WORKING PAPER | ISSUE 18/2023 | 23 OCTOBER 202

RECESSIONS, THE ENERG MIX AND ENVIRONMENTAL POLICY

PRAGYAN DEB, DAVIDE FURCERI, JONATHAN D. OSTRY AND NOUR TAWK

How do severe recessions, such as those brought about by the Global Financial Crisis or the COVID-19 pandemic, a ect the composition of energy generation between green and dirty sources? Does creative destruction during recessions result in a sustained greening of the energy mix? e empirical analysis presented in this paper highlights that recesecese Td [(l)-3 H (ior)15 (es)3 gs.619 0 T (er hi)9 (in)4m01 (i4c)1 (h ase)-2.69 (Tf -Z.n0[(eE)y[(

bruegel

1 Introduction

This paper

The rem

Turning to the green energy sector, Peters *et al* (2012) found that when crises were triggered by energy shocks such as the 1970s and 1980s oil crises, they contributed to major improvements in the production of renewable sources of energy and energy efficiency. While this finding is not surprising, as the increase in the cost of fossil fuels would naturally boost energy efficiency and substitution toward renewables, they also argued that in times of crisis, countries tend to sustain economic output by supporting less energy-intensive activities.

The Global Financial Crisis also was associated with a significant increase in renewables (see UNEP, 2009; IEA, 2020). For example, 2016 – from Furceri *et al* (2022). Third, instead of focusing just on periods of negative growth, we identify peaks and troughs, and thus peak-to-trough slowdowns, in economic activity using the Harding-Pagan algorithm applied to both annual real GDP and annual *per-capita* GDP. Finally, we test our results using changes in (log) GDP as opposed to negative-growth events.

The various economic data needed for our analysis is taken from the IMF's *World Economic Outlook* database, the World Bank's World Development Indicators and the Penn World tables. Environmental policy variables are taken from the EPS index dataset of the OECD (Botta and Kozluk, 2014). This data is the most comprehensive available source for policy measures across countries (28 OECD countries and a few large emerging market economies) and time (1990-2015). The dataset helpfully provides a breakdown by instrument type: (i) market-based measures, which include instruments such as taxation of emissions, trading schemes and feed-in tariffs; and (ii) non-market-based measures, including emission limits and R&D subsidies. The EPS varies from 0 (not stringent at all) to 6 (very stringent). Not surprisingly, the stringency of EPS is corelated with higher renewable shares in electricity generation and lower use of fossil fuels. In addition, EPS is strongly correlated with income levels, with more developed economies having higher environmental protection standards, on average.

To estimate the dynamic effects of recessions on energy use and mix, we use the local projection methods proposed by Jordà (2005) and estimate impulse response functions directly from local projections. Compared to the more traditional Vector Auto-Regression (VAR) approach, local projections allow for more flexible structural impulse response estimations by imposing weaker assumptions on the dynamics of the data. As a result, impulse responses from local projections have a lower bias than VARs (see Barnichon and Brownlees, 2019; and Li *et al*, 2022). Compared to VARs, the local projection method is also .(s)1 (w)sofhe[7w)g-]Jy ui subsamples by income group – that is, advanced economies and emerging market and developing economies.

We do not include time dummies in our baseline specification because several major growth slowdown episodes and crises – including COVID-19 and the global financial crisis – are global in nature and time fixed effects would absorb their impact, which we want to explicitly capture. However, our baseline results are robust when we include both time dummies and a country-specific time PNAJ@Ü to capture trends in energy use or the share of renewables, as well as fluctuations in global fuel prices.

We use the smooth transition autoregressive model developed by Granger and Terävistra (1993) to test whether the effect of recessions on the share of renewables varies across different environmental policy regimes. This method allows the effect of recessions to vary smoothly across regimes by considering a continuum of states, thus making the IRFs more stable and precise than those obtained by estimating responses for each regime. Specifically, we estimate:

¿AÜ

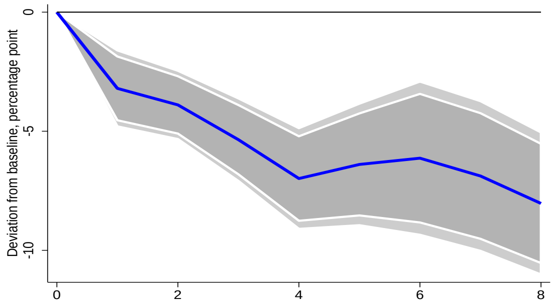
Figure 1: Impact of recessions on energy use

Note: Impulse response functions are estimated using a sample of 176 countries over the period 1965–2021 using equation (1). The graph shows the response and 95 and 90 percent confidence bands. The x-axis shows years after the event, with t=0 is the year of the recession.

Note: Impulse response functions are estimated using a sample of 176 countries over the period 1965–2021 using equation (1). The graph shows the response and

Figure 3: Changes in energy mix after recession

Figure 6: Energy mix in response to various types of economic slowdown



Note: Impulse response functions are estimated using a sample of 172 countries over the period 1985–2021 using equation (1). The graph shows the response and 95 and 90 percent confidence bands. The x-axis shows years after the event, with t=0 is the year of the recession.

Note: Impulse response functions are estimated using a sample of 172 countries over the period 1985–2021 using equation (1). The graph shows the response and 95 and 90 percent confidence bands. The x-axis shows years after the event, with t=0 is the year of the recession.

Note: Impulse response functions are estimated using a sample of 172 countries over the period 1985–2021 using equation (1). The graph shows the response and 95 and 90 percent confidence bands. The x-axis shows years after the event, with t=0 is the year of the recession.

Note: Impulse response functions are estimated using a sample of 172 countries over the period 1985–2021 using equation (1). The graph shows the response and 95 and 90 percent confidence bands. The x-axis shows years after the event, with t=0 is the year of the recession.

Note: Impulse response functions are estimated using a sample of 172 countries over the period 1985–2021 using equation (1). The graph shows the response and 95 and 90 percent confidence bands to changes in GDP growth (inverted).

Note: Impulse response functions are estimated using a sample of 172 countries over the period 1985–2021 using equation (1). The graph shows the response and 95 and 90 percent confidence bands to changes in GDP growth (inverted).

possible explanation for these results is that most EMDEs lack the resources to make the costly investments in renewables-based energy and also have less stringent environmental-protection regulations, factors that can retard the use of greener sources of energy.

To formally test this point, we examine how the response of the share of renewable energy to recessions varies with the EPS index[4]. As noted earlier, comprehensive cross-country data on environmental-policy variables is only available for a limited set of relatively advanced economies and over a shorter period. We therefore begin our analysis by confirming that our baseline results hold for this more limited time sample: they do. Next, we introduce the environmental-policy variables into our baseline specification. In line with the literature highlighting the role of environmental policy stringency in accelerating environmental innovation (Ahmed, 2020; Hassan and Rousselière, 2021), Table 1 shows that both the overall EPS index and market and non-market EPS components are associated with a higher share of renewables in total electricity. In addition, the impact increases over time. In particular, we find that a unitary increase in the EPS indicator (such as took place in the United Kingdom in 2010 when various climate change policies were strengthened, including the introduction of feed-in-tariffs and inflation indexing of the CCL) is associated with a 3-5 percentage points boost in the share of renewable energy. This result has important implications as it suggests that climate polices can be effective in fostering the transition to a greener economy.

Next, we use the smooth transition autoregressive model in Equation 2 to assess formally the impact of EPS on the energy mix after a recession. Our headline result, shown in Figure 7, confirms that overall environmental protection stringency (EPS) can boost the transition towards renewable energy, with high EPS associated with an increase in the share of renewables in total electricity after a recession, while the effect is not statistically significantly different from zero in regimes with low levels of EPS. While on average, we find that a recession is associated with a 2 percentage points increase in the share of renewables, countries with high EPS see a much larger increase – essentially double at around 4 percentage points.

Digging deeper, we look at both market and non-market-based EPS. Market-based EPS measures comprise taxes on pollutants, trading schemes such as carbon trading, energy savings certificates and green energy certificates, and feed-in-tariffs for renewables. In contrast, non-market-based EPS include emission and fuel standards and R&D incentives and investments, including public investment (see Botta and Kozluk, 2014). We find that both market and non-market EPSs are associated with an increase in the share of renewables after a recession (Figure 8). These results are confirmed by looking more narrowly at specific measures (Figure 9). Higher emission and fuel standards are associated with a larger shift towards renewables after recessions. Particularly relevant for renewable electricity generation are feed-in-tariffs and trading schemes such as green certificates and white certificates[5].

Figure 8: Impact on post-recession energy mix by type of EPS: market vs non-market measures

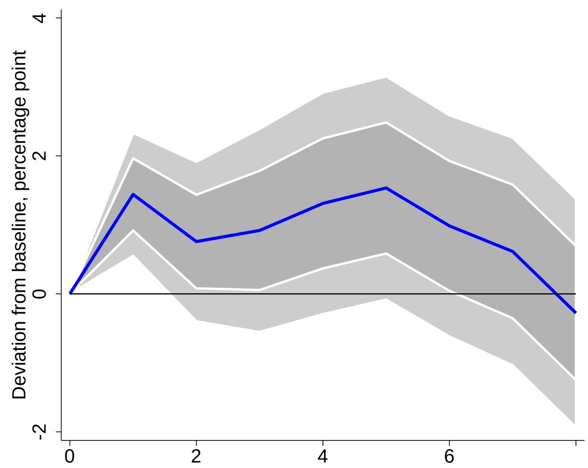
Figure 9: Post-recession energy mix by type of EPS: Standards, feed-in-tariffs, and trading schemes

Note: Impulse response functions are estimated using a sample of 33 countries over the period 1985–2021 using equation (2). The graph shows the response and 95 and 90 percent confidence bands. The left panel denotes the low "regime" wh

(((V)) N ue 3l(w)-(0T 0.04257.689 -0-01278 rg /.2 (e257.689 -t0.58 rg6xi.9 e2.9 (6.7)0.9.9 e2.9 xt<FEF 4 (a)0.9 (p)-2.9 (y-3 (e.58 rg6.5 (h)2 (p)-2.9 (.58 rg6fa)0.9 (a)0.9 (.5 (h)

((V

Figure 10: Impact on post-recession energy mix; role of world energy prices



Note: Impulse response functions are estimated using a sample of 172 countries over the period 1985–2021 using equation (2). The graph shows the response and 95 and 90 percent confidence bands. The left panel denotes the low "regime" when ((V) N1 and the right panel denotes the high `regime; when (1 F ((V)) N1. The x-axis shows years after the event, with t=0 is the year of the recession.

Table 2: Summary statistics

VARIABLE	Period		Full Sample			AEs			EMDEs			Unit	Source
	Start	End	Observations	Mean	Standard Deviation	Observations	Mean	Standard Deviation	Observations	Mean	Standard Deviation		
Energy Data													
Primary Energy	1965	2021	6,895	4.17	2.48	1,707	5.91	1.85	5,188	3.60	2.39	Terawatt-hours, logs	Our World in Data
Coal	1965	2021	3,244	3.34	2.79	1,607	3.70	2.57	1,637	2.99	2.95	Terawatt-hours, logs	Our World in Data
Oil	1965	2021	3,541	5.18	1.43	1,633	5.33	1.59	1,908	5.05	1.26	Terawatt-hours, logs	Our World in Data
Electricity	1985	2021	4,464	2.57	2.50	1,212	4.07	1.87	3,252	2.01	2.47	Terawatt-hours, logs	Our World in Data
Electricity share from													
Fossil Fuels	1985	2021	3,966	62.6%	33%	1,015	55.3%	32%	2,951	65.1%	33%	Percent	Our World in Data
Renewables	1985	2021	4,365	31.8%	33%	1,156	28.7%	30%	3,209	33.0%	33%	Percent	Our World in Data
Solar	1985	2021	4,365	0.5%	2%	1,156	0.7%	2%	3,209	0.4%	2%	Percent	Our World in Data
Wind	1985	2021	4,365	1.2%	4%	1,156	2.9%	7%	3,209	0.6%	2%	Percent	Our World in Data
Hydro	1985	2021	4,365	27.4%	31%	1,156	21.7%	29%	3,209	29.4%	32%	Percent	Our World in Data
Nuclear	1985	2021	4,365	5.5%	14%	1,156	15.7%	21%	3,209	1.8%	8%	Percent	Our World in Data
Shocks													
Recession	1965	2021	6,895	0.15	0.36	1,707	0.12	0.32	5,188	0.16	0.37	Dummy variable	IMF WEO
Financial Crisis	1965	2021	6,757	0.05	0.22	1,638	0.03	0.17	5,119	0.06	0.24	Dummy variable	Laeven and Valencia, 202
Pandemics	1965	2021	6,391	0.15	0.91	1,565	0.16	1.04	4,826	0.15	0.86	Cases/population	Furceri et al, 2020
Peak to trough	1965	2021	6,895	0.24	0.43	1,707	0.21	0.41	5,188	0.26	0.44	Dummy variable	IMF WEO
Peak to trough, per capita	1965	2021	6,895	0.38	0.49	1,707	0.28	0.45	5,188	0.42	0.49	Dummy variable	IMF WEO
GDP growth	1980	2021	5,983	3.3%	6%	1,328	2.7%	3%	4,655	3.5%	6%	Percent	Penn Tables

Buechler, E., S. Powell, T. Sun, C. Zanocco, N. Astier, J. Bolorinos ... R. Rajagopal (2020) 'Power and the pandemic: exploring global changes in electricity demand during COVID-19', arXiv preprint arXiv:2008.06988

Caballero, R.J. and M.L. Hammour (1994) 'The Cleansing Effect of Recessions', *American Economic Review*, *American Economic Association* 84(5): 1350-1368.

Davis, S.J. and J. Haltiwanger (1990) 'Gross job creation and destruction: Microeconomic evidence and macroeconomic implications', *NBER Macroeconomics Annual* 5: 123-168

Furceri, D., P. Loungani, J. Ostry and P. Pizzuto (2022) 'Will Covid-19 have long-lasting effects on inequality? Evidence from past pandemics', *Journal of Economic Inequality* 20(4): 811-839

Gali, J. and J.L. Hammour (1992) 'Long run effects of business cycles', *Papers* 92-26, Columbia - Graduate School of Business

Granger, C.W.J. and T. Teräsvirta (1993) *Modelling Nonlinear Economic Relationships*, Oxford University Press

Grossman, G.M. and E Helpman (1991)

Li, D., M. Plagborg-Møller and C.K. Wolf (2022) 'Local projections vs. vars: Lessons from thousands of DGPs', *Working Paper* 30207, National Bureau of Economic Research

Martin, R. and U. Wagner (2009) 'Survey of firms' responses to public incentives for energy innovation, including the UK Climate Change Levy and Climate Change Agreements', *Contribution to the OECD project on Taxation, Innovation and the Environment,* COM/ENV/EPOC/CTPA/CFA, vol 34

Martin, R., U. Wagner and L.B. de Preux (2011) 'The impacts of the Climate Change Levy on business: evidence from microdata', *Working Paper* 17446, National Bureau of Economic Research

Montiel Olea, J.L. and M. Plagborg-Møller (2021) 'Local projection inference is simpler and more robust than you think', *Econometrica* 89(4): 1789-1823

OECD (2010) *Taxation, innovation and the environment*,' Organisation for Economic Co-operation and Development

Pardo, G.P. (2016) 'Productivity in Europe during the Great Recession: Any evidence for creative destruction?' *European Journal of Government and Economics* 5(2): 82-103

Pesaran, M.H. and T. Yamagata (2008) 'Testing slope homogeneity in large panels', *Journal of Econometrics* 142(1): 50-93

Peters, G.P., G. Marland, C. Le Quéré, T. Boden, J.G. Canadell and M.R. Raupach (2012) 'Rapid growth in CO 2 emissions after the 2008–2009 global financial crisis', *Nature Climate Change* 2(1) BDC /MC9466anc Na

Stern, D.I. (