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Effects of Carbon Pricing on Inflation

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Abstract

We study how carbon pricing has affected inflation ex-post, using dynamic panel estimation of New-Keynesian Phillips curves for 35 OECD economies from 1995 to 2020. As carbon pricing we consider prices of emissions trading systems (ETS) and carbon taxes. We find that an increase in prices of ETS by \$10 per ton of CO₂ equivalents increases energy CPI inflation by 0.8 percentage points (pp), and headline inflation by 0.08pp, but has no significant effects on food and core CPI inflation. We also find that an increase in carbon taxes by \$10 per ton of CO₂ equivalents increases food CPI inflation by 0.1pp, but has no significant effects on energy CPI inflation, headline and core CPI inflation.

JEL-Codes: E310, E520, E580, Q480, Q580.

Keywords: climate policies, carbon tax, carbon emission trading system, climate change, inflation.

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1. Introduction

We study how carbon pricing has affected consumer price inflation ex-post, using dynamic panel estimation of New-Keynesian Phillips curves across countries for 35 OECD economies from 1995 to 2020. As carbon pricing we consider carbon taxes and prices of emissions trading systems (ETS).

Carbon dioxide (CO₂) emissions are a key driver of global warming and climate change, and have continued to increase globally in recent years. With current climate policies, standard climate change models predict an increase of 3°C in global temperatures compared with pre-industrial levels by the end of the century (IPCC, 2014). Climate policies therefore need to be enhanced in order to reduce CO₂ emissions (Stern, 2008). To limit an overshoot of the goal of the Paris agreement of 1.5°C global warming above pre-industrial levels, global net anthropogenic CO₂ emissions need to decline by about 45% from their 2010 level by 2030, reaching net zero around 2050; however, total global greenhouse gas emission in 2030 are expected to be 16% above their 2010 level (United Nations, 2021). Carbon pricing can be an effective policy to reduce carbon dioxide emissions (Kohlscheen et al., 2021). Higher carbon prices make low-carbon energy more competitive, provide incentives to reduce emissions, and reduce demand for carbon-intensive fuels (OECD, 2021; Martin et al., 2016).

Climate change and climate policy are likely to affect inflation and the monetary policy transmission mechanism, and are therefore relevant for monetary policy (Smets, 2020; NGFS, 2020). Carbon pricing could lead to higher inflation via market-based emissions trading or new taxes on high carbon emissions, in particular from fossil fuels (Andersson et al., 2020; Batten et al., 2020). But such higher inflationary pressure could be more than offset by further innovation in renewable energy in response to carbon pricing, leading to lower electricity prices and increased energy efficiency, which could also reduce the weight of energy in the CPI consumption basket (Andersson et al., 2020). A shift in consumer preferences in response to carbon pricing towards climate-friendly products and services, which enter the CPI consumption basket when the consumer basket weights are updated, can also contribute to lower inflation (NGFS, 2020). The overall effect of carbon pricing on inflation is therefore unclear, and is an empirical question, on which there have been surprisingly few studies. Most of the research on the effects of climate change and climate policy on macroeconomic variables so far has focussed on the effects on growth.¹

Monetary policy makers have discussed possible effects of climate policies on inflation. For example, ECB Governing Council member Schnabel (2021) mentioned that the direction of the effect of climate change on inflation was unclear; carbon prices could increase prices, but prices for sustainable energy sources could decline if more efficient technologies were developed, so that it could become cheaper to generate electricity from renewable energy sources. Climate change has been considered within the ECB's monetary policy strategy review (Eurosysteem work stream on climate change, 2021; Smets, 2020; ECB, 2021). Following the conclusion of this monetary policy strategy review, the ECB Governing Council stated its strong commitment to further incorporating climate change considerations into its monetary policy framework (ECB, 2021). The ECB Governing Council also decided to conduct theoretical and empirical analyses on

¹ Recent papers studying the effects of carbon taxes on GDP growth and employment growth include Metcalf and Stock (2020a, 2020b). See Dell et al. (2014) for a survey on the effects of climate change on growth.

the implications of climate change and related policies for the economy and the transmission of monetary policy (ECB, 2021).

Konradt and Weder di Mauro (2021) find for Europe and Canada that higher carbon taxes do not have to be inflationary and may even be deflationary, with an increase in energy prices having been more than offset by a fall in the prices of services and other non-tradables.² They mention that their study is the first to emphasize the impact of carbon taxes on inflation, so that more research on this topic is needed. Similarly, McKibbin et al. (2021) find for the euro area that the inflationary effects of carbon taxes on headline inflation have been contained, and that the impact on core inflation tended to be negative. They conclude that carbon taxes mainly affected relative prices rather than the overall price level. Kaenzig (2021) finds that surprises in carbon prices in the European ETS had a positive effect on energy and consumer prices. Using model simulations, McKibbin et al. (2021) find that carbon taxes only have a transitory effect on inflation.³

Our paper contributes to this literature by providing ex-post empirical analysis of the effects of both carbon taxes and prices of ETS on consumer price inflation and its food, energy and core subcomponents, for a broad sample of countries. In contrast to Konradt and Weder di Mauro (2021) and McKibbin et al. (2021), who only study carbon taxes, we also consider carbon ETS prices. In contrast to Kaenzig (2021), who only considers surprises in ETS prices, we also consider carbon taxes. Moreover, in contrast to Konradt and Weder di Mauro (2021) and McKibbin et al. (2021), whose empirical specification for inflation includes only carbon taxes, lagged inflation and fixed effects, we estimate New-Keynesian Phillips curves, which are commonly used for modelling inflation dynamics in monetary policy analysis, and which also control for output gaps, inflation expectations and exchange rate changes. Furthermore, we consider a wider range of countries globally (35 OECD economies), instead of just European countries and Canada.

New-Keynesian Phillips curves are the standard way to model inflation dynamics in modern monetary policy analysis (Clarida et al., 1999; Smets, 2003; Woodford, 2003; Levin and Moessner, 2005). We choose cross-country panel estimation of New-Keynesian Phillips curves based on Jasova et al. (2019, 2020), in order to capture inflation dynamics well by including the effects of output gaps, exchange rate changes and inflation expectations. This approach allows to exploit cross-country variation to mitigate the difficulties of identification present for country-specific estimates, as discussed by Reichlin (2018) and Forbes (2019) in the case of the output gap.

We find that an increase in prices of ETS by \$10 per ton of CO₂ equivalents increases energy CPI inflation by 0.8pp at the 1% significance level after one year, and headline inflation by 0.08pp at the 10% significance level, but has no significant effects on food and core CPI inflation. We also find that an increase in carbon taxes by \$10 per ton of CO₂ equivalents increases food CPI inflation by 0.1pp at the 5% significance level after one year, but has no significant effects on energy CPI inflation, headline and core inflation.

Our findings are relevant for future climate policies. They suggest that higher carbon taxes and prices of permits in ETS have not led to large increases in headline inflation. Consequently, based on this evidence the use of carbon pricing to speed up the necessary transition to net zero carbon emissions need not be held back by concerns about large overall inflationary effects. This

² This happens despite an insignificant or positive effect of carbon taxes on real GDP per capita in Canada (Konradt and Weder di Mauro, 2021), consistent with earlier evidence of an absence of negative effects of carbon taxes on GDP growth (Metcalf, 2019; Metcalf and Stock, 2020a).

³ At the sectoral level, Hebbink et al. (2018) find that carbon taxes in European Union countries increase production costs of the industrial sector slightly, as measured by changes in the GDP deflator.

is relevant since these carbon pricing policies have been shown to be effective in reducing carbon emissions (Kohlscheen et al., 2021).⁴

The remainder of the paper proceeds as follows. Section 2 summarises the data, and Section 3 presents the method and results. Finally, Section 4 concludes.

2. Data

The main carbon pricing policies are carbon taxes and ETS. The first carbon tax was introduced in Finland in 1990. Emissions trading has been considered a possible tool for mitigating greenhouse gas emissions since the early 1990s and formed a key part of the Kyoto Protocol agreement (Philibert and Reinaud, 2004). For carbon taxes, governments set the price of carbon emissions, and let private agents determine emissions quantities. ETS can be in the form of cap-and-trade and baseline-and-credit ETS; permits and credits are traded and carbon prices are determined by supply and demand in the market (World Bank, 2021). We use data on carbon taxes and ETS implemented at the national and supranational levels since 1990 from the World Bank, in US dollars per ton CO₂ equivalent emissions (\$/tCO₂ equivalents) (World Bank, 2021). Country coverage and prices of these policies are shown in Appendix Figures A1 and A2 separately for carbon taxes and ETS, for the end of our sample period in 2020.

Data on headline consumer price indices (CPI) are from Datastream and national sources. We also use energy CPI indices, food CPI indices (food and non-alcoholic beverages), and core CPI indices (excluding food and energy), based on data from the OECD, national sources and BIS calculations. Data on professionals' survey-based CPI inflation expectations are from Consensus Economics surveys for next-year headline CPI inflation expectations. Data on output gaps (as a percentage of potential GDP) are from the OECD. Nominal effective exchange rate indices (broad indices, annual averages) are from the BIS, with an increase indicating an appreciation of the domestic currency. Brent oil prices (annual averages, US dollar per barrel) are from Datastream.

Our sample of countries consists of 35 OECD economies. They are Austria, Australia, Belgium, Bulgaria, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece, Hungary, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Mexico, the Netherlands, Norway, New Zealand, Poland, Portugal, Romania, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland and the United States. The sample period is from 1995 to 2020 at annual frequency.

3. Method and results

3.1 Effects of carbon pricing

We quantify the effects of carbon pricing on inflation by dynamic panel regressions of New-Keynesian Phillips curves according to

$$\pi_{it} = \theta \pi_{it}^e + \rho \pi_{it-1} + \kappa CT_{i,t-1} + \lambda CETS_{i,t-1} + \phi outputgap_{it} + \mu \Delta NEER_{it} + \alpha_i + \beta_t + \varepsilon_{it}. \quad (1)$$

⁴ See also Lin and Li (2011), Martin et al. (2014), Andersson (2019) and Pretis (2019).

This approach is based on Jasova et al. (2019, 2020), using dynamic panel estimation of New-Keynesian Phillips curves in order to capture inflation dynamics well, and augmented with carbon pricing variables in order to study the additional effects of these policies. New-Keynesian Phillips curves are the standard way to model inflation dynamics in modern monetary policy analysis. To address potential endogeneity concerns, we use lagged carbon pricing variables, which minimises the risk of reverse causality. As climate policies we consider carbon taxes, $CT_{i,t}$, and prices of permits in ETS, $CETS_{i,t}$, implemented at the national or supranational levels.

In our baseline specification of equation (1) π_{it} denotes year-on-year (y/y) CPI inflation in percent, calculated from log differences in consumer price indices (CPI) in country i at time t ; as inflation rates we consider food, energy, core and headline CPI inflation. Moreover, $outputgap_{it}$ denotes the output gap; π_{it}^e denotes next-year CPI inflation expectations from Consensus Economics surveys, y/y in percent; $\Delta NEER_{it}$ is the y/y change in the nominal effective exchange rate in percent, calculated from the log change in the nominal effective exchange rate, with an increase indicating an appreciation of the currency.

Our baseline model includes country fixed effects to capture unobserved heterogeneities across countries that might affect inflation. We also include annual time dummies to control for the effects of global factors, such as global trends or global shocks. We use fixed effect panel estimations and robust standard errors clustered at the country level.

The estimations of equation (1) for the effects of carbon taxes and prices of permits in the ETS on inflation for food, energy, core and headline CPI inflation are shown in columns I to IV of Table 1, respectively. The specifications describe the country-specific evolution of headline and core inflation quite well. The models are able to explain 75–81% of the variation in headline and core inflation across countries and time (Table 1). This is driven by variation both within and between countries, as the R^2 within ranges from 0.72 to 0.79, and the R^2 between ranges from 0.90 to 0.94. The lagged dependent variable has a coefficient of above 0.2 and is statistically significant at the 1% level, which confirms that a dynamic panel specification is appropriate. The output gap, inflation expectations and exchange rate changes are statistically significant with the expected signs. The country-specific evolution of the more volatile food and energy CPI subcomponents is described less well, but still a substantial 62–73% of their variation across countries and time is explained, again driven by variation both within and across countries.

We can see from Table 1 that an increase in carbon taxes by \$10 per ton of CO₂ equivalents increases food CPI inflation by 0.1pp at the 5% significance level, but has no significant effects on energy CPI inflation, headline and core inflation. We can also see that an increase in prices of ETS by \$10 per ton of CO₂ equivalents increases energy CPI inflation by 0.8pp at the 1% significance level, and headline inflation by 0.08pp at the 10% significance level; but it has no significant effects on food and core CPI inflation.

We also consider the persistence of the effects of carbon pricing on inflation by following Jordà (2005)'s local projection method in estimating the New-Keynesian Phillips curves for the effect on inflation at time $t+1$, according to

$$\pi_{it+1} = \theta \pi_{it}^e + \rho \pi_{it-1} + \kappa CT_{i,t-1} + \lambda CETS_{i,t-1} + \phi outputgap_{it} + \mu \Delta NEER_{it} + \alpha_i + \beta_t + \varepsilon_{it}. \quad (2)$$

The results of equation (2) for food, energy, core and headline CPI inflation are shown in Table 2. We can see that at time $t+1$, ie two years after the carbon pricing measure, ETS prices still have a small positive effect on headline CPI inflation, with an increase in prices of ETS by \$10 per ton of CO₂ equivalents increasing headline inflation by 0.10pp at the 10% significance level. By contrast,

the effect of ETS prices on energy CPI inflation is no longer significant after two years. The effects of ETS prices on food and core CPI inflation remain insignificant after two years. We can also see that the effect of carbon taxes on food CPI inflation becomes insignificant after two years. By contrast, carbon taxes have a small positive effect on headline CPI inflation after two years, with an increase in carbon taxes by \$10 per ton of CO₂ equivalents increasing headline inflation by 0.04pp at the 5% significance level. The effects of carbon taxes on energy and core CPI inflation remain insignificant after two years.

3.2 Robustness

We perform several robustness checks. First, we replace time fixed effects by oil price changes in equation (1),

$$\pi_{it} = \theta \pi_{it}^e + \rho \pi_{it-1} + \kappa CT_{i,t-1} + \lambda CETS_{i,t-1} + \phi outputgap_{it} + \mu \Delta NEER_{it} + \gamma \pi_t^{oil} + \alpha_i + \varepsilon_{it}. \quad (3)$$

where π_t^{oil} denotes y/y oil price inflation calculated from log-differences in annual oil prices. The results are shown in Table 3. We can see that our results are generally robust to this change in specification. An increase in carbon taxes by \$10/tCO₂ equivalents increases food CPI inflation by a similar magnitude of 0.13pp at the 1% significance level, and continues to have no significant effects on energy CPI inflation, headline and core inflation. An increase in prices of ETS by \$10 per ton of CO₂ equivalents has a somewhat smaller effect on energy CPI inflation, of 0.27pp at the 10% significance level, and increases headline inflation by a similar magnitude of 0.07pp at the 5% significance level; and it continues to have no significant effects on food and core CPI inflation.

We also estimate the effects of carbon policies when using real carbon prices instead of nominal ones in equations (1) and (3). That is, we consider prices obtained by deflating the nominal US dollar carbon price by the US consumer price index. The corresponding results are shown in Tables 4 and 5. We can see that our results are generally robust to using real carbon prices.

Finally, we re-estimate equation (1) when dropping the inflation expectations term. The results are shown in Table 6, and they are generally robust to this test, but become slightly weaker. The coefficient on ETS prices remains significant for energy CPI inflation with a slightly smaller magnitude of 0.0652, compared with 0.0809 in Table 1. Moreover, the coefficient on ETS prices remains insignificant for food and core CPI inflation. But for headline inflation the coefficient on ETS prices also becomes insignificant. The coefficient on carbon taxes remains significant for food CPI inflation with a very similar magnitude as in Table 1, and it remains insignificant for energy, headline and core CPI inflation.

4 Conclusions

We studied how carbon taxes and prices of ETS have affected inflation ex-post for 35 OECD economies from 1995 to 2020, using dynamic panel estimation of New-Keynesian Phillips curves across countries in order to capture inflation dynamics well. We find that an increase in prices of ETS by \$10/tCO₂ equivalents increased energy CPI inflation by 0.8pp at the 1% significance level after one year, and headline inflation by 0.08pp at the 10% significance level, but had no significant effects on food CPI and core CPI inflation. We also find that an increase in carbon taxes

by \$10/tCO₂ equivalents increased food CPI inflation by 0.1pp at the 5% significance level after one year, but had no significant effects on energy CPI inflation, headline and core CPI inflation.

Our findings are relevant for future climate policies. They suggest that higher carbon taxes and prices of permits in ETS have not led to large increases in headline CPI inflation. Consequently, based on this evidence the use of carbon pricing to speed up the necessary transition to net zero carbon emissions need not be held back by concerns about large overall inflationary effects. This is relevant since these carbon pricing policies have been shown to be effective in reducing carbon emissions (Kohlscheen et al., 2021).

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Tables

Effects of carbon pricing on CPI inflation

Table 1

Dep. var: π_{it}	food CPI	energy CPI	core CPI	headline CPI
	I	II	III	IV
	π_{it}^e	1.0629***	1.2504***	0.8684***
π_{it-1}	0.1699**	0.0516	0.2934***	0.2330***
CT_{it-1}	0.0102**	-0.0147	-0.0008	0.0006
$CETS_{it-1}$	-0.0147	0.0809***	0.0052	0.0082*
outputgap $_{it}$	0.0369	-0.1983**	0.0637***	0.0354**
$\Delta NEER_{it}$	-0.0975***	-0.2907***	-0.0146	-0.0470***
constant	-1.800**	-1.600	-0.3901	-0.9598**
observations	744	731	731	757
number of countries	34	33	33	35
time fixed effects	yes	yes	yes	yes
R2 within	0.591	0.741	0.717	0.788
R2 between	0.815	0.507	0.898	0.940

Notes: Fixed effects panel estimation; sample period: 1995-2020. ***/**/* denote statistical significance at 1/5/10% confidence level. Robust standard errors clustered at the country level.

Effects of carbon pricing on CPI inflation: local projections for time t+1

Table 2

Dep. var: π_{it+1}				
	food CPI	energy CPI	core CPI	headline CPI
	I	II	III	IV
π_{it}^e	0.5087**	1.1019**	0.9569***	0.9085***
π_{it-1}	-0.0388	-0.0190	-0.0476	-0.0599
CT_{it-1}	0.0104	-0.0053	0.0024	0.0037**
$CETS_{it-1}$	0.0182	0.0258	0.0021	0.0098*
$outputgap_{it}$	0.0395	0.0643	0.1021***	0.0754***
$\Delta NEER_{it}$	-0.1236***	-0.0441	-0.0106	-0.0333***
constant	0.7155	1.3155	-0.2250	-0.0003
observations	711	698	698	722
number of countries	34	33	33	35
time fixed effects	yes	yes	yes	yes
R2 within	0.456	0.693	0.590	0.644
R2 between	0.235	0.739	0.712	0.781

Notes: Fixed effects panel estimation; sample period: 1995-2020. ***/**/* denote statistical significance at 1/5/10% confidence level. Robust standard errors clustered at the country level.

Effects of carbon pricing on CPI inflation: with oil prices

Table 3

Dep. var: π_{it}	food CPI	energy CPI	core CPI	headline CPI
	I	II	III	IV
π_{it}^e	1.142***	1.1818***	0.8558***	1.0518***
π_{it-1}	0.1561***	0.1056**	0.2960***	0.2176***
CT_{it-1}	0.0125***	-0.0093	-0.0005	0.0021
$CETS_{it-1}$	0.0060	0.0274*	0.0037	0.0069**
outputgap $_{it}$	0.1078***	-0.0574	0.0687***	0.0584***
$\Delta NEER_{it}$	-0.0819***	-0.3423***	-0.0107	-0.0438***
π_{it}^{oil}	0.0049	0.1800***	-0.0042***	0.0140***
constant	-0.5594	-0.3467	-0.4966***	-0.7359***
observations	744	731	731	757
number of countries	34	33	33	35
time fixed effects	no	no	no	no
R2 within	0.315	0.649	0.688	0.707
R2 between	0.697	0.634	0.898	0.919

Notes: Fixed effects panel estimation; sample period: 1995-2020. ***/**/* denote statistical significance at 1/5/10% confidence level. Robust standard errors clustered at the country level.

Effects of carbon pricing on CPI inflation: real carbon prices

Table 4

Dep. var: π_{it}	food CPI	energy CPI	core CPI	headline CPI
	I	II	III	IV
	π_{it}^e	1.0654***	1.2435***	0.8681***
π_{it-1}	0.1710***	0.0507	0.2935***	0.2335***
CT_{it-1}	0.0113**	-0.0163	-0.0018	0.0001
$CETS_{it-1}$	-0.0147	0.0810***	0.0050	0.0082*
outputgap $_{it}$	0.0372	-0.1995**	0.0638***	0.0354**
$\Delta NEER_{it}$	-0.0979***	-0.2902***	-0.0146	-0.0471***
constant	-1.800	-1.600	-0.3821	-0.9587**
observations	744	731	731	757
number of countries	34	33	33	35
time fixed effects	yes	yes	yes	yes
R2 within	0.591	0.742	0.717	0.788
R2 between	0.795	0.494	0.903	0.942

Notes: Fixed effects panel estimation; sample period: 1995-2020. ***/**/* denote statistical significance at 1/5/10% confidence level. Robust standard errors clustered at the country level.

Effects of carbon pricing on CPI inflation: real carbon prices, with oil prices

Table 5

Dep. var: π_{it}	food CPI	energy CPI	core CPI	headline CPI
	I	II	III	IV
π_{it}^e	1.1297***	1.1840***	0.8535***	1.0471***
π_{it-1}	0.1587***	0.1050**	0.2955***	0.2186***
CT_{it-1}	0.0127**	-0.0095	-0.0018	0.0012
$CETS_{it-1}$	0.0038	0.0277*	0.0031	0.0060**
outputgap $_{it}$	0.1069***	-0.0592	0.0683***	0.0577***
$\Delta NEER_{it}$	-0.0828***	-0.3417***	-0.0109	-0.0440***
π^{oil}_t	0.0046	0.1799***	-0.0043***	0.01391***
constant	-0.5281	-0.3432	-0.4717***	-0.7118***
observations	744	731	731	757
number of countries	34	33	33	35
time fixed effects	no	no	no	no
R2 within	0.313	0.649	0.688	0.706
R2 between	0.685	0.631	0.905	0.926

Notes: Fixed effects panel estimation; sample period: 1995-2020. ***/**/* denote statistical significance at 1/5/10% confidence level. Robust standard errors clustered at the country level.

Effects of carbon pricing on CPI inflation: without inflation expectations

Table 6

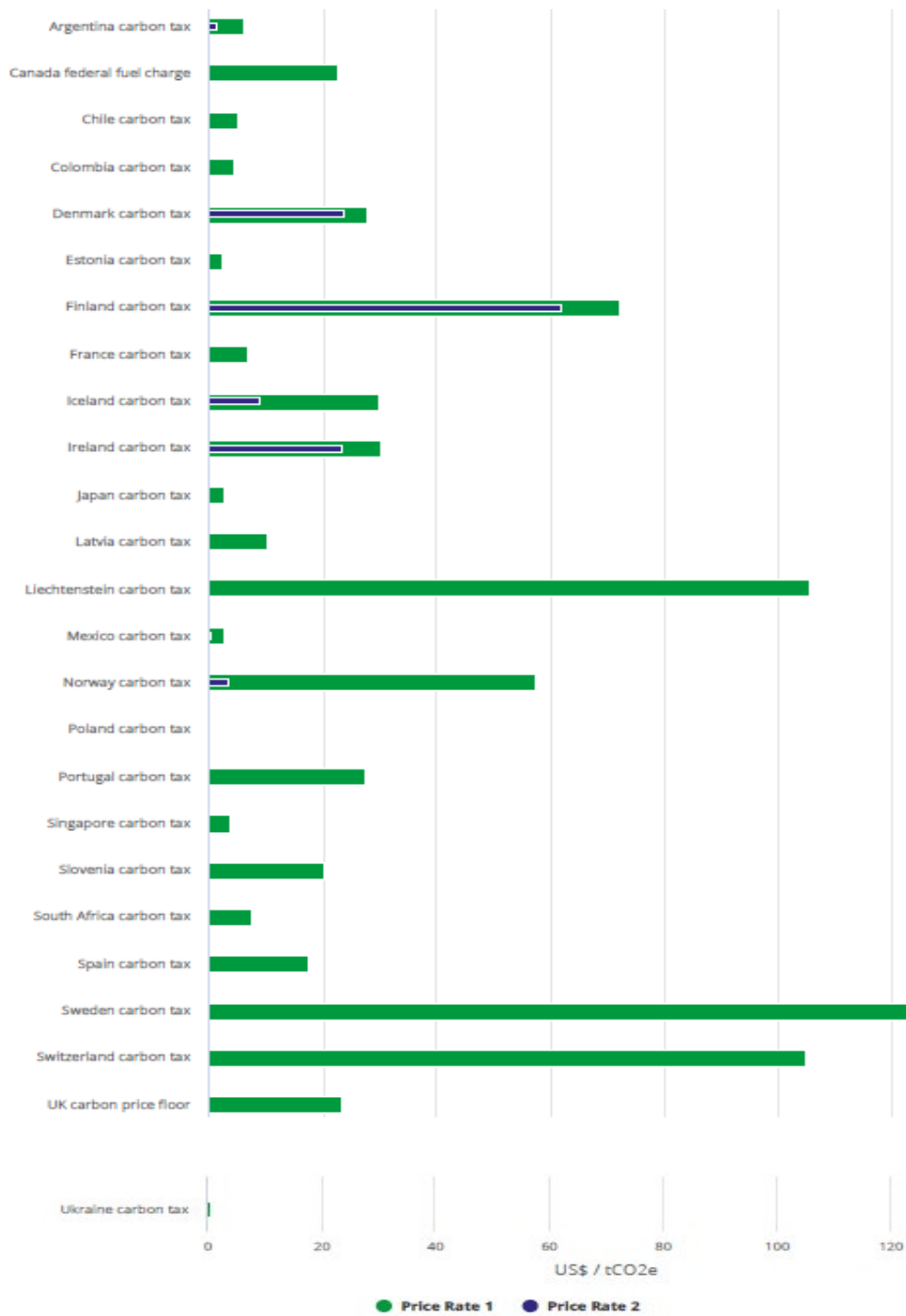
Dep. var: π_{it}	food CPI	energy CPI	core CPI	headline CPI
	I	II	III	IV
	π_{it-1}	0.4177***	0.2967***	0.7038***
CT_{it-1}	0.0101**	0.0005	-0.0001	0.0030
$CETS_{it-1}$	-0.0086	0.0652***	0.0053	-0.0004
$outputgap_{it}$	0.1406***	-0.0059	0.1140***	0.1133***
$\Delta NEER_{it}$	-0.2404***	-0.3881***	-0.1271**	-0.1645***
constant	3.5245***	4.6570***	2.9600***	3.2365***
observations	852	828	825	879
number of countries	34	33	33	35
time fixed effects	yes	yes	yes	yes
R2 within	0.528	0.694	0.761	0.789
R2 between	0.847	0.807	0.977	0.962

Notes: Fixed effects panel estimation; sample period: 1995-2020. ***/**/* denote statistical significance at 1/5/10% confidence level. Robust standard errors clustered at the country level.

Appendix

Prices of carbon taxes implemented at the national level as of 2020

Figure A1

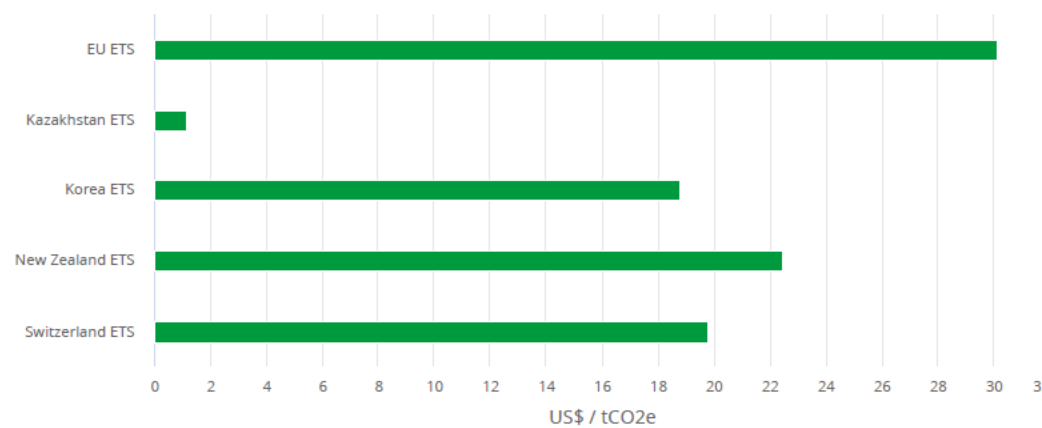


Notes: Nominal prices as of 1 April 2020 in USD/tCO2 equivalents.

Source: World Bank.

Prices of carbon ETS implemented at the national and supranational levels as of 2020

Figure A2



Notes: Nominal prices as of 1 April 2020 in USD/tCO₂ equivalents.

Source: World Bank.
