative relationship between real interest rate changes and CO_2 emissions using panel regressions based on data from Asian and BRICS economies.[5] These authors associate a contractionary (expansionary) monetary policy with an increase (decline) in the real interest rate. However, this approach does not account for the potential endogenous reactions of central banks to economic shocks. Attílio et al. (2023) conduct a structural analysis using a global VAR. They find that a contractionary monetary policy shock in the U.S., the Eurozone or Japan reduces CO_2 emissions domestically but does not spill over to other regions. The impact of U.K. monetary policy shocks on emissions in their study is not statistically significant. In contrast to Attílio et al. (2023), we focus exclusively on U.S. monetary policy and apply a standard framework. Our estimated responses of U.S. macroeconomic variables to monetary policy shocks align with findings from prior U.S.-centered recursive VAR studies (e.g. Christiano et al., 1999; Ramey, 2016) and conform to theoretical predictions in monetary theory.

---

[5] BRICS countries include Brazil, Russia, India, China and South Africa.

Our paper is closely related to the work of Khan et al. (2019), who also employ a recursive scheme to identify U.S. monetary policy shocks. However, we focus solely on monetary policy shocks, rather than a variety of macroeconomic shocks, and conduct a sensitivity analysis of their effects. In addition, we estimate the impact of monetary policy shocks on major polluters. Halkos and Paizanos (2016) is the only other study that uses disaggregated data. They classify emissions from the EIA's sectors into consumption- and production-generated,[6] and identify monetary policy shocks via sign restrictions. Contrary to our estimates, their results imply an increase in both types of emissions after a contractionary monetary policy shock.

Another notable feature that distinguishes our research from the other studies is the ending date of our estimation. Our sample restriction allows us to circumvent the challenges of identifying monetary policy shocks during zero lower bound episodes and avoid the effects of environmental regulation. It also helps us address potential concerns regarding the endogeneity of monetary policy responses to climate change. Our baseline model assumes that the Fed does not react to contemporaneous changes in emissions. We found no evidence to contradict this assumption in the pre-2005 period.[7] However, it may be more challenging to support this assumption in recent years.

The rest of the paper is organized as follows. Section 2 describes the data and methodology. Sections 3.1 and 3.2 analyze the impact of monetary policy shocks on total emissions in the baseline and alternative models. Section 3.3 focuses on major types of polluters. Section 4 concludes.

2 Methodology and Data

We identify monetary policy shocks using the recursiveness assumption in a VAR model. This methodology is well-established, widely used and reviewed in detail by Christiano et al. (1999) and Ramey (2016). In this section, we describe how this methodology is employed in our application.

Most economists would agree that a significant variation in the federal funds rate (FFR), the key policy instrument, can be attributed to the Fed's responses to the state of the economy. Such responses can be represented by a feedback rule $f(\Omega_t)$ defined on the Fed's information set Ω_t. For example, according to the interest rate rule proposed by Taylor (1993), the Fed reacts to changes in aggregate output and prices.[8] In practice, the policy rate may diverge from the path specified by the policy rule due to potential revisions in preliminary data or shifts in the Fed's policy priorities.

---

[6] These authors define emissions from the residential and transportation sectors as consumption-generated and label those from the industrial and commercial sectors as production-generated.

[7] Rudebusch (2019) may be the earliest reference on the importance of climate change considerations for the Fed.

[8] A Taylor-type rule is a popular way to model monetary policy in theoretical models. Recently, several researchers have investigated the macroeconomic implications of augmenting a Taylor-type rule with environmental variables, such as CO_2 emissions, in theoretical models (see the references in footnote 2).

Following Christiano et al. (1999), we describe the actual interest rate behaviour by an equation

$$FFR_t = f(\Omega_t) + \sigma_m \varepsilon_t^m, \tag{1}$$

and define a *monetary policy shock* as the random variable $\sigma_m \varepsilon_t^m$. The parameter σ_m represents the standard deviation of the monetary policy shock, and ε_t^m is normalized to have unit variance.

The *recursiveness* assumption requires monetary policy shocks to be orthogonal to the information set of the monetary authority (Christiano et al., 1999, p. 68). This assumption is based on the timing restrictions. It effectively imposes that all variables in the Fed's information set remain unaffected by a monetary policy shock within the period it occurs. Under the recursiveness assumption, monetary policy shocks and their effects on economic variables can be estimated using a VAR model. This approach assumes that $f(.)$ is a linear function and the information set Ω_t is characterized by the variables included in a VAR.

A reduced-form VAR describes the evolution of a vector of endogenous variables y_t:

$$y_t = B_0 + B_1 y_{t-1} + B_2 y_{t-2} + ... + B_n y_{t-n} + u_t,\ u_t \sim N(0, \Sigma_u). \tag{2}$$

We assume that y_t includes k variables. Then B_0 represents a k-dimensional vector of constants and B_j are $(k\text{x}k)$ matrices of the VAR coefficients $(j = 1, ..., n)$. The residuals u_t are the one-step-ahead forecast errors in y_t, and Σ_u is their variance-covariance matrix.

Let ε_t denote a vector of fundamental economic shocks, including the monetary policy shock. The fundamental economic shocks are mutually uncorrelated structural disturbances, with zero means and the variance-covariance matrix $E\varepsilon_t\varepsilon_t' = I$. We assume a linear relationship between the fundamental economic shocks and the VAR residuals,

$$Au_t = \varepsilon_t, \tag{3}$$

where A is an invertible matrix. The identification problem arises because an infinite number of solutions for A satisfy the equation $\Sigma_u = A^{-1}(A^{-1})'$. The recursiveness assumption imposes zero restrictions on the elements of A. Christiano et al. (1999) demonstrate that these restrictions are sufficient to identify the responses of y_t to a monetary policy shock.

To convey the intuition behind the monetary policy shock identification, we partition the endogenous variables y_t according to the assumed timing of their responses to monetary policy shocks. The k_1 slow-moving variables $X_{1,t}$ appear in the Fed's information set Ω_t and react to monetary policy actions only with a lag. The k_2 fast-moving variables $X_{2,t}$ are allowed to respond to monetary policy shocks contemporaneously. However, they enter the Fed's information set with a lag. The policy rate is also included in the VAR, so that

$$y_t = \begin{pmatrix} X_{1,t} \\ FFR_t \\ X_{2,t} \end{pmatrix} \text{ and } k = k_1 + 1 + k_2. \tag{4}$$

A monetary policy shock is identified from the FFR equation in the linear system (3). This equation excludes current movements in the $X_{2,t}$ variables, imposing k_2 restrictions on the matrix A. Additionally, k_1x$(k_2 + 1)$ zero restrictions on the elements of A arise from excluding both direct and indirect contemporaneous effects of monetary actions on the variables $X_{1,t}$. In practice, the parameters in A are estimated by applying the Cholesky factorization to the variance-covariance matrix Σ_u. We refer the reader to Christiano et al. (1999) for technical details.

Our monetary VAR consists of the macroeconomic variables and abstracts from environmental indicators. We use the monthly average of the daily effective federal funds rate for FFR. As in Coibion (2012), the slow-moving variables $X_{1,t}$ include the log of industrial production (IP), the unemployment rate (UR), the log of the consumer price index and the log of a commodity price index. We add the log of the M1 monetary aggregate in $X_{2,t}$. This variable should help us isolate the effects of money demand changes on the policy rate. Appendix A describes the data sources.

Belongia and Ireland (2016, p. 1246) highlight the resemblance of the monetary policy shock identification equation to the Taylor rule. In our application, the Fed reacts to contemporaneous movements in output and prices, as in Taylor (1993). It also reacts to current changes in the unemployment rate and commodity prices. The unemployment rate provides additional information about real economic activity, while commodity prices are expected to capture anticipatory effects.

Our goal is to understand how monetary policy affects environmental outcomes. In this paper, we analyze the data on CO_2 emissions from energy consumption published by the U.S. Energy Information Administration. We work with total CO_2 emissions for the U.S. economy and sector-specific emissions from the residential, commercial, industrial, and transportation sectors. The data are available monthly, starting in January 1973. We adjust the log of the monthly series for seasonality using the X13 ARIMA-SEATS procedure.

Our analysis mainly focuses on two periods. Our primary sample period, from January 1973 to December 1996, closely aligns with those studied by Christiano et al. (1999) and Coibion (2012). However, our starting date is restricted by the availability of the environmental statistics. According to Ramey (2016, p.111), earlier periods tend to offer the most compelling evidence regarding the effects of conventional monetary policy shocks. Our extended sample period continues through December 2005. The ending date helps us address two potential threats to identifying monetary policy shocks and, hence, achieve a more accurate assessment of their effects on emissions.

First, the traditional recursive identification is ineffective during zero lower bound episodes, when a central bank cannot reduce the policy rate further to stimulate the economy. The methods fail to work for statistical and economic reasons (Rossi, 2021). In response to the financial crisis, the Fed kept the federal funds rate close to zero between December 2008 and December 2015. Estimating a VAR model with an endogenous variable that remains constant over an extended time period poses significant statistical challenges, and may result in unreliable parameter estimates. Unconventional monetary policy tools, such as quantitative easing and forward guidance, introduce further challenges for identification in samples from the post-2007 period. When a central bank employs multiple tools to achieve similar objectives, it becomes difficult to capture the overall stance of monetary policy and to disentangle the individual effects of each policy tool. Although various solutions to these challenges have been proposed in the literature (Rossi, 2021), we focus on the traditional approach in this paper and leave the alternative strategies for future work.

Second, environmental regulation may confound the VAR parameter estimates, potentially distorting inferences regarding the effects of monetary policy on emissions. The Regional Greenhouse Gas Initiative (RGGI) is the first market-based U.S. regional initiative to reduce CO_2 emissions.[9] It operates as a mandatory cap-and-trade program for the power sector. The RGGI agreement was signed on December 20, 2005. Although the first auction of CO_2 emissions allowances occurred in 2008, some adjustments in the power sector could have occurred in anticipation of this event. By ending the estimation in 2005, we aim to exclude any potential anticipatory effects of RGGI on our estimates. U.S. state renewable portfolio and clean electricity standards are additional factors that may affect how emissions respond to monetary policy shocks. These policies aim to limit the use of fossil fuels, thereby reducing emissions. Although some policies were in place before 2005, their number and stringency took a notable uptake starting in 2007 (Barbose, 2024). Our sample restriction mitigates the confounding influence of these factors on the VAR parameter estimates.

To estimate the effect of monetary policy shocks on emissions, we augment the standard monetary VAR with environmental indicators. Our key results are derived from specifications that include emissions in the block of fast-moving variables $X_{2,}$, after M1. By placing emissions last, we assume that the Fed does not respond to contemporaneous movements in the environmental indicators. This approach is consistent with the view that climate change was not a factor influencing monetary policy decisions before 2005. However, we explore the implications of placing emissions first in the sensitivity analysis.

We estimate VAR models with a constant term and twelve lags of the endogenous variables, using ordinary least squares. The parameter estimates in the "level" specification are asymptotically consistent, even in the presence of cointegration. They are minimally affected if a linear

---

[9] Eleven Northeastern states currently participate in RGGI: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. Detailed information can be found on the RGGI website at `https://www.rggi.org/`.

trend is included in our models. Throughout the paper, we focus on the effects of a contractionary monetary policy shock. However, the linear structure of a VAR model implies symmetric effects of contractionary and expansionary monetary policy shocks. We follow Coibion (2012) in estimating the confidence bands for the impulse response functions. Specifically, we take 1,000 repeated draws from the asymptotic distribution of the VAR parameters to generate a distribution of impulse responses and compute one-standard-error bands.

3 Results

We assess the environmental impact of monetary policy shocks using impulse response functions (IRFs), forecast error variance (FEV) decompositions, and historical decompositions. Sections 3.1 and 3.2 discuss the results for total CO_2 emissions in the baseline model and alternative specifications. Section 3.3 extends the analysis to emissions from different polluters.

3.1 The Impact of Monetary Contraction on Total Emissions: Baseline

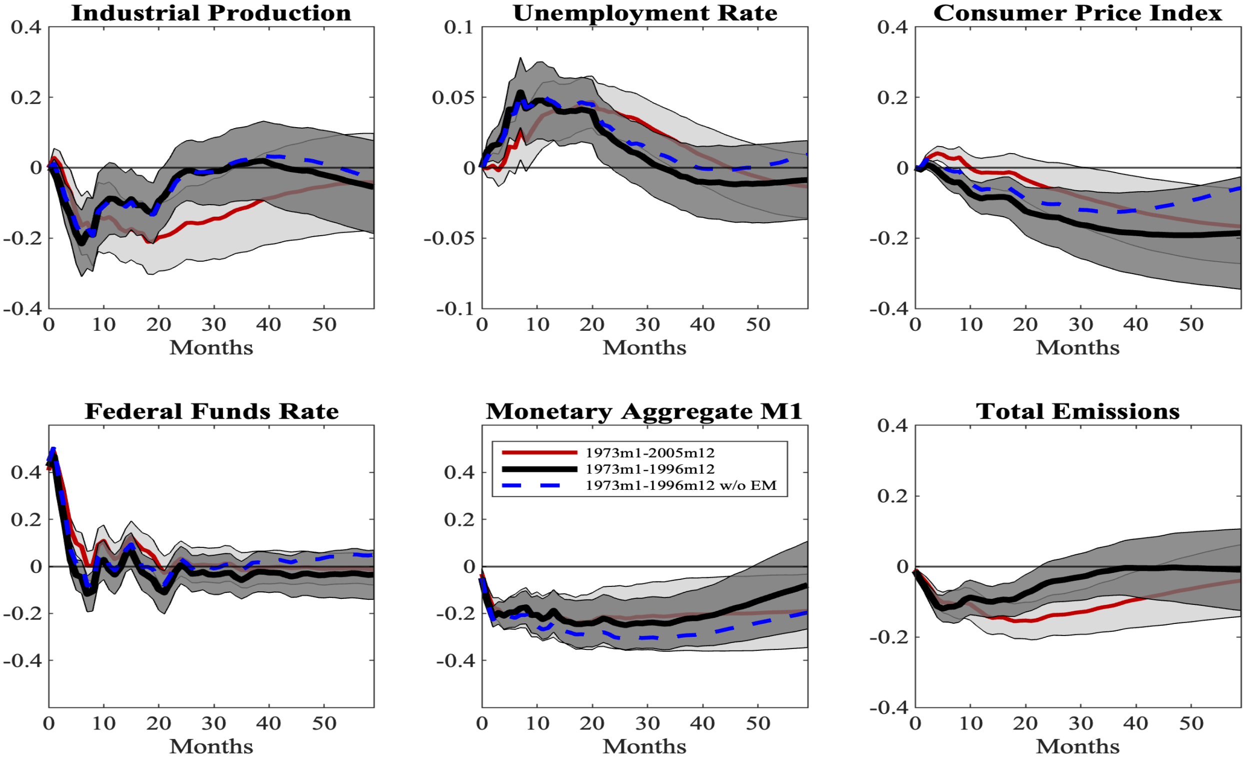
Figure 1 reports the results from our baseline: a monetary VAR augmented with total CO_2 emissions. The size of the monetary policy shock is set to its estimated standard deviation, σ_m. In our baseline VAR, such shock raises the federal funds rate by 42.5 basis points in the primary period and 40.5 basis points in the extended period. Thick black lines and darker shaded areas represent the IRF point estimates and confidence bands for the primary period, while thin red lines and lighter bands indicate the results for the extended period. Dashed blue lines depict the IRF point estimates from the monetary VAR model without emissions.

We first note that adding emissions to the monetary VAR has a limited impact on the responses of the macroeconomic variables. The IRF point estimates from the monetary VAR closely track those from our baseline and fall within the confidence bands. Second, the dynamic paths of the macroeconomic variables in both periods are consistent with the conventional theoretical predictions and empirical results in Christiano et al. (1999), Coibion (2012), and Ramey (2016). A contractionary monetary policy shock induces a short-lived increase in FFR and a persistent decline in M1. Output contracts and the unemployment rate surges, with the peak impacts at around twenty months. The monetary policy impacts on the real activity measures (IP and UR) dissipate over time. Finally, prices fall, although a short-lived price puzzle is present in the extended period. As noted by Ramey (2016), the price puzzle is a recurrent result in monetary VAR models.

The bottom right chart in Figure 1 depicts our first key finding: a contractionary monetary policy shock has a statistically significant negative impact on total CO_2 emissions. The emissions' response is hump-shaped, reaching its trough of -0.12% five months after the shock and becoming insignificant in two years in the primary period. This response is more persistent in the extended period, with the trough of -0.16% eighteen months after the shock.

Figure 1: Effects of Monetary Policy Tightening (%)

Baseline Model



Notes: Responses to a one-standard-deviation contractionary monetary policy shock. Monetary VAR 1973m1-1996m12: *dashed blue lines*. Baseline VAR with total emissions, 1973m1-1996m12: *thick black lines*; 1973m1-2006m12: *thin red lines*. Darker and lighter shaded areas are the one-standard-error bootstrap confidence bands.

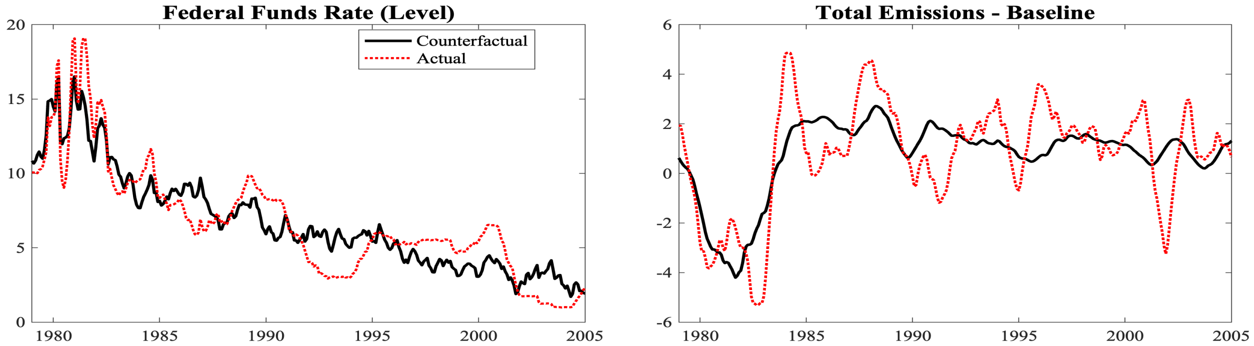
Table 1 reports the percent of the forecast error variance of total CO_2 emissions and industrial production attributed to the monetary policy shock. The statistics correspond to the maximal contribution within the first sixty months. Our baseline model indicates that monetary policy shocks have played a relatively minor role in explaining historical fluctuations in industrial production. However, these FEV results fall in the range reported by Ramey (2016). The monetary policy shock's contribution to the forecast error variance of emissions is larger, peaking at 11.30% at the horizon of 18 months in the primary sample and 12.47% at 22 months in the extended sample.

Figure 2 provides another perspective on the quantitative relevance of monetary policy shocks. Solid black lines depict the counterfactual paths of the federal funds rate and emissions that would have prevailed if monetary policy shocks were the only shocks hitting the U.S. economy in the extended sample. Note that the counterfactual series start in January 1978 to remove the dependence of the simulations on the initial conditions.[10] Red dotted lines in Figure 2 denote the actual realized

---

[10] Starting in Jan. 1973, we iterated VAR forward, setting to zero all disturbances except for the estimated monetary

Figure 2: Historical Contribution of Monetary Policy Shocks in the Baseline Model (%)



Notes: *Dotted lines* are the historical values of FFR and total CO_2 emissions. *Solid lines* represent the counterfactuals attributed solely to the U.S. monetary policy shocks. Emissions are expressed as the year-over-year growth rates.

FFR and emissions. Emissions are reported as the year-over-year growth rates for visibility.

The historical decomposition relies on the estimated monetary policy shocks, which include both positive and negative values. Recall that a positive monetary policy shock raises the federal funds rate and contracts the money supply, thus indicating a tightening of monetary policy. A negative shock, with opposite effects, signals a monetary policy easing. The left chart in Figure 2 reveals large differences between the actual and counterfactual paths for the federal funds rate. These differences illustrate the importance of separating the feedback responses of the Fed to the state of the economy from exogenous changes in monetary policy in evaluating the policy effects. The right chart illustrates that monetary policy tightening during the Volcker disinflation period was a key factor in the emissions decline observed in the early 1980s. The contribution of monetary policy shocks at other points within this sample period was moderate, with other factors either offsetting or amplifying the effects of monetary policy actions.

3.2 The Impact of Monetary Contraction on Total Emissions: Alternatives

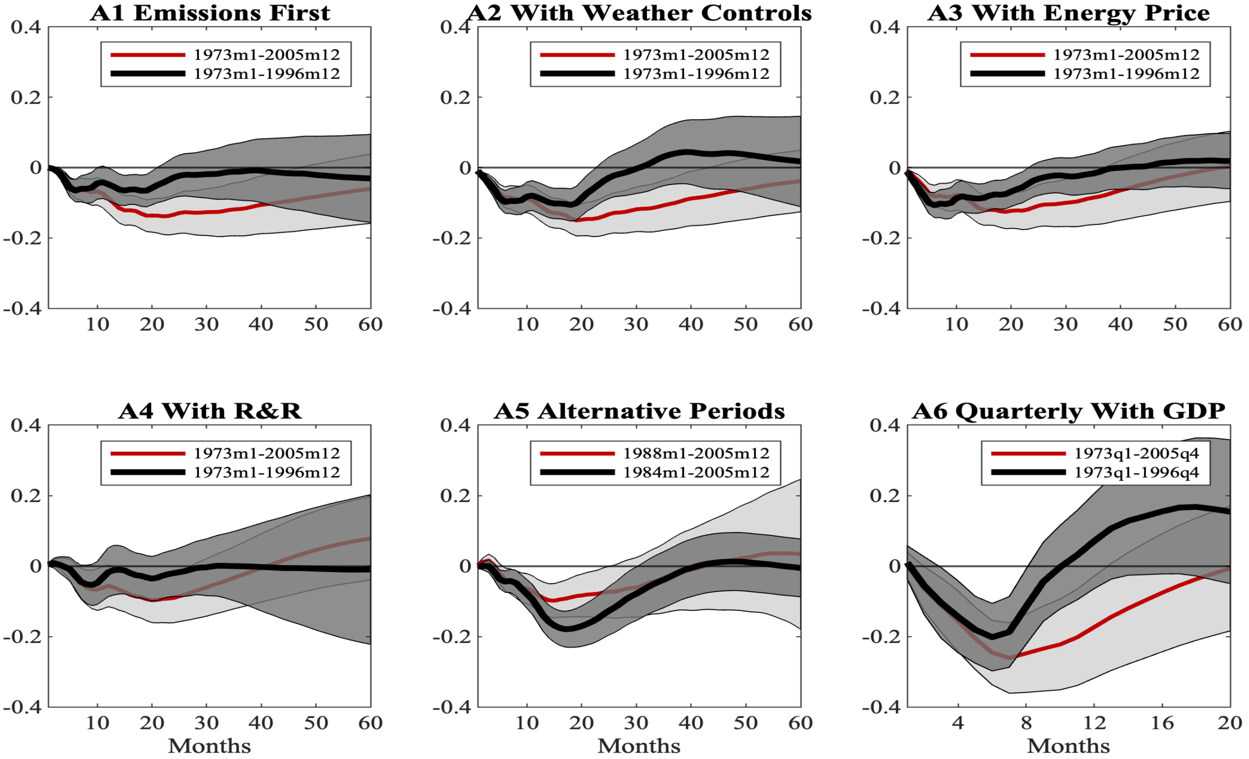
Our first key finding - that a monetary policy tightening reduces total emissions - is robust across several modifications of the baseline model. We examine the implications of switching the emissions placement, controlling for weather indicators and energy prices, replacing FFR with another monetary policy instrument, changing the estimation periods, and using the quarterly baseline model with real GDP. We report the responses of emissions in Figure 3 and present the results for the macroeconomic variables in Figure 5 of the appendix. Table 1 summarizes the trough effects and the monetary policy shock contribution to the forecast error variance of total CO_2 emissions.

The VAR alternative A1 places total CO_2 emissions first in the list of $X_{1,t}$ variables. This ordering rules out any impact effects of monetary policy shocks on emissions but allows the Fed to

---

policy shocks. Following Coibion (2012), we truncated the first sixty months in reporting the results in Figure 2.

Figure 3: Effects of Monetary Policy Tightening on Total Emissions (%)
Alternative Specifications



Notes: Responses to a one-standard-deviation contractionary monetary policy shock. Darker shaded areas are the bootstrap one-standard-error confidence bands for the impulse responses represented by the *thick black lines*. Lighter shaded areas are the confidence intervals for the *thin red lines*. The estimation periods are indicated in the labels.

react to contemporaneous movements in emissions. In this VAR specification, the through impact and FEV contribution of the monetary policy shock to total emissions are smaller relative to the baseline in the primary period. However, their magnitudes are more comparable in the extended period. More importantly, total emissions still decline in both periods.

EIA estimates CO_2 emissions series from fossil fuel consumption. The next two alternative models augment the baseline VAR with the variables pertinent to explaining energy demand. First, we expect weather variations and energy price changes to affect the demand for energy for heating and cooling and, consequently, CO_2 emissions generated by this energy consumption. The alternative A2 adds the U.S. average temperature and precipitation to the baseline VAR. Both series are from the U.S. National Oceanic and Atmospheric Administration. They are expressed as a change from a year ago due to high seasonality and placed after emissions in the VAR. Second, we expect the energy demand to be responsive to energy price changes. In the baseline VAR, energy prices were a part of the commodity price index. The VAR alternative A3 investigates the sensitivity of the results to including an energy price series explicitly. We use the cost of fossil fuel receipts at electric generating plants, inclusive of taxes, as a proxy for an aggregate price of fossil fuels.

Figure 3 shows that the response of total emissions to a contractionary monetary policy shock is negative and statistically significant for about two years in both periods for the A2 and A3 models. Although the contribution of monetary policy shocks to the forecast error variance of emissions in Table 1 declines relative to the baseline, it remains close to 10%.

Romer and Romer (2004) constructed a monetary policy shock from the minutes of the Federal Open Market Committee meetings and the Fed's internal forecasts. Their narrative shock has been widely used in the literature. Following Coibion (2012), we replace the federal funds rate with the cumulative sum of Romer and Romer's series (R&R) in our baseline VAR. We label this model specification as A4. The impact of a monetary policy tightening on total CO_2 emissions remains negative, as documented in Figure 3 and Table 1. However, the responses are less precisely estimated, and the monetary policy shock's contribution to the FEV of emissions drops considerably.

Previous studies (e.g., Coibion, 2012 and Ramey, 2016) have documented the sensitivity of the macroeconomic effects of R&R shocks to different periods and estimation methods. For example, Ramey (2016) finds that a contractionary monetary policy shock based on the Romer&Romer's series has a stimulative effect on U.S. industrial production in the sample from January 1983 until December 2007. Figure 5-(d) documents similarly puzzling positive positive output responses in our samples. From this perspective, the estimated effects of monetary policy shocks on macroeconomic variables in the baseline VAR with the federal funds rate align more closely with the expected theoretical outcomes than those from the A4 model using the R&R measure.

Next, we investigate the sensitivity of our results to the periods of our analysis. Two additional samples are motivated by prior literature identifying monetary policy shocks. First, Coibion (2012) highlights a potential influence of the non-borrowed reserve targeting (1979-81) on VAR estimates. Starting our estimation in January 1984 ensures that the federal funds rate was an appropriate policy instrument of the Fed during our study period. Second, Barakchian and Crowe (2013) show that recursive VAR models yield puzzling results in the sample from December 1988 to November 2007. In several leading specifications that they examine, a contractionary monetary policy shock increases both industrial production and prices. Hence, we re-estimate our baseline VAR using two additional periods: January 1984 to January 2005, and December 1988 to December 2005.

Figure 5-(e) in the appendix shows that the initial responses of industrial production, the unemployment rate and CPI to a contractionary monetary policy shock go against the expected outcomes. However, the puzzling effects on the real activity measures are only short-lived, contrary to Barakchian and Crowe (2013). Industrial production declines and the unemployment rate increases, eventually. The peak policy effects on these variables are observed in the later periods. Prices also decline, although their IRF point estimates are not statistically significant.[11]

---

[11] Relative to Barakchian and Crowe (2013), we use a different set of variables. For example, we abstract from reserve measures but include the M1 aggregate and the unemployment rate. We have found that adding reserve

Despite some puzzling results for the macroeconomic variables, our baseline VAR model produces robust predictions for total emissions in the alternative samples. A contractionary monetary policy shock has a statistically significant negative impact on total CO_2 emissions in Figure 3. The impact is transitory, with the trough eighteen months after the shock. Another point to note is the smaller size of a typical monetary policy shock in the new samples. The estimated standard deviation σ_m declines to 14.4 and 9.6 basis points. Nevertheless, the trough effects on emissions in the alternative periods, -0.18% and -0.10%, are comparable to those observed in our main sample.

Our final alternative, A6, focuses on quarterly data. We replace industrial production with real GDP and convert other series to quarterly by averaging the monthly values. Figure 3 and Table 1 reveal that the IRF and FEV results related to the effects of a monetary policy tightening on total emissions in the quarterly models are comparable with the statistics in the monthly samples.

In summary, all alternative VAR models consistently demonstrate a negative influence of monetary policy shocks on total CO_2 emissions. A one-standard-deviation shock that increases the policy rate temporarily reduces total emissions, with the trough effects between -0.18% and -0.05% in the monthly specifications. These estimates center around -0.11% to -0.13%. The models disagree more on the quantitative relevance of monetary policy in explaining emissions fluctuations. However, the estimates of the monetary policy shock contribution to the FEV of total emissions remain modest.[12] This finding aligns with the conclusions of Attílio et al. (2023) and Khan et al. (2024), who document the limited role of U.S. monetary policy in different empirical models.

3.3 The Impact of Monetary Policy Shocks on Major Types of Polluters

To enhance our understanding of the environmental impact of monetary policy, we investigate how monetary policy shocks affect major types of polluters. To this end, we use the EIA's data on CO_2 emissions from the residential (homes and apartments), commercial (offices, stores, restaurants, and public gathering places), industrial (manufacturing, agriculture, mining, and construction), and transportation (movement of people and goods) sectors.

Table 2 reports millions of metric tons of CO_2 emitted by each EIA's sector in 1996. We chose this year for illustration as it belongs to all of our data samples. Table 2 also shows the composition of emissions by sources. Each sector directly contributes to air pollution by consuming coal, natural gas, or petroleum products. In addition, each sector pollutes indirectly because of its use of electricity. Electricity is an intermediate good, and its generation and distribution are energy-intensive. EIA allocates emissions from the electricity sector to the four energy end-use sectors in proportion to their electricity consumption. For example, 25.85% of 1098.65 MMT of CO_2

---

measures led to more unstable monetary policy effects on the macroeconomic variables.

[12] Notably, the FEV statistics for emissions often surpass those for aggregate output, even though the trough effects of total emissions to monetary policy shocks are typically smaller.

emitted by the residential sector came from its use of natural gas, whereas 64.5% were assigned from electricity generation and transmission.

The EIA's sectors differ in their primary energy usage and rely on varying mixes of energy sources. The industrial and transportation sectors use fossil fuels as direct production inputs. Over 60% of industrial emissions stem from the combined use of coal, natural gas, and petroleum, while more than 95% of transportation emissions are linked to petroleum products. We expect emissions from these sectors to be closely tied to the level of aggregate economic activity and, therefore, relatively sensitive to the effects of monetary policy. By contrast, we expect lower sensitivity for residential and commercial emissions. Energy consumption is vital in maintaining physical comfort in homes and buildings (e.g., temperature, lighting, humidity) and fulfilling essential needs, such as refrigeration, laundry, and entertainment. A monetary contraction may reduce the energy demand through a fall in total income and changes in energy prices. However, the reduction in emissions could be offset by a decreased demand for clean air and environmental quality.

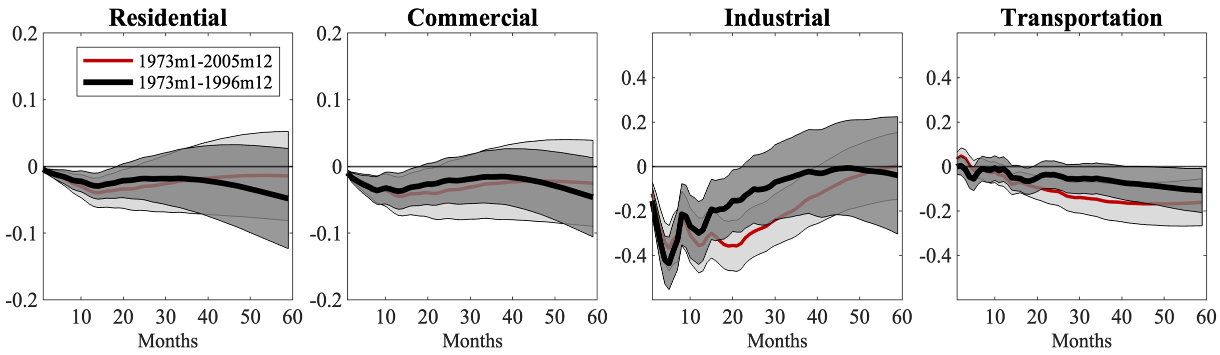
We re-estimate our baseline VAR by substituting total emissions with one of the sectoral emissions. To assess robustness, we include U.S. average temperature, precipitation, and one of the energy price measures, which is closely tied to a specific energy end-use sector. Specifically, we use the CPI for household energy, the producer price index (PPI) for electric power, the PPI for total energy, and the CPI for motor fuel.

Figure 4 and Table 3 reveal heterogeneous effects of a monetary policy tightening on major polluters. The industrial sector exhibits the most significant reaction, with emissions declining immediately and reaching its trough five months after the shock. Their trough response ranges from -0.44% to -0.32%. Transportation emissions also decrease, exhibiting a more pronounced response in the extended period. By contrast, the residential and commercial sectors are minimally affected by monetary policy shocks. Although the IRF point estimates are negative and statistically significant, their magnitudes are small. The FEV statistics in Table 3 support the conclusions drawn from the IRF results, indicating that the Fed's actions historically had a pronounced impact on the industrial sector while exerting a weak influence on emissions from the residential and commercial sectors. Comparing the responses in panels (a) and (b), we conclude that adding weather controls and energy prices to the VAR models does not substantially alter our inferences about the effects of monetary policy shocks on sector-specific emissions.

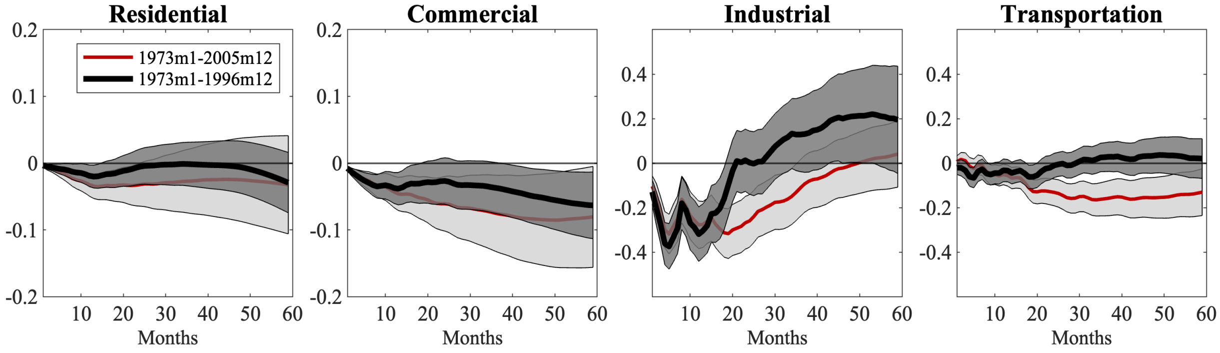
The residential and commercial sectors jointly emit around 35% of all CO_2 emissions from energy consumption in the U.S. economy. Muted responses of emissions from these two sectors weaken the IRFs of total emissions. Table 1 shows that, in many VAR specifications, the trough effects of a monetary policy shock on total emissions are often less than half the magnitude of its trough effect on industrial production. Total CO_2 emissions are often viewed as being directly tied to aggregate output. Our results indicate that a more nuanced approach to incorporating different

Figure 4: Effects of Monetary Policy Tightening on Emissions From Major Types of Polluters (%)

(a) Monetary VAR With Sector-Specific Emissions



(b) Monetary VAR With Sector-Specific Emissions, Energy Prices, and Weather Controls



Notes: Responses to a one-standard-deviation contractionary monetary policy shock. Panel (a): monetary VAR with emissions from a specific energy end-use sector. Panel (b): VAR in panel (a) + average temperature and precipitation + the energy price specific to each sector. 1973m1-1996m12: *thick black lines*; 1973m1-2005m12: *thin red lines*. Darker and lighter shaded areas are the one-standard-error bootstrap confidence bands. See section 3.3 for details.

polluting sectors is required for accurately assessing the environmental impacts of monetary policy.

4 Conclusions

Driven by the increasing involvement of central banks in addressing climate change, we examined the empirical effects of U.S. monetary policy on CO_2 emissions. Our analysis focused on conventional monetary policy shocks to the policy rate identified using the recursiveness assumption. The effect of monetary policy tightening on total emissions was consistently negative, though transitory and modest. However, the policy impact varied in strength across different polluting sectors.

Our findings have several implications for monetary policy. Theoretical models are critical inputs into policy design and evaluation, forecasting and scenario analysis. In a climate-changing world, monetary models must be adapted to integrate environmental factors. To ensure reliability, such models must be rigorously validated against empirical evidence, including environmental statistics. Our paper provides new empirical estimates. We find that a monetary policy tightening reduces total CO_2 emissions, in line with the interest rate transmission channel. Additionally, we find that emissions from energy end-use sectors respond differently to policy changes, reflecting variations in their energy needs. A common modelling approach that links emissions to aggregate output overlooks sectoral differences and may, therefore, overestimate the environmental impact of monetary policy. By refining theoretical models to include sector-specific polluters, researchers can better capture the complex interactions between monetary policy and climate outcomes.[13]

Another takeaway from our study concerns the role of central banks in reducing emissions. Monetary policy actions affect environmental outcomes. Theoretical studies (e.g., McKibbin et al., 2020) demonstrate complementarity between monetary and climate policies. When adjusted jointly, these two policies can lessen the adverse effects of a carbon tax on output and inflation. Our empirical results confirm the ability of the Fed to influence CO_2 emissions. However, it is important not to overstate the potential of monetary policy in addressing climate change. The historical and forecast error variance decompositions indicate that monetary policy shocks have played a limited role in explaining emissions fluctuations. Even though central banks can adjust policies to complement environmental objectives, the primary responsibility for reducing emissions lies with fiscal measures and environmental regulation.

We focused on the impact of monetary policy shocks identified as surprise changes in the federal funds rate. Since the financial crises of 2007-2008, the toolkit of central banks has expanded to include alternative policy instruments, such as quantitative tightening, credit easing and forward guidance. Future research can investigate the environmental impact of unconventional policy.

References

ANNICCHIARICO, B. AND F. DI DIO (2015): "Environmental Policy and Macroeconomic Dynamics in a New Keynesian Model," *Journal of Environmental Economics and Management*, 69, 1–21.

ANNICCHIARICO, B. AND F. DI DIO (2017): "GHG Emissions Control and Monetary Policy," *Environmental and Resource Economics*, 67, 823–851.

ATTÍLIO, L. A., J. R. FARIA, AND M. RODRIGUES (2023): "Does Monetary Policy Impact CO2 Emissions? A GVAR Analysis," *Energy Economics*, 119, 106559.

BARAKCHIAN, S. M. AND C. CROWE (2013): "Monetary Policy Matters: Evidence From New Shocks Data," *Journal of Monetary Economics*, 60, 950–966.

---

[13] McKibbin et al. (2020) and Boneva and Ferruci (2022) also emphasize the need for disaggregated analysis.

BARBOSE, G. (2024): "U.S. State Renewables Portfolio & Clean Electricity Standards: 2024 Status Update," Lawrence Berkeley National Laboratory report, the U.S. Department of Energy.

BELONGIA, M. T. AND P. N. IRELAND (2016): "Money and Output: Friedman and Schwartz Revisited," *Journal of Money, Credit and Banking*, 48, 1223–1266.

BONEVA, L. AND G. FERRUCI (2022): "Inflation and Climate Change: The Role of Climate Variables in Inflation Forecasting and Macro Modelling," Tech. rep., Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.

BÖSER, F. AND C. C. SENNI (2020): "Emission-based Interest Rates and the Transition to a Low-carbon Economy," Economics Working Paper Series 20/337, Center of Economic Research at ETH Zurich, Zurich.

CARNEY, M. (2015): "Breaking the Tragedy of the Horizon – Climate Change and Financial Stability," Speech at Lloyd's of London, `https://www.bankofengland.co.uk/-/media/boe/files/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability.pdf.`

CHAN, Y. T. (2020): "Are Macroeconomic Policies Better in Curbing Air Pollution Than Environmental Policies? A DSGE Approach with Carbon-dependent Fiscal and Monetary Policies," *Energy Policy*, 141, 111454.

CHEN, C., D. PAN, Z. HUANG, AND R. BLEISCHWITZ (2021): "Engaging Central Banks in Climate Change? The Mix of Monetary and Climate Policy," *Energy Economics*, 103, 105531.

CHISHTI, M. Z., M. AHMAD, A. REHMAN, AND M. K. KHAN (2021): "Mitigations Pathways Towards Sustainable Development: Assessing the Influence of Fiscal and Monetary Policies on Carbon Emissions in BRICS Economies," *Journal of Cleaner Production*, 292, 126035.

CHRISTIANO, L. J., M. EICHENBAUM, AND C. L. EVANS (1999): "Monetary Policy Shocks: What Have We Learned And to What End?" in *Handbook of Macroeconomics*, ed. by J. B. Taylor and M. Woodford, Elsevier, vol. 1 of *Handbook of Macroeconomics*, chap. 2, 65–148.

COIBION, O. (2012): "Are The Effects of Monetary Policy Shocks Big or Small?" *American Economic Journal: Macroeconomics*, 4, 1–32.

ECB (2024): "ECB Steps up Climate Work with Focus on Green Transition, Climate and Nature-related risks," Press release: January 30, 2024, European Central Bank, `https://www.ecb.europa.eu/press/pr/date/2024/html/ecb.pr240130~afa3d90e07.en.html`.

EIA (2023): "Monthly Energy Review," June issue, U. S. Energy Information Administration, `https://www.eia.gov/totalenergy/data/monthly`.

FERRARI, A. AND V. NISPI LANDI (2024): "Whatever it Takes to Save the Planet? Central Banks and Unconventional Green Policy," *Macroeconomic Dynamics*, 28, 299–324.

HALKOS, G. E. AND E. A. PAIZANOS (2016): "The Effects of Fiscal Policy on CO2 Emissions: Evidence from the U.S.A," *Energy Policy*, 88, 317–328.

HANSEN, L. P. (2022): "Central Banking Challenges Posed by Uncertain Climate Change and Natural Disasters," *Journal of Monetary Economics*, 125, 1–15.

KHAN, H., K. METAXOGLOU, C. R. KNITTEL, AND M. PAPINEAU (2019): "Carbon Emissions and Business Cycles," *Journal of Macroeconomics*, 60, 1–19.

——— (2024): "Carbon Emissions and Business Cycles - *Corrigendum*," .

MCKIBBIN, W. J., A. C. MORRIS, P. J. WILCOXEN, AND A. J. PANTON (2020): "Climate Change and Monetary Policy: Issues for Policy Design and Modelling," *Oxford Review of Economic Policy*, 36, 579–603.

QINGQUAN, J., S. I. KHATTAK, M. AHMAD, AND L. PING (2020): "A New Approach to Environmental Sustainability: Assessing the Impact of Monetary Policy on CO2 Emissions in Asian Economies," *Sustainable Development*, 28, 1331–1346.

RAMEY, V. (2016): "Macroeconomic Shocks and Their Propagation," in *Handbook of Macroeconomics*, ed. by J. B. Taylor and H. Uhlig, Elsevier, vol. 2 of *Handbook of Macroeconomics*, chap. 0, 71–162.

RAMLALL, I. (2023): "Should Central Banks Manage Climate Change Risk via a CO2 Emissions Augmented Taylor Rule? Evidence Using a DSGE Approach," *Journal of Environmental Management*, 343, 117989.

ROMER, C. D. AND D. H. ROMER (2004): "A New Measure of Monetary Shocks: Derivation and Implications," *American Economic Review*, 94, 1055–1084.

ROSSI, B. (2021): "Identifying and Estimating the Effects of Unconventional Monetary Policy: How to Do it and What Have We Learned?" *The Econometrics Journal*, 24, C1–C32.

RUDEBUSCH, G. D. (2019): "Climate Change and the Federal Reserve," *FRBSF Economic Letter*, 2019-09, Federal Reserve Bank of San Francisco.

TAYLOR, J. B. (1993): "Discretion Versus Policy Rules in Practice," *Carnegie-Rochester Conference Series on Public Policy*, 39, 195–214.

Table 1: Effects of Monetary Policy Shocks on Total Emissions and Output

Model Name	**Trough effect** (%)				**Maximal FEV contribution** (%)			
	Total Emissions		Ind.Production		Total Emissions		Ind. Production	
	73-96	73-05	73-96	73-05	73-96	73-05	73-96	73-05
Monetary VAR			-0.19	-0.23			3.81	6.16
Baseline VAR	-0.12	-0.16	-0.22	-0.21	11.30	12.47	4.67	5.16
A1 Emissions First	-0.07	-0.14	-0.17	-0.18	3.54	7.96	2.30	3.50
A2 With Weather Controls	-0.11	-0.15	-0.22	-0.21	9.63	10.08	6.32	5.28
A3 With Energy Price	-0.11	-0.13	-0.24	-0.18	9.18	8.10	5.82	4.12
A4 With R&R	-0.05	-0.10	-0.11	-0.09	1.02	2.76	1.99	2.98
	84-05	88-05	84-05	88-05	84-05	88-05	84-05	88-05
A5 Alternative Periods	-0.18	-0.10	-0.35	-0.28	31.86	14.26	19.72	12.98
	Total Emissions		GDP		Total Emissions		GDP	
	73-96	73-05	73-96	73-05	73-96	73-05	73-96	73-05
A6 Quarterly with GDP	-0.20	-0.26	-0.30	-0.23	8.11	8.14	28.0	6.79

Notes: Columns 2-5 report the trough effects of emissions and output measures (IP or GDP) to a one-standard-deviation monetary policy shock. Columns 6-9 report the percentage contribution of the monetary policy shock to the forecast error variance of total CO_2 emissions and output. See Sections 3.1 and 3.2 for the model description.

Table 2: Composition of CO_2 Emissions by Sector in 1996

Sector	**Residential**		**Commercial**		**Industrial**		**Transportation**	
E Source	MMT	(%)	MMT	(%)	MMT	(%)	MMT	(%)
Direct use of								
Coal	1.54	(0.14)	11.63	(1.32)	229.79	(12.70)	0.00	(0.00)
Natural Gas	284.00	(25.85)	171.08	(19.41)	507.71	(28.06)	39.07	(2.26)
Petroleum	104.48	(9.51)	57.12	(6.48)	395.17	(21.84)	1686.26	(97.55)
Sectoral share of Electric Power E	708.63	(64.50)	641.58	(72.79)	676.71	(37.40)	3.28	(0.19)
Total Emissions	1098.65	(100)	881.41	(100)	1809.39	(100)	1728.61	(100)

Notes: Authors' calculations from the annual Tables 11.2-11.5 in EIA (2023). MMT = millions of metric tons. E=emissions. Emissions from coal include coal coke net imports. Emissions from petroleum exclude biofuels. Columns with (%) report the percent contribution of each emissions source to total sector-specific emissions.

Table 3: Effects of Monetary Policy Shocks on Sector-Specific Emissions

Sector	**Trough effect** (%)		**Maximal FEV contribution** (%)	
	73-96	73-05	73-96	73-05
(a) Monetary VAR with Sector-Specific Emissions				
Residential	-0.05	-0.04	3.07	3.29
Commercial	-0.05	-0.04	3.95	2.86
Industrial	-0.44	-0.37	12.82	16.92
Transportation	-0.11	-0.17	3.63	9.06
(b) Monetary VAR with Emissions, Energy Prices, and Weather Controls				
Residential	-0.03	-0.03	1.72	3.15
Commercial	-0.06	-0.08	5.59	5.33
Industrial	-0.37	-0.32	13.70	11.25
Transportation	-0.07	-0.16	2.04	9.24

Notes: Columns 2-3 report the trough effects of emissions from the EIA's end-use sectors to a one-standard-deviation contractionary monetary policy shock. Columns 4-5 report the percentage contribution of the monetary policy shock to the forecast error variance of emissions.

A Data Sources

This appendix lists data sources, labels and types. The data transformations used in the paper are specified in Sections 3.1-3.3.
EIA = U.S. Energy Information Administration [`https://www.eia.gov/totalenergy/data/monthly`]; FRED = the database of the Federal Reserve Bank of St. Louis [`https://fred.stlouisfed.org/`]; NOAA = National Oceanic and Atmospheric Administration [`https://www.ncdc.noaa.gov/cag/global/time-series`]. Ramey (2016): [`https://econweb.ucsd.edu/~vramey/research.html#mon`]; sa = seasonally adjusted; nsa=not seasonally adjusted.

Macroeconomic variables IP: Industrial production total index (index 2017=100, sa); FRED [label INDPRO]. UR: Unemployment rate (percent, sa); FRED [label UNRATE]. CPI: Consumer Price Index for all urban consumers: all items in U.S. city average (index 1982-1984=100, sa); FRED [label CPIAUCSL]. Commodity price index (index); Ramey (2016) [label LPCOM]. FFR: Federal funds effective rate, averages of daily figures (percent, nsa); FRED [label FEDFUNDS]. M1 monetary aggregate (billions of dollars, sa); FRED [label M1SL]. RR: cumulative sum of the Romer&Romer's series; Ramey (2016) [label CUMRRSHOCK]. GDP: real gross domestic product (billions of chained 2012 dollars, sa annual rate, quarterly); FRED [label GDPC1].

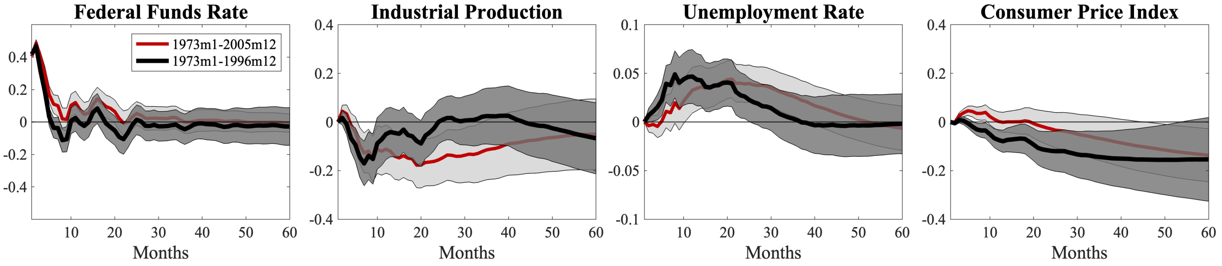
Environmental variables Total CO_2 emissions: total energy CO_2 emissions from energy consumption (MMT of carbon dioxide, nsa); Table 11.1 in EIA (2023). Sector-specific emissions: Total energy *residential / commercial / industrial / transportation* sector CO_2 emissions (MMT of carbon dioxide, nsa); Tables 11.2-11.5 in EIA (2023). Average temperature: Contiguous U.S. average temperature (Fahrenheit, nsa); NOAA. Precipitation: Contiguous U.S. precipitation (inches, nsa); NOAA.

Energy prices Fossil fuel costs: Cost of fossil fuel receipts at electric generating plants (dollars per million Btu, nsa); Table 9.9 in EIA (2023) [Costs of coal, total petroleum, natural gas, and fossil fuel receipts, including taxes]. CPI Electricity: CPI for all urban consumers: Electricity in U.S. City Average (index 1982-1984=100, sa); FRED [label CUSR0000SEHF01]. CPI Motor fuel: CPI for all urban consumers: Motor Fuel in U.S. city average (index 1982-1984=100, sa); FRED [label CUSR0000SETB]. PPI Electric Power: PPI by Commodity: Fuels and Related Products and Power: Electric Power (index 1982=100, sa); FRED [label WPS054].

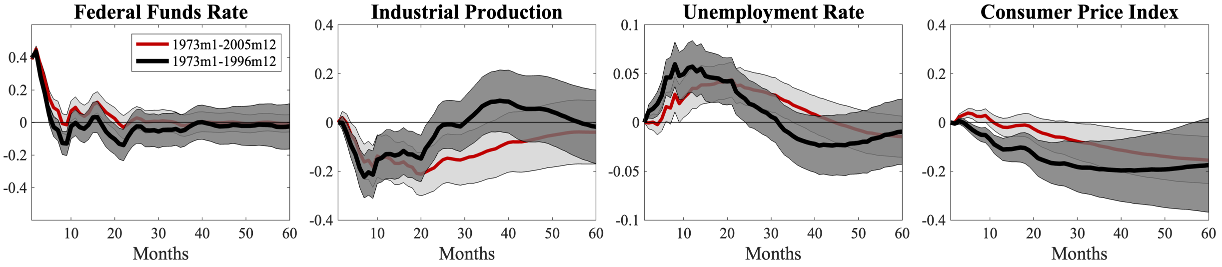
B Responses of Macroeconomic Variables

Figure 5: Effects of Monetary Policy Tightening on the Macroeconomic Indicators (%)
Alternative Specifications

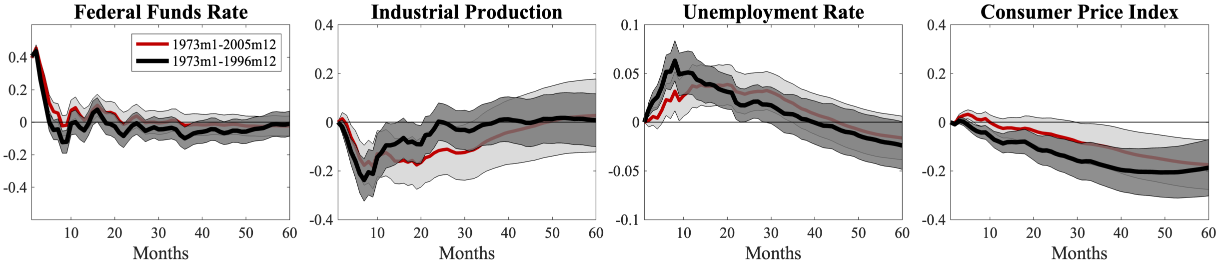
(a) A1 Emissions First



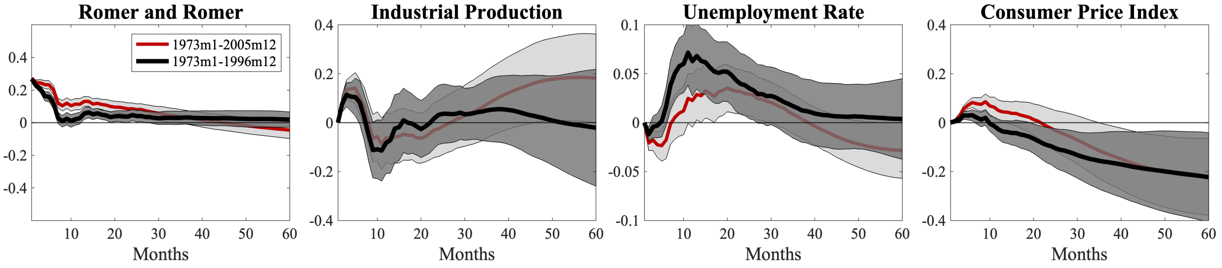
(b) A2 With Weather Controls



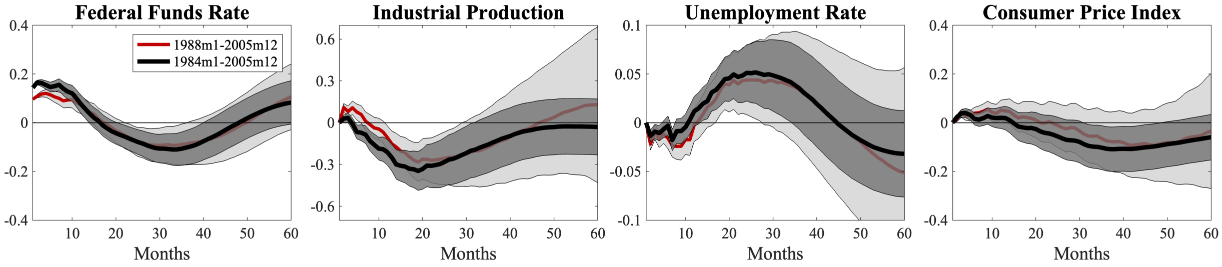
(c) A3 With Energy Price



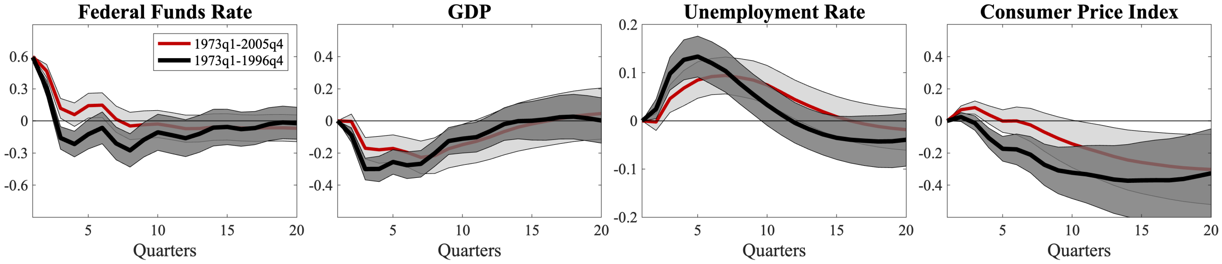
(d) A4 With R&R



(e) A5 Alternative Periods



(f) A6 Quarterly With GDP



Notes: The size of a monetary policy shock is normalized to increase the policy indicator (FFR or R&R) by 100 basis points in a monetary VAR augmented with emissions of a specific energy end-use sector. 1973m1-1996m12: thick black lines; 1973m1-2006m12: thin red lines. Darker and lighter shaded areas are the bootstrap one-standard-error confidence bands. See section 3.2 for the model description.