BANCA D'ITALIA
EUROSISTEMA

Temi di discussione

(Working Papers)

The macroeconomic effects of a greener technology mix

by Fabrizio Ferriani, Andrea Gazzani and Filippo Natoli

March 2025

Number 1482

BANCA D'ITALIA
EUROSISTEMA

Temi di discussione

(Working Papers)

The macroeconomic effects of a greener technology mix

by Fabrizio Ferriani, Andrea Gazzani and Filippo Natoli

Number 1482 - March 2025

The papers published in the Temi di discussione *series describe preliminary results and are made available to the public to encourage discussion and elicit comments.*

The views expressed in the articles are those of the authors and do not involve the responsibility of the Bank.

ISSN 2281-3950 (online)

Designed by the Printing and Publishing Division of the Bank of Italy

THE MACROECONOMIC EFFECTS OF A GREENER TECHNOLOGY MIX

by Fabrizio Ferriani*, Andrea Gazzani* and Filippo Natoli*

Abstract

What are the macroeconomic implications of shifting to greener technologies in the transition towards a low-emission economy? We identify shocks to the composition of US innovation entailing a shift towards greener technologies by exploiting granular data on the universe of patents granted in the United States. The rebalancing towards green technology is costly in the short run – lowering output and raising inflation – but Pareto-improving in the medium run, when the recessionary effects dissipate, the emissions intensity of output declines persistently, and energy production shifts towards renewables. These effects are independent of variations in national and international climate policy commitments.

JEL Classification: E31, E32, O34, Q5.

Keywords: patents, technology shock, green transition, business cycle.

DOI: 10.32057/0.TD.2025.1482

---

* Bank of Italy. Email: fabrizio.ferriani@bancaditalia.it; andreagiovanni.gazzani@bancaditalia.it; filippo.natoli@bancaditalia.it

1 Introduction[1]

The transition towards a low-carbon economy is at the forefront of the policy debate. As this process requires substantially reducing the environmental impact of production and consumption patterns, it may profoundly transform the economy. However, the empirical evidence on the aggregate implications of the transition for output and consumer prices is still scarce. One reason is that the literature has mainly focused on public policies for the transition, such as carbon taxes and cap-and-trade systems that, while effective in reducing emissions in some jurisdictions, may still fail to reach the emission targets at the global scale if not accompanied by an outright shift towards greener technologies in production.[2] Whether adopting greener technologies is effective in reducing emissions in the medium run and how it affects aggregate output and price dynamics are still unanswered questions.

We take up this issue by investigating the aggregate trade-offs that arise from shifting the innovation paradigm towards greener technologies. By leveraging on granular US patent data, we construct proxies of future aggregate technological developments, following the approach introduced in Miranda-Agrippino et al. (2020). Our analysis differs from previous works as we do not focus on the potential benefits of scaling up green innovation in itself but on the effects of a *recomposition* of technological development towards greener innovation. Within this perspective, green and non-green technologies compete as in the theoretical frameworks developed by Acemoglu et al. (2016a) and Lemoine (2024). In the context of such a decision problem, in which entrepreneurs decide how to invest under

[1]We are grateful to Piergiorgio Alessandri, Luisa Carpinelli, Ambrogio Cesa-Bianchi, Antonio Di Cesare, Silvia Miranda-Agrippino, Paolo Surico, Marco Taboga, and two anonymous referees for fruitful discussions. We also thank participants in seminars at Banca d'Italia, ECB, ESCB research cluster, Luiss University, and in the Banca d'Italia-EUI-EABCN conference "The macroeconomic and financial dimensions of the green transition" for their feedback. The views expressed in the paper are those of the authors and do not involve the responsibility of the Bank of Italy or the Eurosystem.

[2]See for instance Green (2021), Metcalf and Stock (2023), Coenen et al. (2023), among others.

limited resources, Acharya et al. (2024) show theoretically that green innovation can accelerate the green transition when climate policy instruments are constrained, as a direct result of intertemporal profit maximization strategy.By exploiting patent-level data from the US Patent and Trademark Office (USPTO), we construct a monthly variable proxying for the role that green technology will play in the future technology mix. We build this measure as the share of granted patents that are specifically designed for climate change mitigation over total patents.Employing the *ratio* of green patents is key as it nets out the common component in US patenting (green and brown) driven by expected macroeconomic conditions. However, because recent works have documented that energy prices (Acemoglu et al., 2024; Hu et al., 2023) and credit conditions (Aghion et al., 2024; Fornaro et al., 2024) affect green more than brown patenting, we cleanse our measure from oil shocks (Baumeister and Hamilton, 2019; Känzig, 2021) and from variations in the excess bond premium (EBP; Gilchrist and Zakrajšek, 2012), which is a measure of investors' risk appetite. The residual series passes a broad set of exogeneity tests and is orthogonal to the most popular macroeconomic shocks identified in the literature.

We then use the exogenous fluctuations in the incidence of green patents within Vector Autoregressive (VAR) models of the US economy, estimated over 1980-2019, to gauge the macroeconomic effects of green technology recomposition shocks. Our results show that the trade-off coming from greening US innovation is mainly between its short- and medium-run effects. Indeed, a shift towards a greener technology mix leads to a fall in carbon emissions, a drop in output, and a surge in producer and consumer prices in the short-run. The shock can thus be interpreted as a *temporary negative supply-side* disturbance. At the root of this downside effect lies the negative impact on aggregate productivity (TFP) that squares with the fact that green (emission-constrained) technologies are overall less mature than brown ones; consequently, increasing their weight in firms' technology mix makes production temporarily less efficient.However, the estimated stagflationary effects of a green technology recomposition are short-lived: economic activity recovers within five years and, although emissions decline more gradually than output, the carbon emissions intensity of output (i.e., the quantity of emissions per unit of production) eventually drops. These dynamics go hand-in-hand with a recomposition of energy consumption away from fossil fuels and towards renewable sources, and make our shock stand apart from a general, negative TFP shock. In other words, the technological recomposition leads to a Pareto improvement in the medium-run, as the adverse output effects dissipate while the decline in emission intensity persists over time.

Quantitatively, our green technology recomposition shock contributes for a significant variance share of carbon emissions (10%) while it explains a more modest portion of the volatility in macroeconomic aggregates, further validating the interpretation of our shock as a shock to the composition (and not to the level) of technological innovation.

While technology is the key ingredient in the low carbon transition, such a complex process is shaped by various forces, including climate policy and the general concern over future climate-related risks shaping households' and firms' preferences. Our results are unaffected by if we include (national and international) climate policy indicators, as well as changes in public attention on climate change.[3] Moreover, by linking the patenting activity of a subsample of quoted firms to their financial performance, we show that financial markets positively reward the filing of new green patents (see also Hege et al., 2023). Positive equity returns may explain why firms decide to switch to green innovation in the first place and, together with the absence of any significant influence from policy, it suggests an autonomous role of entrepreneurs' green innovation choices in driving the recomposition of production.

Related literature. This paper contributes to the literature in two ways. First, it pro-

[3]The interplay between green technology and climate policy connects this paper to the literature deriving measures of transition risk exposure from media or earnings calls: Engle et al. (2020), Ardia et al. (2023), Sautner et al. (2023), Gavriilidis et al. (2023), Meinerding et al. (2023).

vides empirical estimates that qualify and quantify the economic consequences of the green transition from an innovation perspective. Under the lens of our findings, the trade-off between going green and fostering economic growth looks only temporary, in line with earlier model-based results (Ferrari and Nispi Landi, 2022; Airaudo et al., 2022; Bartocci et al., 2022; Coenen et al., 2023).

Our work also relates to a growing strand of literature that explores the transition towards a low-emission economy, with emphasis on changing citizens' and consumers' values (Besley and Persson, 2023, Aghion et al., 2023, , Phelan and Love, 2023, Hong et al., 2023) or on the innovation-led transition driven by scientists (Lemoine, 2024) and amplified by firms' profit maximization (Acharya et al., 2024). In particular, Besley and Persson (2023) and Aghion et al. (2023) emphasize the prominent role of the intrinsic incentives – consumers being climate concerned and caring about the environmental effects of their actions – in pushing firms to compete on green innovation; differently, climate policy may fail to deliver such strong signals being subject to changes in political preferences (Besley and Persson, 2023). As our evidence points to green innovation as a stand-alone driver of the low-carbon transition, our paper empirically supports such views. In this sense, our findings offer a motivation for directly subsidizing green innovation, which is deemed effective in pursuing the transition according to theoretical models (Acemoglu et al., 2012, 2016b).

Finally, this paper connects to the empirical literature that exploits patents to identify technology shocks.[4] Recently, Miranda-Agrippino et al. (2020) proposed a way to exploit the information embedded in patenting activity to extract news shocks on future TFP growth, and showed that such shocks cause a business cycle expansion in anticipation of the expected productivity gains. We build on this intuition to construct a shock

[4]Among earlier contributions see for instance Griliches (1998), Lach (1995), Hall and Trajtenberg (2004), and Kogan et al. (2017).

to the greenness of the future technology mix, bridging developments in the empirical literature on technology shocks with that on green innovation. Within the latter, a growing strand is investigating the drivers and consequences of green patenting (e.g. Popp et al., 2010; Popp, 2019; Cohen et al., 2021; Hege et al., 2023; Ciccarelli and Marotta, 2023). In particular, two works study the economic consequences of an increase in the *number* of green patents in the economy finding aggregate expansionary effects (Moench and Soofi Siavash, 2023; Hasna et al., 2023). This result follows from the fact that, by construction, a surge in the number of patents shifts the production possibility frontier upwards (at least weakly). We focus instead on a technological recomposition from brown to green technology, which involves trade-offs for innovators under limited resources and, therefore, is closer in the spirit to the transition towards a low-carbon economy.

Structure of the paper. The remainder of the paper is organized as follows. Section 2 describes the data and the construction of our proxy for technology recomposition. Section 3 presents the main empirical findings. Section 4 shows the results coming from robustness exercises. Section 5 concludes.

2 Measuring green technological recomposition

2.1 Data

The primary data sources used to construct our green technology news measure for the United States are the *PatEx* and *Patents View* datasets from the U.S. Patent and Trademark Office (USPTO). *PatEx* is a valuable research-oriented, patent-level database (Marco et al., 2017), while *PatentsView* provides the *Cooperative Patent Classification* (CPC) for each granted patent: the category "Y02" specifically refers to green patents, i.e. those innovations related to *climate mitigation* efforts. Crucially, the availability of patent data at

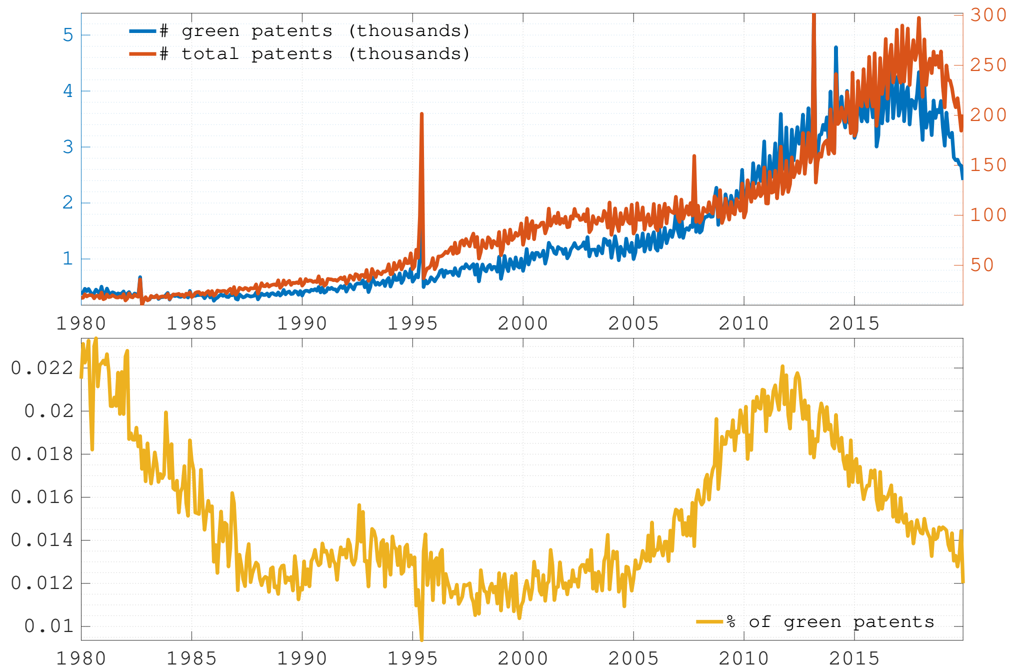

FIGURE 1: *Total vs green patent filing activity (upper panel) and share of green patents over total patents (lower panel); data only refers to granted patents. Source: USPTO PatEx and Patent Views.*

monthly frequency allows us to study the business cycle consequences of the transition and, moreover, to tackle the endogeneity in patenting documented in Miranda-Agrippino et al. (2020).

In order to quantify future shifts towards green technology, we calculate the ratio between the number of green patents (pat_G) filed in a given month t to the total number of of patents (pat_T) filed in the same month (Eq. 1). We consider the filing date (instead of the approval date) as in Miranda-Agrippino et al. (2020) who argue that some news about the underlying technology might potentially spread out already at the filing date. In formulas, we define our green patent proxy as

$$gp_t = \frac{pat_{G,t}}{pat_{T,t}} \tag{1}$$

where $pat_{G,t}$ indicates the number of green patents filed in month t, while $pat_{T,t}$ is the total number of patents filed in the same period. Figure 1 displays the dynamics of green versus total patent filing activity (top panel) and of the ratio of the number of green over total patents gp_t (bottom panel) from 1980. A potential concern is the correlation between gp and oil prices: their level was high at beginning of the '80s after the major oil supply shocks, and peaked again before the shale revolution in the 2010s. We address this endogeneity concern in Section 2.2.

Green patents examples

To gain deeper insights on the green patents that we exploit to identify green technology recomposition shocks, we report some illustrative examples of patents classified with the "Y02" CPC code. Patents under the Y02 label cover technologies aimed at mitigating climate change by reducing greenhouse gas emissions, such as electric vehicles, renewable energy systems, and carbon capture processes. Importantly, as shown below, important technologies for the green transition were patented decades ago, confirming that green innovation was already ongoing well before climate change and green transition gained larger media attention in the year 2010s.

Electric car. In 1977, Lee Raymond Organization Inc. filed a patent request titled "Electric car" that introduced efficiency gains for electric motors by improving the torque-to-weight ratio and energy management of onboard batteries, representing an early step toward the commercial viability of electric vehicles.[5]

Hydrogen engine. In 1983, a private individual filed a patent application titled "Hydrogen engine" that enhanced methods for generating hydrogen gas from water and utilizing it directly as fuel in an internal combustion engine. This patent is an example of an early attempt to shift away from fossil fuels, and it widely anticipated the later interest in

[5]Further details are available at https://tinyurl.com/49prpmby.

hydrogen as a clean energy vector.[6]

Method and apparatus for producing parts by selective sintering . In 1986, the University of Texas filed a patent application titled "Method and apparatus for producing parts by selective sintering" that improved the production of manufacturing components for renewable energy systems, potentially enhancing production efficiency and reducing material waste through additive processes.[7]

Stratospheric Welsbach seeding for reduction of global warming . In 1990, Hughes Aircraft Co. filed a patent application titled "Stratospheric Welsbach seeding for reduction of global warming" that developed a method aimed at reflecting a portion of solar radiation with the aim of reducing the pace of global warming.[8]

Method and apparatus for sequestering carbon dioxide in the deep ocean or aquifers. In 1992, the Electric Power Research Institute filed a patent application titled "Method and apparatus for sequestering carbon dioxide in the deep ocean or aquifers" that developed a carbon capture and storage (CCS) solution, i.e. a method for removing carbon dioxide from power plant emissions or from the general atmospheric environment and storing it in deep ocean reservoirs. [9]

Lithium-ion battery. In 2000, Motorola Inc. filed a patent application titled "Lithium-ion battery" that allowed the production of improved lithium-ion or lithium-polymer batteries that are capacity-fade resistant over multiple charging cycles. This innovation marked a significant advancement in the clean-energy market, as reliable battery performance is crucial for the widespread adoption of electric vehicles and the efficiency of consumer electronics.[10]

System and process of biodiesel production. In 2009, a private individual filed a

[6] Further details are available at https://tinyurl.com/2fbf383y.
[7] Further details are available at https://tinyurl.com/js57danu.
[8] Further details are available at https://tinyurl.com/mrx4pzzf.
[9] Further details are available at https://tinyurl.com/5fvxauam.
[10] Further details are available at https://tinyurl.com/2kv8rksa.

patent application titled "System and process of biodiesel production" detailing an integrated approach to producing biodiesel from waste oils using reusable sugar-based catalysts, minimizing the environmental impact of biodiesel production.[11]

Production of ammonia from air and water. In 2010, a private individual filed a patent application titled "Production of ammonia from air and water" which introduced a method to produce ammonia without relying on fossil fuels. The process uses air as a source of nitrogen and water as a source of hydrogen, offering a cleaner and more sustainable alternative for industries such as agriculture and energy.[12]

Electrical vehicle charging station with power management. In 2019, Eaton Intelligent Power Ltd filed a patent application titled "Electrical vehicle charging station with power management". This patent proposes a smart charging station for electric vehicles that enhances grid interaction and reduces greenhouse gas emissions by efficiently distributing power within a network that includes residential buildings, local energy producers (e.g., solar panels), and energy consumers.[13]

2.2 Addressing endogeneity

Recent works document that green patenting is endogenous to fossil fuels prices (Acemoglu et al., 2024 ; Hu et al., 2023) and credit conditions (Aghion et al., 2024; Fornaro et al., 2024). For this reason, we purge gp_t by the oil shocks identified in Baumeister and Hamilton (2019) and by oil supply news shocks from Känzig (2021). To address the concerns related to credit conditions, we also control for variations in the excess bond premium (Gilchrist and Zakrajšek, 2012).[14] Specifically, we regress gp_t on a constant (α), its

[11] Further details are available at https://tinyurl.com/yc3rjk9r.

[12] Further details are available at https://tinyurl.com/yeyte568.

[13] Further details are available at https://tinyurl.com/4y8tmmf9.

[14] We find that gp_t is orthogonal to the Baumeister and Hamilton (2019) economic activity shocks (thus not appearing in eq. 2), suggesting that only sector-specific shocks affect incentives across green and brown patents. We employ the EBP rather than monetary policy shocks as in Aghion et al. (2024) and Fornaro

own 12 lags and contemporaneous and lagged values of oil supply (ε^{s}), oil precautionary demand (ε^{pd}), and oil-specific demand shocks (ε^{os}), oil supply news (ε^{sn}) and the EBP:

$$\begin{aligned} gp_t &= \alpha + \sum_{h=1}^{12} \beta_h^{gp} gp_{t\,t-h} + \sum_{h=0}^{12} \beta_h^{s} \varepsilon_{t-h}^{s} + \sum_{h=0}^{12} \beta_h^{pd} \varepsilon_{t-h}^{pd} + \\ &\quad + \sum_{h=0}^{12} \beta_h^{od} \varepsilon_{t-h}^{od} + \sum_{h=0}^{12} \beta_h^{sn} \varepsilon_{t-h}^{sn} + \sum_{h=0}^{12} \beta_h^{ebp} EBP_{t-h} + \epsilon_t^{gp} \end{aligned} \tag{2}$$

We extract the time series of the residuals from the estimated Eq.(2) $\widehat{\epsilon}^{gp}$ and employ it in our empirical analysis.

3 Macroeconomic effects

3.1 Econometric framework

Consider the standard VAR model:

$$\mathbf{y}_t = \mathbf{a} + \mathbf{A}_1 \mathbf{y}_{t-1} + \cdots + \mathbf{A}_p \mathbf{y}_{t-p} + \mathbf{u}_t \tag{3}$$

where p is the lag order, $\mathbf{y}_t$ is a $n \times 1$ vector of endogenous variables, $\mathbf{u}_t$ is a $n \times 1$ vector of reduced-form innovations with covariance matrix $\text{Var}(\mathbf{u}_t) = \mathbf{\Sigma}$, $\mathbf{a}$ is a $n \times 1$ vector of constants, and $\mathbf{A}_1, \ldots, \mathbf{A}_p$ are $n \times n$ matrices. The innovations $\mathbf{u}_t$ are typically expressed as a linear combination of the structural shocks ε_t under the assumption of invertibility:

$$\mathbf{u}_t = \mathbf{B}\boldsymbol{\varepsilon}_t \tag{4}$$

$\text{Var}(\varepsilon_t) = \Omega$ is diagonal as the structural shocks are by construction uncorrelated. Con-

et al. (2024) because our preliminary test indicate contamination from the EBP rather than monetary policy shocks. This result is compatible with the crucial role played by the EBP in the transmission of US monetary policy (see Alessandri et al., 2023).

versely, $\Sigma = \mathbf{B}\Omega\mathbf{B}'$ is not diagonal as, generally, the reduced-form residuals are correlated. We are interested in estimating the causal impact of a single shock in the system, i.e. the green technological recomposition shock ε_t^{gp}. Because we employ the proxy $\widehat{\epsilon}^{gp}$ for our shock of interest ε_t^{gp} as an internal instrument, we can avoid the invertibility assumption in Eq.(4) (Plagborg-Møller and Wolf, 2021; Miranda-Agrippino and Ricco, 2023). Identification is instead achieved under the following assumptions:

$$\mathbb{E}\left[\widehat{\epsilon}^{gp}\varepsilon_t^{gp}\right] = \alpha \neq 0 \tag{5}$$

$$\mathbb{E}\left[\widehat{\epsilon}^{gp}\boldsymbol{\varepsilon}_{2:n,t}\right] = \mathbf{0} \tag{6}$$

$$\mathbb{E}\left[\widehat{\epsilon}^{gp}\boldsymbol{\varepsilon}_{t+i}\right] = \mathbf{0} \quad \text{for } i \neq 0 \tag{7}$$

where Eq.(5-6) are the typical conditions for the validity of an instrument. Eq.(7) is an additional condition that is necessary in this dynamic setting according to which the instrument is orthogonal to lags and leads of all structural shocks. Under those conditions, the dynamic effects are obtained as the impulse responses to $\widehat{\epsilon}^{gp}$ that is included in the VAR as an additional endogenous variable.

Our baseline monthly VAR model of the US economy includes $\widehat{\epsilon}^{gp}$, industrial production, the unemployment rate, the commodity producer prices, consumer prices (proxied by the deflator of Personal Consumption Expenditures - PCE), the level of CO2 emissions released in the US, and the 3-month Tbill rate.[15] The VAR includes 12 lags and the variables enter in log-level following Sims et al. (1990). We estimate the VAR on the sample from January 1980 to December 2019.

[15]CO2 emissions are interpolated as in Gavriilidis et al. (2023).

3.2 Diagnostics on structural shocks

Before presenting the macroeconomic effects of ε_t^{gp} shocks, we display a battery of tests aimed at diagnose the potential endogeneity ε_t^{gp} to other structural shocks (monetary and fiscal policy shocks, among others). Notice that ε_t^{gp} differs from $\widehat{\varepsilon}^{gp}$ because it has been regressed on lags of all the endogenous variables in the VAR. We regress ε_t^{gp} on a broader set of commodity prices – in particular the price of other fossil fuels and metals related to the green transition – macroeconomic factors and forecasts. We run the following regression for each potential explanatory factor x_t, which enters the set of regressors both contemporaneously and up to 12-month lags:

$$\varepsilon_t^{gp} = \alpha + \sum_{h=0}^{12} \delta_h x_{t-h} + \nu_t \tag{8}$$

Table 1 (panel a) reports the F statistic and associated p-values from a test on the joint statistical significance of the δs. We also test the correlation between ε_t^{gp} and several macroeconomic shocks from the literature (panels b-c). The test does not diagnose a spurious contamination of our ε^{gp} measure by confounding factors.

Panel (a): Macroeconomic aggregates

Variables	F-stat	P-value	Obs.
Commodity prices (level)	1.01	0.46	468
Fossil fuels price (level)	0.74	0.86	444
Transition metal prices (level)	0.90	0.63	468
Commodity prices (growth rate)	1.15	0.23	467
Fossil fuels price (growth rate)	0.85	0.72	443
Transition metal prices (growth rate)	0.98	0.51	467
Long-term Consensus Forecast	1.03	0.42	318
FRED-MD factors	1.10	0.28	456

Panel (b): Monthly structural shocks

Shocks	ρ	P-value	Obs.
Gertler and Karadi (2015) monetary	-0.01	0.83	324
Romer and Romer (2004) monetary	0.06	0.41	192
Baker et al. (2016) EPU	0.08	0.11	390
Känzig (2022) carbon policy	0.00	0.98	246

Panel (c): Quarterly structural shocks

Shocks	ρ	P-value	Obs.
Romer and Romer (2010) fiscal	0.13	0.18	112
Ramey (2011) fiscal	0.10	0.28	124
Fisher and Peters (2010) fiscal	0.12	0.22	116
Mertens and Ravn (2013) tax	0.01	0.92	108
Smets and Wouters (2007) monetary	0.06	0.58	100
Romer and Romer (2010) fiscal	0.13	0.18	112
Smets and Wouters (2007) TFP	-0.13	0.19	100
Basu et al. (2006) TFP	-0.15	0.11	128
Barsky and Sims (2011) news	-0.01	0.95	111
Kurmann and Otrok (2013) news	-0.16	0.12	102
Beaudry and Portier (2014) news	-0.08	0.37	131

Table 1: Orthogonality of ε_t^{gp}

Notes. Panel (a): ε_t^{gp} is regressed on a constant, and the explanatory variables of interest (contemporaneous and up to 12 lags). The F-test statistics correspond to the joint significance test for energy, agriculture, industrial metals, precious metals commodity price indexes (commodity prices); oil, gas and coal prices (fossil fuels); copper, nickel, and zinc (transition metals); Long Term Consensus Forecasts includes GDP, CPI, and bond yields 1 and 4 years ahead; FRED-MD stands for 7 factors extract from the FRED-MD database. In the case of FRED-MD factors, the explanatory variable of interest is the first 12 lags of 7 factors extracted from the FRED-MD database. Panel (b)-(c) report the correlation between the ε_t^{gp} and various structural shocks from the literature. In the case of the quarterly exercise, ε_t^{gp} is aggregated as quarterly averages.

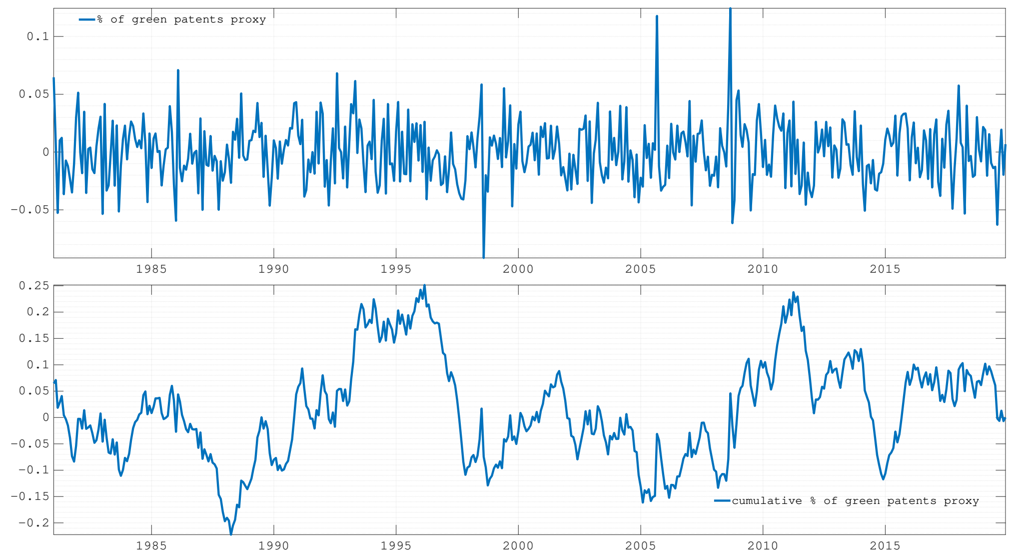

FIGURE 2: *Structural shocks ε_t^{gp} extracted from the VAR. Raw values in upper panel; cumulative value in lower panel.*

Figure 2 displays our structural shock of interest ε_t^{gp} extracted from the VAR and their cumulative sum over the sample.

3.3 Macroeconomic implications of a green technology recomposition

Figure 3 displays the dynamic causal effect, i.e. the impulse responses (IRFs), of ε_t^{gp} on the variables included in the VAR. Consistently with the delayed diffusion of innovation, all variables display a gradual response to the shock. Industrial production falls, reaching a trough after three years before mean-reverting back to zero. Consistently, the unemployment rate increases, reaching a peak around three years after the shock. Producer and consumer prices increase corroborating the interpretation of ε_t^{gp} as a negative supply-side disturbance. Crucially, the technological shift successfully reduces CO2 emissions in a delayed yet persistent fashion.

The forecast error variance decomposition (FEVD) gauges the quantitative relevance of switches towards greener technologies for the US economy (Figure 4). Albeit green

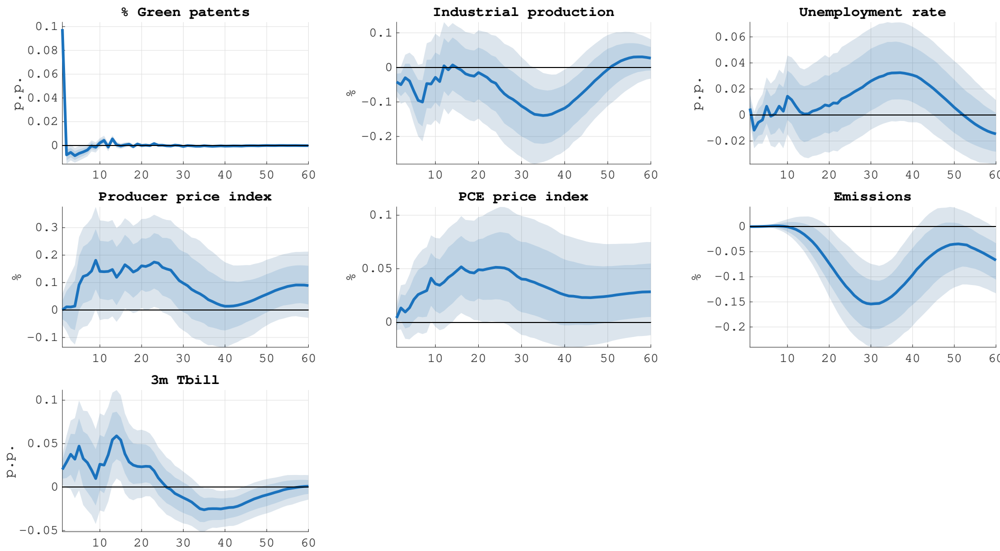

FIGURE 3: *Baseline IRFs to a green technology recomposition shock. Shaded areas denote 68% and 90% confidence bands; the horizon is in months.*

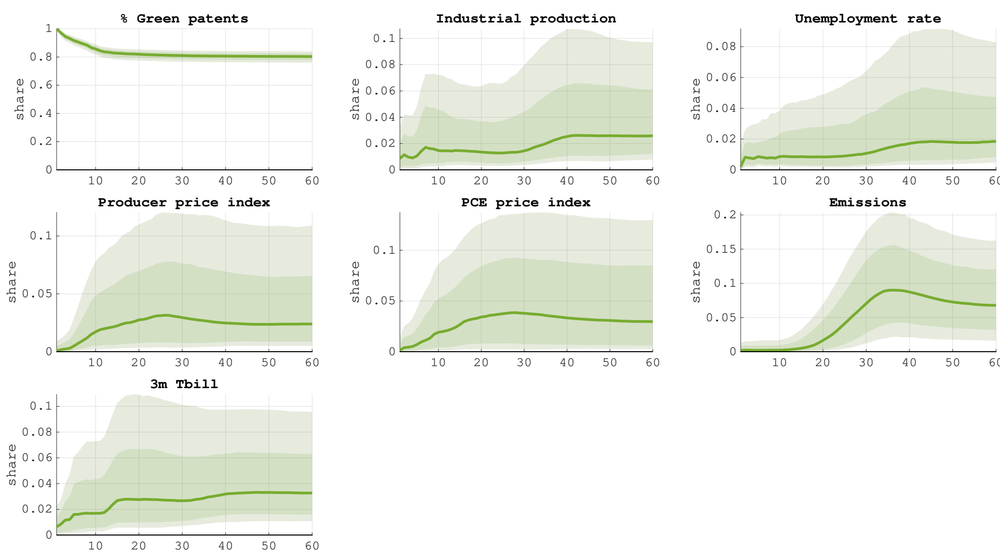

FIGURE 4: *Baseline FEVD of a green technology recomposition shock. Shaded areas denote 68% and 90% confidence bands; the horizon is in months.*

technology recomposition shocks are arguably not a major driver of the US business cycle, they nonetheless explain a significant share of the forecast error variance of carbon emissions (10%). The higher explanatory power for emissions rather than economic activity further corroborates our interpretation of ε_t^{gp} as a technology recomposition shock.

3.4 Transmission mechanism

This Section digs further into the channels that drive the aggregate responses of a green technology recomposition shock. First, we investigate the role of TFP, and then we focus on the interpretation of our shock of interest by examining the behavior of additional variables.

3.4.1 The TFP channel

As TFP is only available at the quarterly frequency, we extract ε^{gp} from our monthly baseline VAR; then, we average the latter at the quarterly frequency and employ it in a local projection estimation as done in Känzig (2022). We use utilization-adjusted TFP constructed by Basu et al. (2006) as dependent variable. The left panel in Figure 5 shows a delayed negative response of TFP to a ε^{gp} shock, which validates the interpretation of the shock as a negative supply shock. The right panel corroborates this finding by displaying the heterogeneous effects of green and non-green patenting on TFP.[16] An increase in the number of brown patents exerts a lagged positive influence on TFP; conversely, a rise in the number of green patents does not lead to any significant effects.

3.4.2 Cleaner production process

Figure 6 provides important insights on the medium-term effects on the economy after a green technology recomposition. First, the emission intensity of industrial production drops, albeit with a marked delay. Second, the weight of renewables in the mix of primary energy consumption of US households surges. These results corroborate our interpretation of a technology recomposition shocks towards an economy less reliant on fossil fuels and overall less carbon-intensive.

[16] We are using the number of green (non-green) patents to estimate these effects.

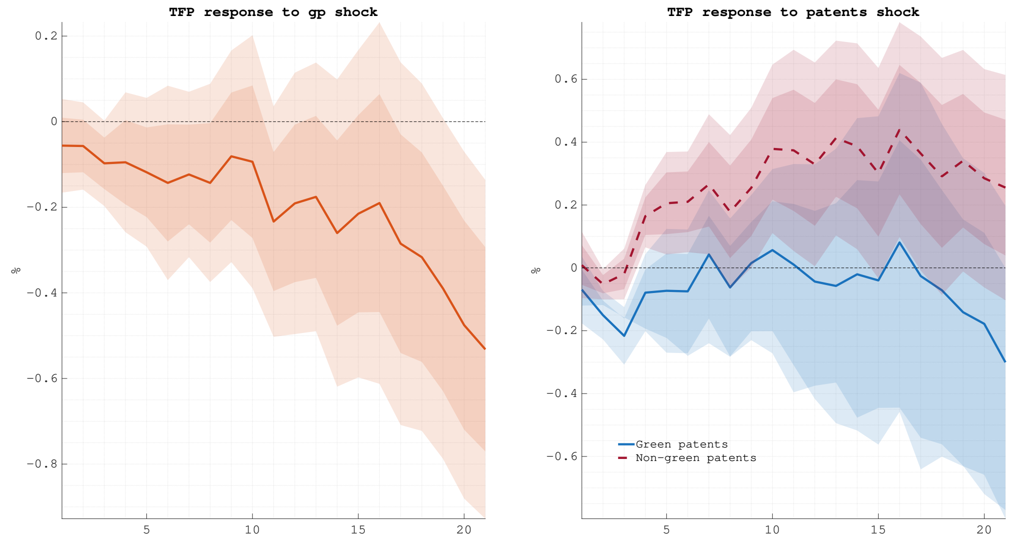

FIGURE 5: *TFO response to a green recomposition shock estimate with local projections. Shaded areas denote 68% and 90% confidence bands; the horizon is in quarters.*

3.5 Accounting for climate policy

Climate policy constitutes a factor that can affect green patenting and the incentive of undertaking green or brown innovation. Indeed, expectations of future climate policy interventions in the US, or changes in the international commitments on the fight to climate change might affect those incentives over time. For this reason, we enrich our VAR model with the Climate Policy Uncertainty (CPU - Gavriilidis et al., 2023) that captures information on climate policy events both at US and at the global level.[17] In a conservative exercise, we include CPU prior to $\widehat{\epsilon}^{gp}$ in a recursive ordering identification of ε_t^{gp}. In this way, ε_t^{gp} is orthogonal to both contemporaneous and lagged values of the CPU. Within this specification, results are similar to the baseline but the picture that emerges is even more clear cut and the estimates more precise.

[17]The sample is slightly shorter than in the baseline as the CPU is available since 1987.

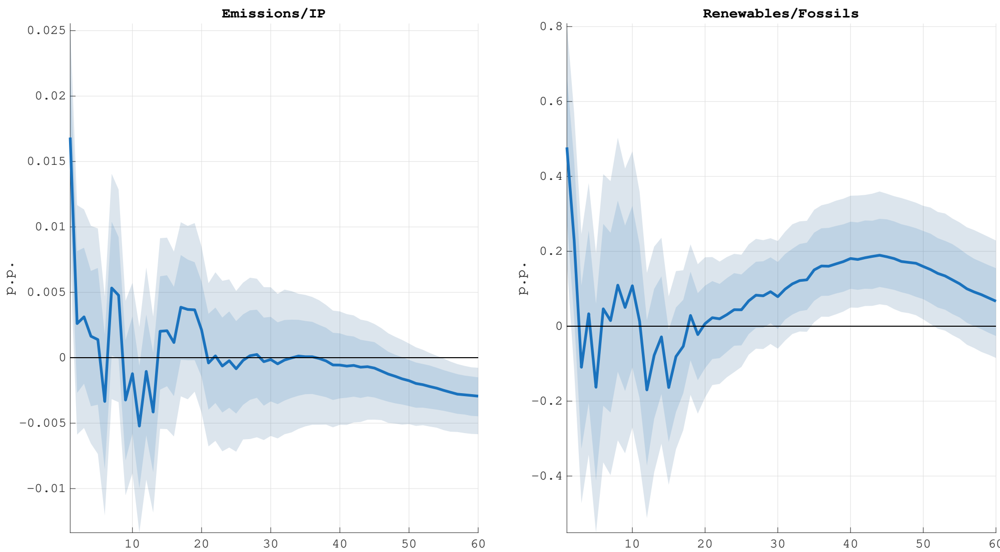

FIGURE 6: *Shift to greener production in response to a green recomposition shock in a monthly VAR. Shaded areas denote 68% and 90% confidence bands; the horizon is in months.*

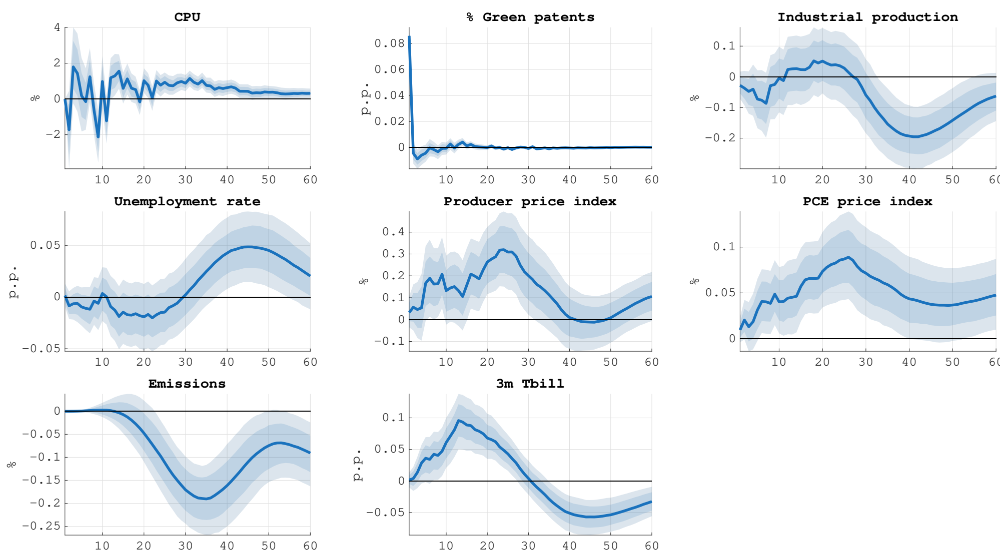

FIGURE 7: *IRFs to a green technology recomposition shock - controlling for CPU. Shaded areas denote 68% and 90% confidence bands; the horizon is in months.*

4 Additional results and robustness analysis

In this Section, we replicate the analysis, modifying our empirical strategy along several dimensions, including the definition of the green technology shock, the identification scheme, the specification of the VAR model, and the sample period.

Alternative definitions of gp. Employing a citation-weighted measure of patents to build gp yields qualitatively similar results. For this purpose, we retrieve from *PatentsView* the information on the total number of citations associated with each patent. More precisely, we rely on the number of citations made to U.S. patent applications by other U.S. patents. Using this information significantly boosts the explanatory power of green technology recomposition shocks (see Figure A.1).[18] We do not employ this weighted measure as a baseline because it uses information that is not available in real-time to economic agents. Results consistent with our baseline hold also if we exclude from our analysis green patents filed by the US oil and gas industry. This evidence confirms that our results are pervasive across industrial sectors and not limited to energy-producing firms, which recent literature has found to lead green innovation (Cohen et al., 2021).

Alternative identification strategy. Our baseline analysis employs gp as an internal instrument within a VAR model. Comparable results hold if we include both the number of non-green and green patents (in logs) in the VAR and identify our shock of interest as the unpredictable change in the number of green patents (not their share) *that is orthogonal* to surprise changes in non-green patents (Figure A.2). This amounts to ordering the number of non-green patents first and the number of green patents second in a recursively identified SVAR where we are interested only in the second structural shock. As we have already mentioned, this orthogonality condition is necessary to identify a technological configuration that leads to a fall in carbon emissions and is thus consistent with the green transition.

Alternative VAR specifications. The conclusions from our analysis hold in a large set of alternative specifications of the baseline VAR. In terms of variables, we made the following modifications: i) we include stock prices (Figure A.3); ii) we include the VIX as

[18] The number of citations per patent comes from PatViews; we associate patents to firm using the matching provided by Arora et al. (2021a) and Arora et al. (2021b).

a proxy for uncertainty shocks and the global financial cycle (Figure A.4); iii) we add the EBP to explicitly control for financial shocks (Figure A.5); iv) we include the total number of patents in the VAR and impose that this variable is not affected by our shock at any horizon to control for potentially endogenous variation in the number of patents due to the business cycle (Figure A.6).

Subsets of gp. The CPC classification also provides sub-categories of green patents: energy, goods, transport, building, and digital. We repeat our analysis for these categories and find results that are comparable to the aggregate measure overall (Figures A.7-A.11). Among them, a green push seems to produce larger effects when it comes from the building industry and from the goods and energy ones.

Equity response to green patenting. Firm value and equity returns can motivate firms to pursue green innovation independently of environmental regulation. While the aggregate economic consequences of green patenting shocks may be recessionary, this does not mean that firms do not benefit from green patenting (see Table in Appendix B). In an event study, we study the impact of green innovation on corporate equity returns using a monthly panel from 1980 to 2019. We find that the filing of one additional green patent is associated with higher stock market returns, suggesting that financial investors reward firms doing green innovation.

5 Conclusions

Our study sheds light on the macroeconomic and environmental implications of shifting innovation from brown to green technologies. We find that, empirically, this shift acts as a negative supply-side shock in the short term: output falls, unemployment raises while consumer prices surge. From an environmental perspective, however, such technological shift is able to reduce carbon emissions persistently. Crucially, the negative implications for economic activity and prices dissipate in the medium-run leading to a Pareto improvement in terms of the trade-off between keeping economic activity strong and reducing carbon emissions in the longer run.

References

Acemoglu, D., P. Aghion, L. Barrage, and D. Hémous (2024): "Climate Change, Directed Innovation, and Energy Transition: The Long-run Consequences of the Shale Gas Revolution," .

Acemoglu, D., P. Aghion, L. Bursztyn, and D. Hemous (2012): "The Environment and Directed Technical Change," *American Economic Review*, 102, 131â66.

Acemoglu, D., U. Akcigit, D. Hanley, and W. Kerr (2016a): "Transition to clean technology," *Journal of political economy*, 124, 52–104.

——— (2016b): "Transition to Clean Technology," *Journal of Political Economy*, 124, 52–104.

Acharya, V. V., R. F. Engle, and O. Wang (2024): "Strategic commitments to decarbonize: The role of large firms, common ownership, and governments," .

Aghion, P., R. Bénabou, R. Martin, and A. Roulet (2023): "Environmental preferences and technological choices: Is market competition clean or dirty?" *American Economic Review: Insights*, 5, 1–19.

Aghion, P., A. Bergeaud, M. De Ridder, and J. Van Reenen (2024): "Lost in transition: Financial barriers to green growth," .

Airaudo, F. S., E. Pappa, and H. D. Seoane (2022): "Greenflation: The cost of the green transition in small open economies," *CAF - WORKING PAPER*, 26.

Alessandri, P., F. Venditti, and Ò. Jordà (2023): "Decomposing the monetary policy multiplier," *Bank of Italy Temi di Discussione (Working Paper) No*, 1422.

Ardia, D., K. Bluteau, K. Boudt, and K. Inghelbrecht (2023): "Climate Change Concerns and the Performance of Green vs. Brown Stocks," *Management Science*, 0, null.

Arora, A., S. Belenzon, and L. Sheer (2021a): “Knowledge spillovers and corporate investment in scientific research,” *American Economic Review*, 111, 871–898.

——— (2021b): “Matching patents to Compustat firms, 1980–2015: Dynamic reassignment, name changes, and ownership structures,” *Research Policy*, 50, 104217.

Baker, S. R., N. Bloom, and S. J. Davis (2016): “Measuring economic policy uncertainty,” *The quarterly journal of economics*, 131, 1593–1636.

Barsky, R. B. and E. R. Sims (2011): “News shocks and business cycles,” *Journal of monetary Economics*, 58, 273–289.

Bartocci, A., A. Notarpietro, and M. Pisani (2022): “"Green" fiscal policy measures and non-standard monetary policy in the euro area,” Temi di discussione (Economic working papers) 1377, Bank of Italy, Economic Research and International Relations Area.

Basu, S., J. G. Fernald, and M. S. Kimball (2006): “Are technology improvements contractionary?” *American Economic Review*, 96, 1418–1448.

Baumeister, C. and J. D. Hamilton (2019): “Structural interpretation of vector autoregressions with incomplete identification: Revisiting the role of oil supply and demand shocks,” *American Economic Review*, 109, 1873–1910.

Beaudry, P. and F. Portier (2014): “News-driven business cycles: Insights and challenges,” *Journal of Economic Literature*, 52, 993–1074.

Besley, T. and T. Persson (2023): “The political economics of green transitions,” *The Quarterly Journal of Economics*, 138, 1863–1906.

Ciccarelli, M. and F. Marotta (2023): “Demand or supply? An empirical exploration of the effects of climate change on the macroeconomy,” *Energy Economics*, 107163.

COENEN, G., M. LOZEJ, AND R. PRIFTIS (2023): "Macroeconomic effects of carbon transition policies: an assessment based on the ECBâs New Area-Wide Model with a disaggregated energy sector," Working Paper Series 2819, European Central Bank.

COHEN, L., U. G. GURUN, AND Q. NGUYEN (2021): "The ESG - Innovation Disconnect: Evidence from Green Patenting," *European Corporate Governance Institute â Finance Working Paper*, 744.

ENGLE, R., S. GIGLIO, B. KELLY, H. LEE, AND J. STROEBEL (2020): "Hedging Climate Change News," *Review of Financial Studies*, 33, 1184–1216.

FERRARI, A. AND V. NISPI LANDI (2022): "Will the green transition be inflationary? Expectations matter," Questioni di Economia e Finanza (Occasional Papers) 686, Bank of Italy, Economic Research and International Relations Area.

FISHER, J. D. AND R. PETERS (2010): "Using Stock Returns to Identify Government Spending Shocks*," *The Economic Journal*, 120, 414–436.

FORNARO, L., V. GUERRIERI, AND L. REICHLIN (2024): "Monetary Policy for the Energy Transition," Tech. rep.

GAVRIILIDIS, K., D. R. KÄNZIG, AND J. H. STOCK (2023): "The Macroeconomic Effects of Climate Policy Uncertainty," *Unpublished working paper*.

GERTLER, M. AND P. KARADI (2015): "Monetary policy surprises, credit costs, and economic activity," *American Economic Journal: Macroeconomics*, 7, 44–76.

GILCHRIST, S. AND E. ZAKRAJŠEK (2012): "Credit spreads and business cycle fluctuations," *American economic review*, 102, 1692–1720.

GREEN, J. F. (2021): "Does carbon pricing reduce emissions? A review of ex-post analyses," *Environ. Res. Lett.*, 16.

GRILICHES, Z. (1998): "Patent statistics as economic indicators: a survey," 287–343.

HALL, B. H. AND M. TRAJTENBERG (2004): "Uncovering GPTs with patent data," .

HASNA, Z., F. JAUMOTTE, J. KIM, S. PIENKNAGURA, AND G. SCHWERHOFF (2023): "Green Innovation and Diffusion: Policies to Accelerate Them and Expected Impact on Macroeconomic and Firm-Level Performance," *Staff Discussion Notes*.

HEGE, U., S. POUGET, AND Y. ZHANG (2023): "The Impact of Corporate Climate Action on Financial Markets: Evidence from Climate-Related Patents," .

HONG, H. G., N. WANG, AND J. YANG (2023): "Mitigating Disaster Risks in the Age of Climate Change," *Econometrica*, 91.

HU, X., J. YU, AND A. ZHONG (2023): "The asymmetric effects of oil price shocks on green innovation," *Energy Economics*, 125, 106890.

KÄNZIG, D. R. (2021): "The macroeconomic effects of oil supply news: Evidence from OPEC announcements," *American Economic Review*, 111, 1092–1125.

——— (2022): "The unequal economic consequences of carbon pricing," *Available at SSRN 3786030*.

KOGAN, L., D. PAPANIKOLAOU, A. SERU, AND N. STOFFMAN (2017): "Technological innovation, resource allocation, and growth," *The Quarterly Journal of Economics*, 132, 665–712.

KURMANN, A. AND C. OTROK (2013): "News shocks and the slope of the term structure of interest rates," *American Economic Review*, 103, 2612–2632.

LACH, S. (1995): "Patents and productivity growth at the industry level: A first look," *Economics Letters*, 49, 101–108.

LEMOINE, D. (2024): "Innovation-led transitions in energy supply," *American Economic Journal: Macroeconomics*, 16, 29–65.

MARCO, A. C., A. TOOLE, R. MILLER, AND J. FRUMKIN (2017): "USPTO patent prosecution and examiner performance appraisal," .

MEINERDING, C., Y. S. SCHÃŒLER, AND P. ZHANG (2023): "Shocks to transition risk," Discussion Papers 04/2023, Deutsche Bundesbank.

MERTENS, K. AND M. O. RAVN (2013): "The dynamic effects of personal and corporate income tax changes in the United States," *American economic review*, 103, 1212–1247.

METCALF, G. E. AND J. H. STOCK (2023): "The macroeconomic impact of Europeâs carbon taxes," *American Economic Journal: Macroeconomics*, 15, 265–286.

MIRANDA-AGRIPPINO, S., S. H. HOKE, AND K. BLUWSTEIN (2020): "Patents, News, and Business Cycles," CEPR Discussion Papers 15062, C.E.P.R. Discussion Papers.

MIRANDA-AGRIPPINO, S. AND G. RICCO (2023): "Identification with external instruments in structural VARs," *Journal of Monetary Economics*, 135, 1–19.

MOENCH, E. AND S. SOOFI SIAVASH (2023): "Carbon Intensity, Productivity, and Growth," *Productivity, and Growth (March 23, 2023)*.

PHELAN, G. AND D. LOVE (2023): "Sustainability with Risky Growth," .

PLAGBORG-MØLLER, M. AND C. K. WOLF (2021): "Local projections and VARs estimate the same impulse responses," *Econometrica*, 89, 955–980.

POPP, D. (2019): "Environmental policy and innovation: a decade of research," .

POPP, D., R. G. NEWELL, AND A. B. JAFFE (2010): "Energy, the environment, and technological change," *Handbook of the Economics of Innovation*, 2, 873–937.

Ramey, V. A. (2011): "Identifying government spending shocks: It's all in the timing," *The Quarterly Journal of Economics*, 126, 1–50.

Romer, C. D. and D. H. Romer (2004): "A new measure of monetary shocks: Derivation and implications," *American economic review*, 94, 1055–1084.

——— (2010): "The macroeconomic effects of tax changes: estimates based on a new measure of fiscal shocks," *American Economic Review*, 100, 763–801.

Sautner, Z., L. van Lent, G. Vilkov, and R. Zhang (2023): "Firm-Level Climate Change Exposure," *The Journal of Finance*, 78, 1449–1498.

Sims, C. A., J. H. Stock, and M. W. Watson (1990): "Inference in linear time series models with some unit roots," *Econometrica: Journal of the Econometric Society*, 113–144.

Smets, F. and R. Wouters (2007): "Shocks and frictions in US business cycles: A Bayesian DSGE approach," *American economic review*, 97, 586–606.

A Appendix - additional results

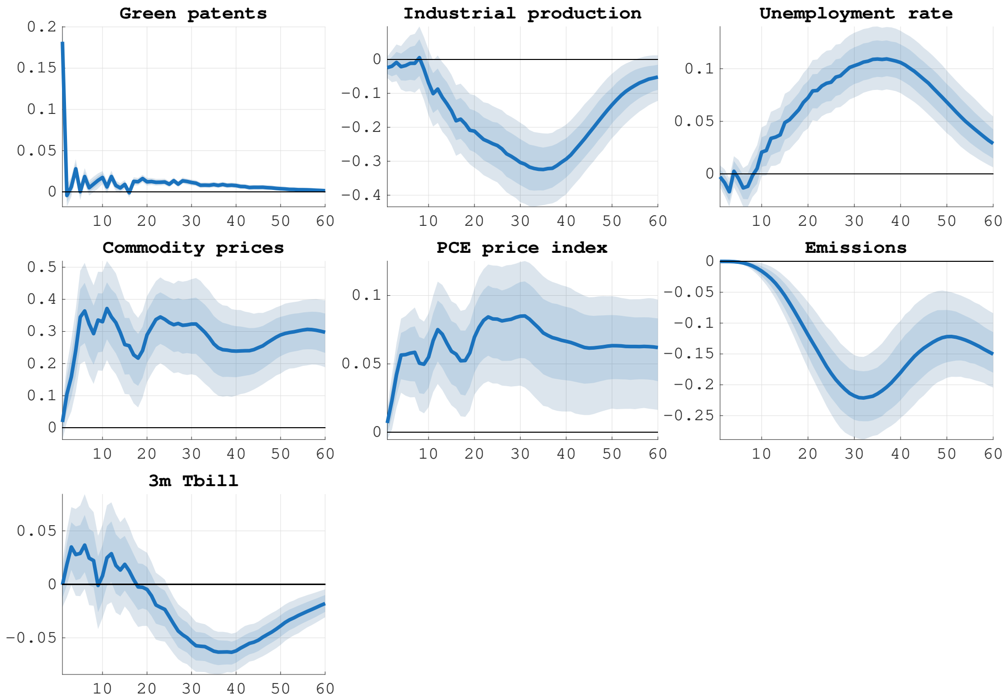

FIGURE A.1: *Monthly VAR: citations. Coefficients represent the IRF to a 1 standard deviation increase in a citation weighted measure of gp. Shaded areas denote 68% and 90% confidence bands; the horizon is monthly.*

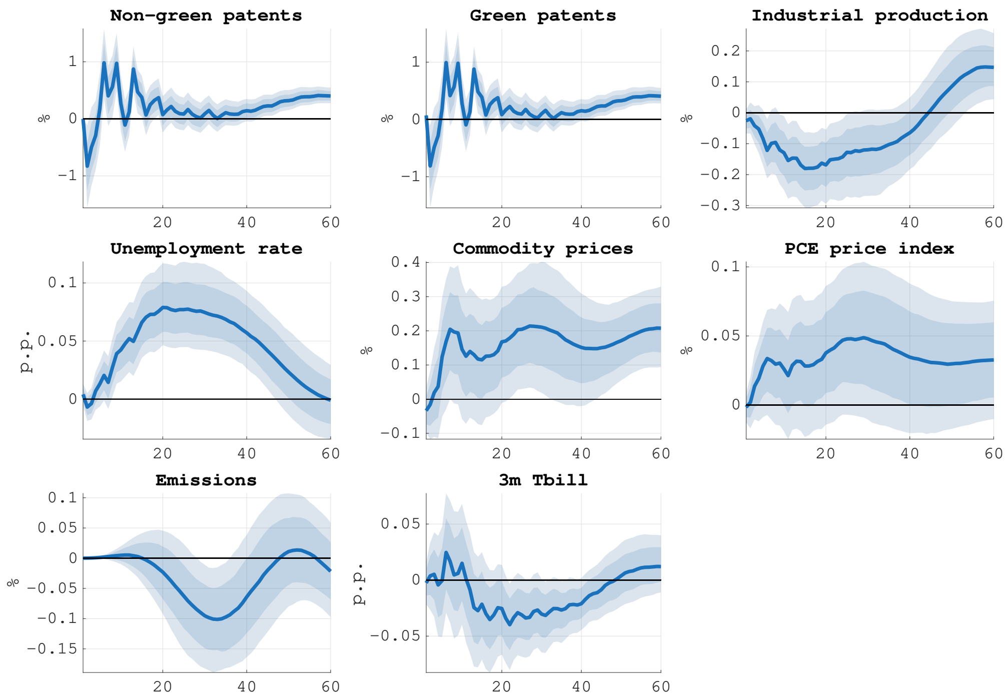

FIGURE A.2: *Monthly VAR: alternative identification strategy ordering the number of green patents second after the number of non green patents. Coefficients represent the IRF to a 1 standard deviation increase in the number of green patents.Shaded areas denote 68% and 90% confidence bands; the horizon is monthly.*

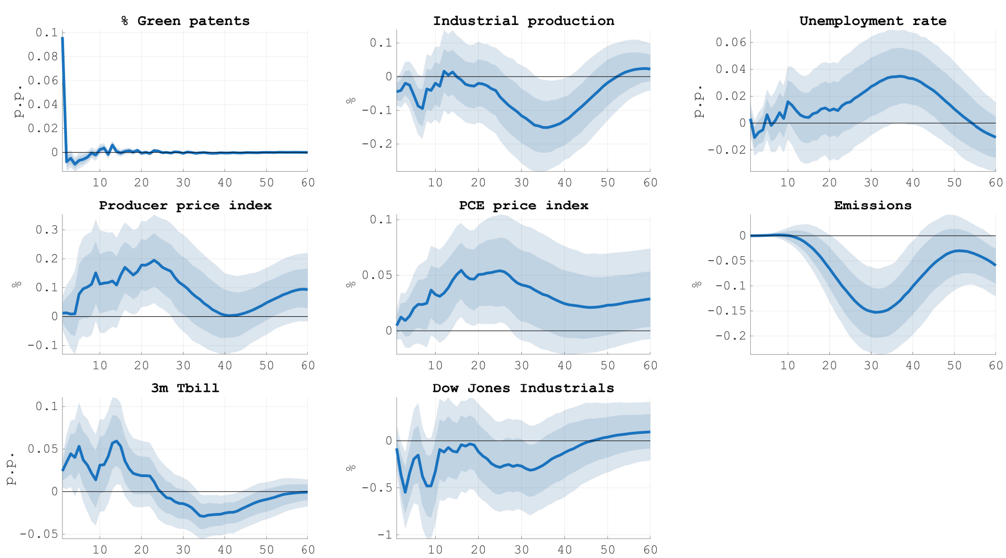

FIGURE A.3: *Monthly VAR: shocks to green patents - including stock prices. Coefficients represent the IRF to a 1 standard deviation increase in the raw number of green patents. Shaded areas denote 68% and 90% confidence bands; the horizon is monthly.*

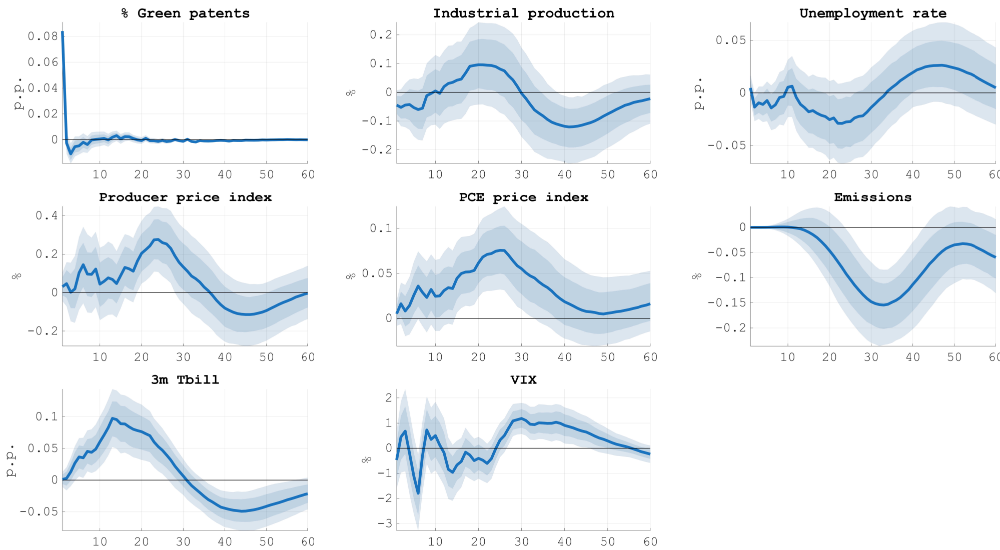

FIGURE A.4: *Monthly VAR: shocks to green patents - including VIX. Coefficients represent the IRF to a 1 standard deviation increase in the raw number of green patents. Shaded areas denote 68% and 90% confidence bands; the horizon is monthly.*

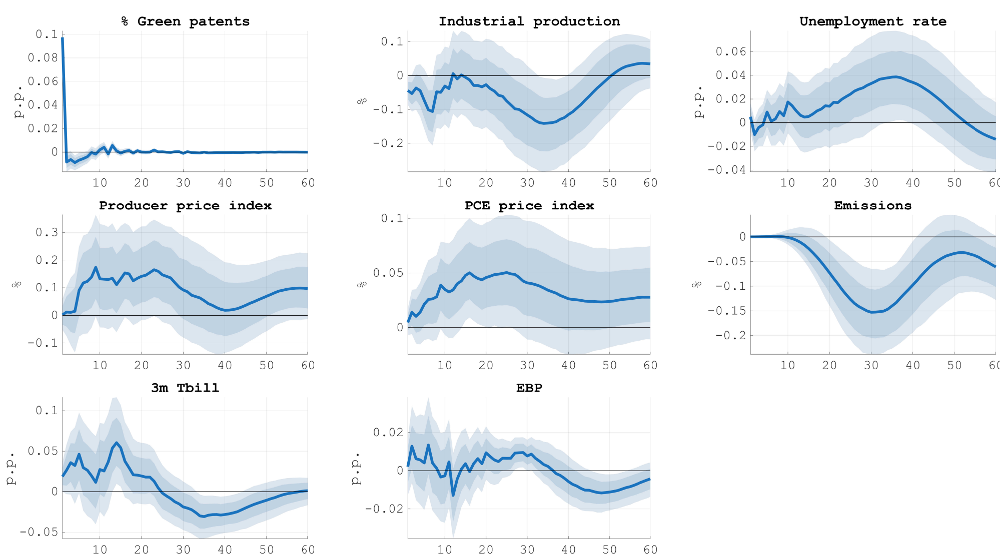

FIGURE A.5: *Monthly VAR: shocks to green patents - including EBP. Coefficients represent the IRF to a 1 standard deviation increase in the raw number of green patents. Shaded areas denote 68% and 90% confidence bands; the horizon is monthly.*

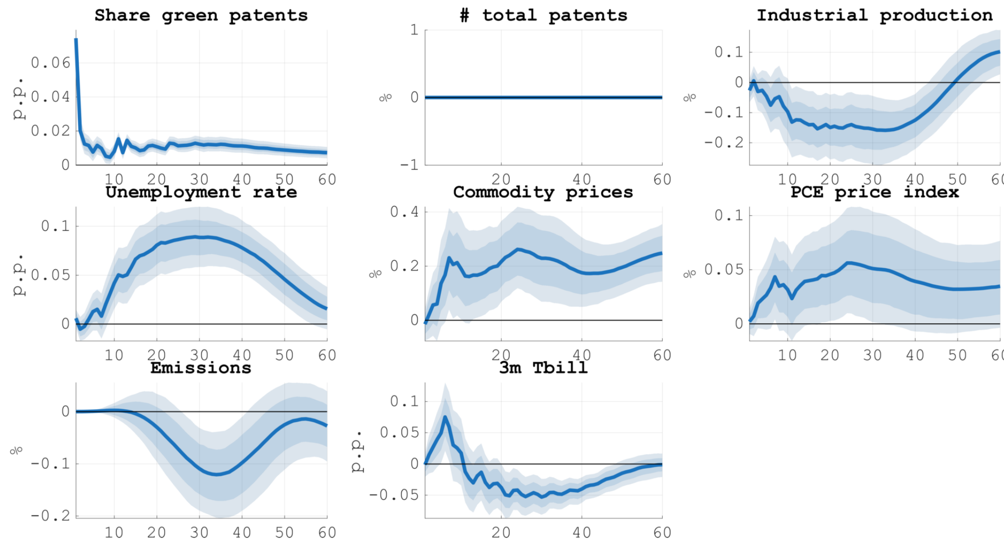

FIGURE A.6: *Monthly VAR: imposing no variations in the total number of parents. Coefficients represent the IRF to a 1 standard deviation increase in gp. Shaded areas denote 68% and 90% confidence bands; the horizon is monthly.*

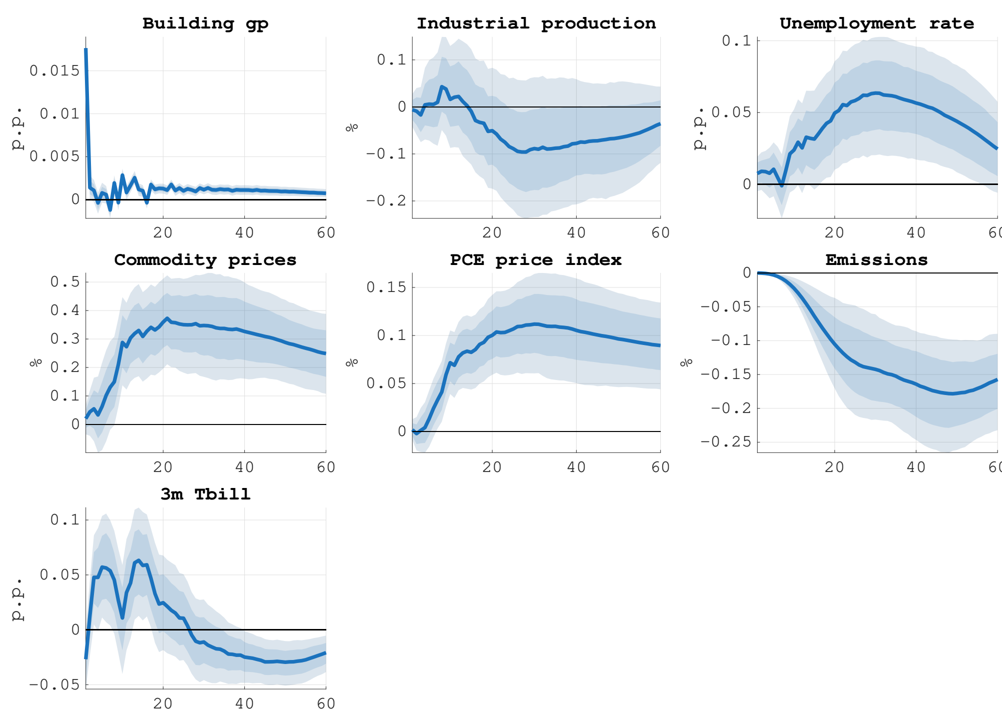

FIGURE A.7: *Monthly VAR: buildings. Coefficients represent the IRF to a 1 standard deviation increase in gp, limiting the analysis to green patents in the building sector. Shaded areas denote 68% and 90% confidence bands; the horizon is monthly.*

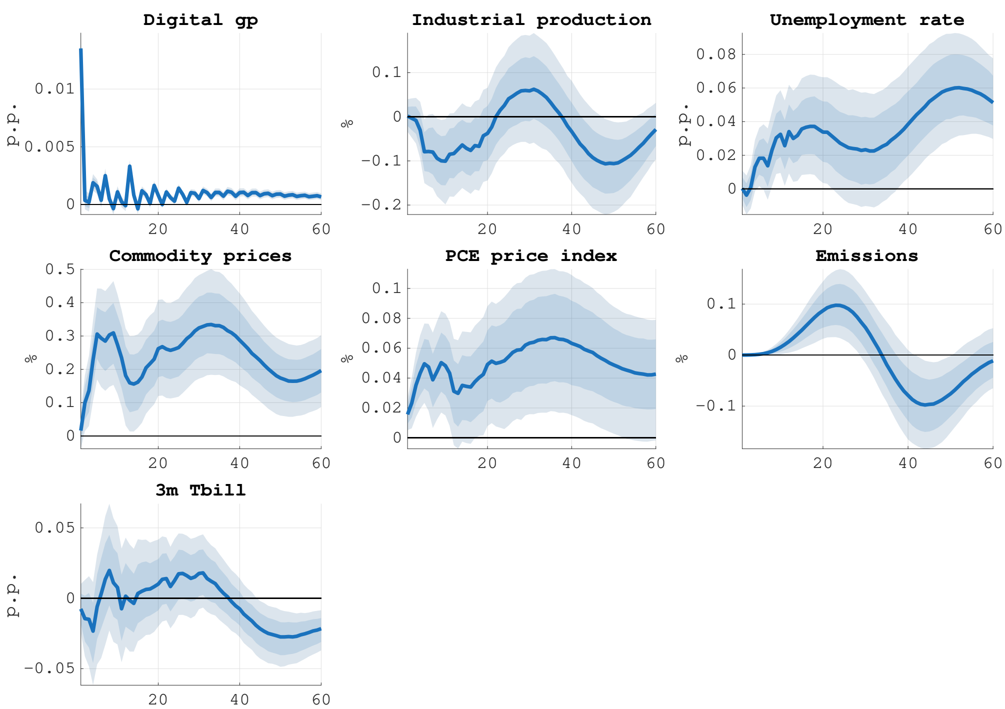

FIGURE A.8: *Monthly VAR: digital. Coefficients represent the IRF to a 1 standard deviation increase in gp, limiting the analysis to green patents in the digital sector. Shaded areas denote 68% and 90% confidence bands; the horizon is monthly.*

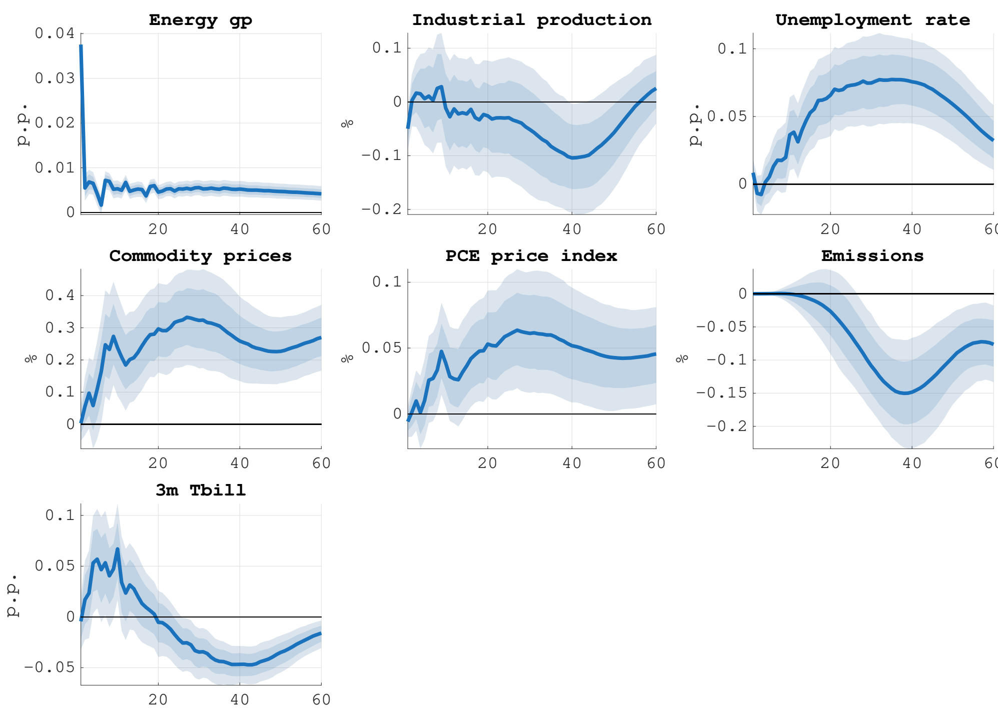

FIGURE A.9: *Monthly VAR: energy. Coefficients represent the IRF to a 1 standard deviation increase in gp, , limiting the analysis to green patents in the energy sector. Shaded areas denote 68% and 90% confidence bands; the horizon is monthly.*

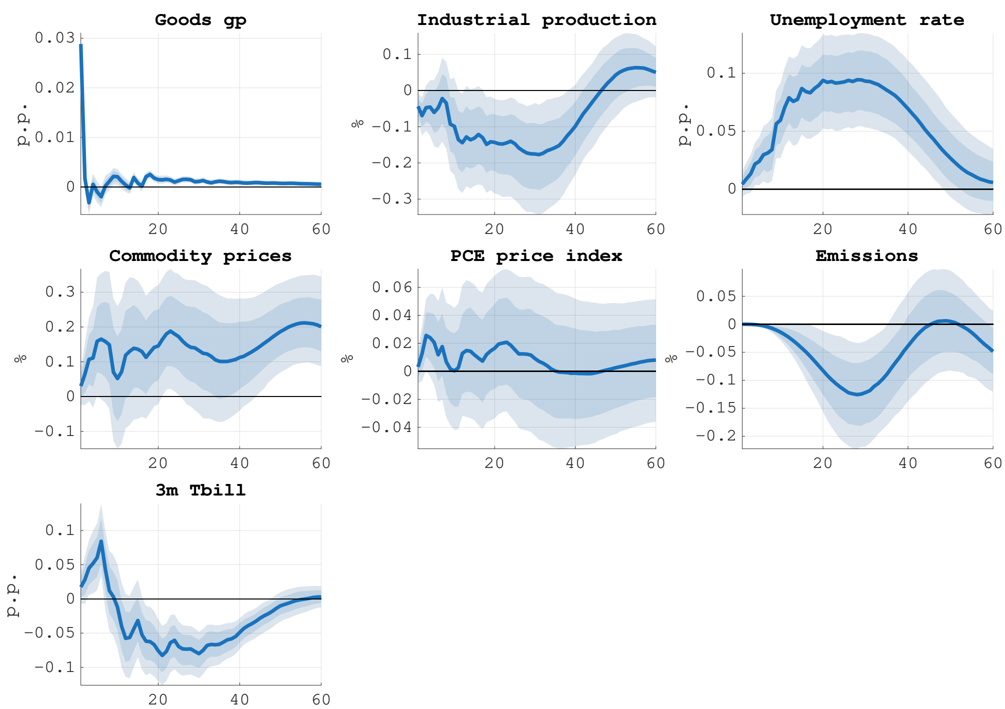

FIGURE A.10: *Monthly VAR: goods. Coefficients represent the IRF to a 1 standard deviation increase in gp, , limiting the analysis to green patents in the good sector. Shaded areas denote 68% and 90% confidence bands; the horizon is monthly.*

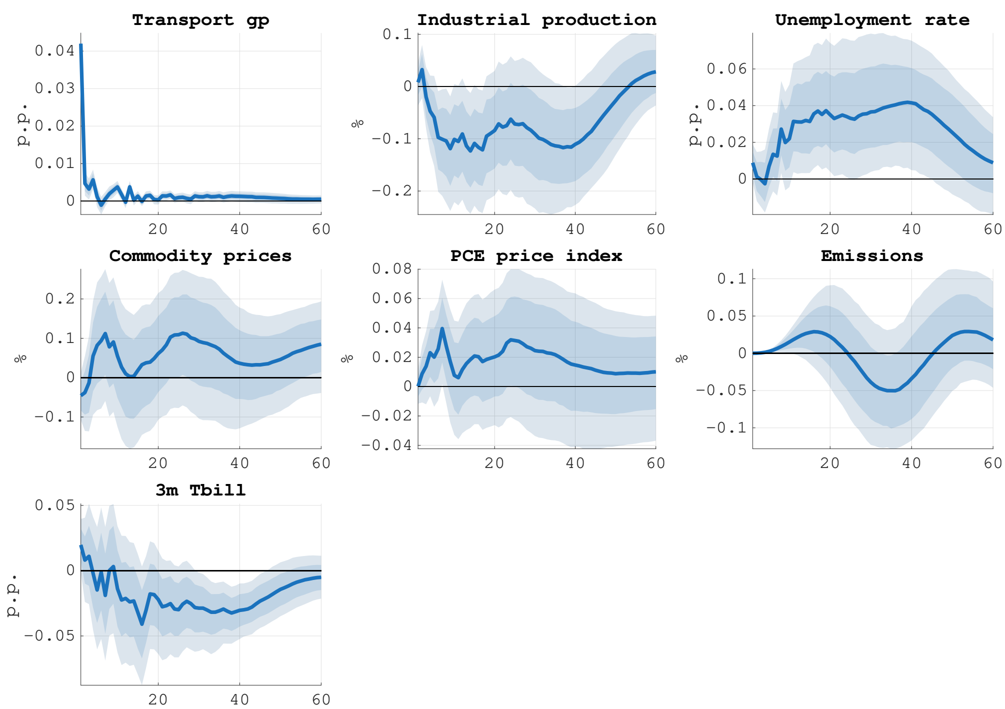

FIGURE A.11: *Monthly VAR: transport. Coefficients represent the IRF to a 1 standard deviation increase in gp, limiting the analysis to green patents in the transport sector. Shaded areas denote 68% and 90% confidence bands; the horizon is monthly.*

B Appendix - Green patents and equity returns

This Appendix presents the results of an event study exercise to demonstrate how an increase in firm value may serve as a driver of green innovation even in the absence of stringent regulatory requirements. More precisely, we focus on the equity response of firms issuing green patents. We rely on the firm-patent matching procedure developed by Arora et al. (2021a) and Arora et al. (2021b) to identify ISIN codes for firms issuing green patents. Consistent with our macro analysis, we study the impact of green innovation on corporate equity returns using a monthly panel from 1980 to 2019, employing the following specification:

$$R_{i,t} = \alpha_i + d_t + \beta R_{i,t-1} + \gamma \, \# \, green\ pat._{i,t-1} + \epsilon_{i,t} \tag{9}$$

where R is the monthly return of firm i in month t, and $greenpat$ is the key regressor of interest and measures the number of green patents that the firm has filed in the previous month. Results are displayed in Table B.1 and show that the filing of one additional green patent is associated with a 0.04 higher return in the following month. This finding is consistent with the evidence in Hege et al., 2023 suggesting that financial markets react to the signaling value of green patents, which may reflect a firm's enhanced commitment to climate action.

Variables	R_t
R_{t-1}	-0.149***
	(0.000)
$\#greenpat$	0.044**
	(0.048)
Obs.	724,211
R-squared	0.11
Time FE	YES
Firms FE	YES

Table B.1: Estimates of the impact of green patents on firms' monthly equity returns. Standard errors (in parentheses) clustered by time and firm. *, **, and *** denote significance at, respectively, the 10%, 5% and 1% level.

RECENTLY PUBLISHED "TEMI" (*)

N. 1457 – *The structural Theta method and its predictive performance in the M4-Competition*, by Giacomo Sbrana and Andrea Silvestrini (June 2024).

N. 1458 – *Mom's out: employment after childbirth and firm-level responses*, by Francesca Carta, Alessandra Casarico, Marta De Philippis and Salvatore Lattanzio (July 2024).

N. 1459 – *Mortgage lending and bank involvement in the insurance business: the effects of cross-selling*, by Federico Apicella, Leandro D'Aurizio, Raffaele Gallo and Giovanni Guazzarotti (July 2024).

N. 1460 – *The impact of macroeconomic and monetary policy shocks on the default risk of the euro-area corporate sector*, by Marco Lo Duca, Diego Moccero and Fabio Parlapiano (July 2024).

N. 1461 – *Geographic shareholder dispersion and mutual fund flow risk*, by Javier Gil-Bazo, Alexander Kempf and Raffaele Santioni (July 2024).

N. 1462 – *The allocation of public guaranteed loans to firms during Covid-19: credit risk and relationship lending*, by Emilia Bonaccorsi di Patti, Roberto Felici, Davide Moretti and Francesca Rinaldi (October 2024).

N. 1463 – *The distributional effects of carbon taxation in Italy*, by Francesco Caprioli and Giacomo Caracciolo (October 2024).

N. 1464 – *As soon as possible: the effectiveness of a financial education program in Italian schools*, by Tommaso Agasisti, Alessio D'Ignazio, Gabriele Iannotta, Angela Romagnoli and Marco Tonello (October 2024).

N. 1465 – *Climate supervisory shocks and bank lending: empirical evidence from microdata*, by Maria Alessia Aiello (October 2024).

N. 1466 – *The global transmission of U.S. monetary policy*, by Riccardo Degasperi, Seokki Simon Hong and Giovanni Ricco (October 2024).

N. 1467 – *The market externalities of tax evasion*, by Irene Di Marzio, Sauro Mocetti and Enrico Rubolino (October 2024).

N. 1468 – *Sanctions and Russian online prices*, by Jonathan Benchimol and Luigi Palumbo (October 2024).

N. 1469 – *Bank beliefs and firm lending: evidence from Italian loan-level data*, by Paolo Farroni and Jacopo Tozzo (November 2024).

N. 1470 – *The origins of the gender pay gap: education and job characteristics*, by Giulia Bovini, Marta De Philippis and Lucia Rizzica (November 2024).

N. 1471 – *Green granular borrowers*, by Margherita Bottero and Michele Cascarano (December 2024).

N. 1472 – *The macroeconomic effects of reducing a central bank monetary policy portfolio: a model-based evaluation*, by Anna Bartocci, Alessandro Notarpietro and Massimiliano Pisani (December 2024).

N. 1473 – *Partial identification of treatment response under complementarity and substitutability*, by Tiziano Arduini and Edoardo Rainone (December 2024).

N. 1474 – *Monetary policy shocks and inflation inequality*, by Christoph Lauper and Giacomo Mangiante (December 2024).

N. 1475 – *FraNK: fragmentation in the NK model*, by Alessandro Moro and Valerio Nispi Landi (December 2024).

N. 1476 – *Artificial intelligence and relationship lending*, by Leonardo Gambacorta, Fabiana Sabatini and Stefano Schiaffi (February 2025).

N. 1477 – *Business loan characteristics and inflation shocks transmission in the euro area*, by Valentina Michelangeli and Fabio Massimo Piersanti (February 2025).

N. 1478 – *Uncovering the inventory-business cycle nexus*, by Luca Rossi (February 2025).

(*) Requests for copies should be sent to:
Banca d'Italia – Servizio Studi di struttura economica e finanziaria – Divisione Biblioteca e Archivio storico – Via Nazionale, 91 – 00184 Rome – (fax 0039 06 47922059). They are available on the Internet www.bancaditalia.it.

2023

APRIGLIANO V., S. EMILIOZZI, G. GUAITOLI, A. LUCIANI, J. MARCUCCI and L. MONTEFORTE, *The power of text-based indicators in forecasting Italian economic activity,* International Journal of Forecasting, v. 39, 2, pp. 791-808, **WP 1321 (March 2021).**

BALTRUNAITE A., G. BOVINI and S. MOCETTI, *Managerial talent and managerial practices: are they complements?,* Journal of Corporate Finance, v. 79, Article 102348, **WP 1335 (April 2021).**

BARTOCCI A., A. NOTARPIETRO and M. PISANI, *Non-standard monetary policy measures in non-normal times,* International Finance, v. 26, 1, pp. 19-35, **WP 1251 (November 2019).**

CAPPELLETTI G. and P. E. MISTRULLI, *The role of credit lines and multiple lending in financial contagion and systemic events,* Journal of Financial Stability, v. 67, Article 101141, **WP 1123 (June 2017).**

CECI D. and A. SILVESTRINI, *Nowcasting the state of the Italian economy: the role of financial markets,* Journal of Forecasting, v. 42, 7, pp. 1569-1593, **WP 1362 (February 2022).**

CIAPANNA E, S. MOCETTI and A. NOTARPIETRO, *The macroeconomic effects of structural reforms: an empirical and model-based approach,* Economic Policy, v. 38, 114, pp. 243-285, **WP 1303 (November 2020).**

CORNELI F., *Sovereign debt maturity structure and its costs,* International Tax and Public Finance, v. 31, 1, pp. 262-297, **WP 1196 (November 2018).**

DAURICH D, S. DI ADDARIO and R. SAGGIO, *The macroeconomic effects of structural reforms: an empirical and model-based approach,* Review of Economic Studies, v. 90, 6, pp. 2880–2942, **WP 1390 (November 2022).**

DI ADDARIO S., P. KLINE, R. SAGGIO and M. SØLVSTEN, *The effects of partial employment protection reforms: evidence from Italy,* Journal of Econometrics,v. 233, 2, pp. 340-374, **WP 1374 (June 2022).**

FERRARI A. and V. NISPI LANDI, *Toward a green economy: the role of central bank's asset purchases,* International Journal of Central Banking, v. 19, 5, pp. 287-340, **WP 1358 (February 2022).**

FERRIANI F., *Issuing bonds during the Covid-19 pandemic: was there an ESG premium?,* International Review of Financial Analysis, v. 88, Article 102653, **WP 1392 (November 2022).**

GIORDANO C., *Revisiting the real exchange rate misalignment-economic growth nexus via the across-sector misallocation channel,* Review of International Economics, v. 31, 4, pp. 1329-1384, **WP 1385 (October 2022).**

GUGLIELMINETTI E., M. LOBERTO and A. MISTRETTA, *The impact of COVID-19 on the European short-term rental market,* Empirica, v. 50, 3, pp. 585-623, **WP 1379 (July 2022).**

LILLA F., *Volatility bursts: a discrete-time option model with multiple volatility components,* Journal of Financial Econometrics, v. 21, 3, pp. 678-713, **WP 1336 (June 2021).**

LOBERTO M., *Foreclosures and house prices,* Italian Economic Journal / Rivista italiana degli economisti, v. 9, 1, pp. 397-424, **WP 1325 (March 2021).**

LOMBARDI M. J., M. RIGGI and E. VIVIANO, *Worker's bargaining power and the Phillips curve: a micro-macro analysis, and wages,* Journal of the European Economic Association, v. 21, 5, pp. 1905–1943, **WP 1302 (November 2020).**

MODENA F., S. PEREDA-FERNANDEZ and G. M. TANZI, *On the design of grant assignment rules,* Politica economica/Journal of Economic Policy, v. 1/2023, pp. 3-40, **WP 1307 (December 2020).**

NERI S., *Long-term inflation expectations and monetary policy in the Euro Area before the pandemic*, European Economic Review, v. 154, Article 104426, **WP 1357 (December 2021).**

ORAME A., *Bank lending and the European debt crisis: evidence from a new survey*, International Journal of Central Banking, v. 19, 1, pp. 243-300, **WP 1279 (June 2020).**

RIZZICA L., G. ROMA and G. ROVIGATTI, *The effects of shop opening hours deregulation: evidence from Italy,* The Journal of Law and Economics, v. 66, 1, pp. 21-52, **WP 1281 (June 2020).**

TANZI G. M., *Scars of youth non-employment and labour market conditions,* Italian Economic Journal / Rivista italiana degli economisti, v. 9, 2, pp. 475-499, **WP 1312 (December 2020).**

2024

BALTRUNAITE A. and E. KARMAZIENE, *Fast tracks to boardrooms: director supply and board appointments,* Journal of Corporate Finance, v. 88, Article 102642, **WP 1278 (June 2020).**

BARTOCCI A., A. CANTELMO, P. COVA, A. NOTARPIETRO and M. PISANI, *Monetary and fiscal policy responses to fossil fuel price shocks,* Energy Economics, v. 136, Article 107737, **WP 1431 (December 2023).**

BENCHIMOL J. and L. PALUMBO, *Sanctions and Russian Online Prices,* Journal of Economic Behavior & Organization, v. 225, pp. 483-521, **WP 1468 (October 2024).**

BRANZOLI N., R. GALLO, A. ILARI and D. PORTIOLI, *Central banks' corporate asset purchase programmes and risk-taking by bond funds in the aftermath of market stress,* Journal of Financial Stability, v. 72, Article 101261, **WP 1404 (March 2023).**

BRANZOLI N., E. RAINONE and I. SUPINO, *The role of banks' technology adoption in credit markets during the pandemic,* Journal of Financial Stability, v. 71, Article 101230, **WP 1406 (March 2023).**

BUONO I, F. CORNELI and E. DI STEFANO, *Capital inflows to emerging countries and their sensitivity to the global financial cycle,* International Finance, v. 27,2, pp. 17-34, **WP 1262 (February 2020).**

CANTELMO A., N. FATOUROS, G. MELINA and C. PAPAGEORGIOU, *Monetary policy under natural disaster shocks,* International Economic Review, v.65, 3, pp. 1441-1497, **WP 1443 (March 2024).**

DEL PRETE S, G. PAPINI and M. TONELLO, *Gender quotas, board diversity and spillover effects. Evidence from Italian banks,* Journal of Economic Behavior & Organization, v. 221, pp. 148-173, **WP 1395 (December 2022).**

DE MARCHI R. and A. MORO, *Forecasting fiscal crises in emerging markets and low-income countries with machine learning models,* Open Economies Review. v. 35, 1, pp. 189-213, **WP 1405 (March 2023).**

FERRARI A. and V. NISPI LANDI, *Whatever it takes to save the planet? Central banks and unconventional green policy,* Macroeconomic Dynamics, v. 28, 2, pp. 299-324, **WP 1320 (February 2021).**

FLACCADORO M., *Exchange rate pass-through in small, open, commodity-exporting economies: lessons from Canada,* Journal of International Economics, v. 148, Article 103885, **WP 1368 (May 2022).**

GAUTIER E., C. CONFLITTI, R. FABER, B. FABO, L. FADEJEVA, V. JOUVANCEAU, J.-O. MENZ, T. MESSNER, P. PETROULAS, P. ROLDAN-BLANCO, F. RUMLER, S. SANTORO, E. WIELAND and H. ZIMMER, *New facts on consumer price rigidity in the euro area,* American Economic Journal: Macroeconomics, v. 16, 4, pp. 386-431, **WP 1375 (July 2022).**

LATTANZIO S., *Schools and the transmission of Sars-Cov-2: evidence from Italy,* Economics & Human Biology, v. 52, Article 101342, **WP 1453 (February 2023).**

MORO A. and V. NISPI LANDI, *The external financial spillovers of CBDCs,* Journal of Economic Dynamics and Control, v. 159, Article 104801, **WP 1416 (July 2023).**

PORRECA E. and A. ROSOLIA, *Immigration and unemployment. Do natives get it right?,* Journal of Economic Behavior & Organization, v. 225, pp. 522–540, **WP 1273 (April 2020).**

RAINONE E., *Real-time identification and high frequency analysis of deposits outflows,* Journal of Financial Econometrics, v. 22, 4, pp. 868–907, **WP 1319 (December 2017).**

ROSOLIA A., *Do firms act on their inflation expectations? Another look at Italian firms,* Journal of Political Economy Macroeconomics, v. 2, 4, pp. 651-686, **WP 1353 (October 2021).**

ZAGHINI A., *Unconventional Green,* Journal of Corporate Finance, v. 85, Article 102556, **WP 1453 (April 2024).**

2025

BERNARDINI M. and A. DE NICOLA, *The market stabilization role of central bank asset purchases: high-frequency evidence from the COVID-19 crisis,* Journal of International Money and Finance, v. 152, Article 103257, **WP 1310 (December 2020).**

LOSCHIAVO D., F. TULLIO and A. DI SALVATORE, *Measuring households' financial fragilities: an analysis at the intersection of income, financial wealth, and debt,* Review of Income and Wealth, v. 71, 1, e12691, **WP 1452 (April 2024).**

MISTRETTA A., *Synchronization vs transmission: the effect of the German slowdown on the Italian business cycle,* International Journal of Central Banking, v. 21, 1, pp. 331-386, **WP 1346 (October 2021).**

FORTHCOMING

BALTRUNAITE A., M. CANNELLA, S. MOCETTI and G. ROMA, *Board composition and performance of state-owned enterprises: quasi experimental evidence,* The Journal of Law, Economics, and Organization, **WP 1328 (April 2021).**

BENVENUTI M. and S. DEL PRETE, *The evolution of banking competition in italian credit markets using a profit elasticity approach,* Italian Economic Journal / Rivista italiana degli economisti, **WP 1237 (October 2019).**

BOTTERO M. and S. SCHIAFFI, *Firm liquidity and the transmission of monetary policy,* International Journal of Central Banking, **WP 1378 (July 2022).**

CIANI E., A. GROMPONE and E. OLIVIERI, *Jobs for the long-term unemployed: place-based policies in depressed areas,* Italian Economic Journal / Rivista italiana degli economisti, **WP 1249 (November 2019).**

CUCINIELLO V. and N. DI IASIO, *Determinants of the credit cycle: a flow analysis of the extensive margin,* Journal of Money, Credit and Banking, **WP 1266 (March 2020).**

CUCINIELLO V., C. MICHELACCI and L. PACIELLO, *Subsidizing business entry in competitive credit markets,* Journal of Political Economy, **WP 1424 (October 2023).**

DESTEFANIS S. and V. DI GIACINTO, *The heterogeneous effects of EU structural funds: a spatial VAR approach,* Journal of Regional Science, **WP 1409 (April 2023).**

FLACCADORO M., *Exchange rate pass-through in small, open, commodity-exporting economies: lessons from Canada,* Journal of International Economics, **WP 1365 (April 2022).**

FRATTOLA E., *Parental retirement and fertility decisions across family policy regimes,* Review of Economics of the Household, **WP 1417 (July 2023).**

GNOCATO N., *Energy price shocks, unemployment, and monetary policy,* Journal of Monetary Economics, **WP 1450 (March 2024).**

MICHELANGELI V. and E. VIVIANO, *Can internet banking affect households' participation in financial markets and financial awarness?,* Journal of Money, Credit and Banking, **WP 1329 (April 2021).**

MORO A., *Optimal policies in a small open economy with an environmental externality and shallow foreign exchange markets,* Portuguese Economic Journal, **WP 1348 (October 2021).**

RAINONE E., *Reservation rates in interbank money markets,* Journal of Money, Credit and Banking, **WP 1160 (February 2021).**

ROPELE T., Y. GORODNICHENKO and O. COIBION, *Inflation expectations and misallocation of resources: evidence from Italy,* American Economic Review: Insights, **WP 1437 (December 2023).**