Supplemental Appendix for

The Economic Consequences of Effective Carbon Taxes

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A Data Sources of the Carbon Taxes

Country	**Denmark**	**Finland**	**Norway**	**Sweden**
Source	Statistics Denmark (Danmarks Statistik)	Finnish Tax Administration (Vero Skatt)	Statistics Norway (Statistisk sentralbyrå)	Statistics Sweden (Statistiska centralbyrån)
Table name (Table Nr.)	SKAT: Taxation total, divided into rates and dues by type	Excise duty	Environmental taxes, by type of tax (10645)	Total environmental taxes in Sweden 1993–2020
Explicit carbon taxes	(a) Duty on carbon dioxide (CO2)	(a) Carbon dioxide tax on liquid fuels (b) Carbon dioxide tax on certain fuels	(a) Tax on CO2 emissions (b) Tax on CO2 emissions in the petroleum sector (c) Motor vehicle registration tax - imputed CO2 component (d) Tax on greenhouse gases HFC and PFC	(a) Carbon dioxide tax
Implicit carbon taxes	(a) Duty on petrol (b) Duty on certain oil products (c) Duty on natural gas (d) Duty on gas (e) Duty on coal, etc.	(a) Energy content tax on liquid fuels (b) Supply security fee of liquid fuels (c) Energy content tax on certain fuels (d) Energy taxation on certain fuels (e) Supply security fee of certain fuels (f) Oil waste duty (g) Oil damage duty	(a) Petrol tax (b) Diesel tax (c) Road tax on natural gas and LPG (d) Tax on lubricating oils (e) Tax on mineral oils	(a) Energy tax on fuels (b) Tax on diesel oil

Table A1: Excise taxes for the construction of explicit and implicit carbon tax rates.

B Carbon Tax Histories

	Implicit carbon taxes in Denmark			Explicit carbon taxes in Denmark
Date	**Energy tax on mineral oil products (Energiafgifter af miner-alolieprodukter mv.)**	**Energy tax on coal and heat from waste (Energiafgift af kul og affaldsvarme)**	**Energy tax on natural gas (Energiafgift af naturgas og bygas)**	**Carbon dioxide tax (Kuldioxidafgift)**
15 May 1992				introduction
01 Jan 1993				coverage
01 Jan 1996			price, coverage	price, coverage
01 Jan 1997				coverage
01 Jan 1998				coverage
01 Jan 1999				coverage
01 July 1999			coverage	coverage
01 Jan 2001			coverage	
01 Jan 2005				price
01 Jan 2006			price, coverage	
01 Jan 2007	price	price	price	
01 Jan 2008	price	price	price	price, coverage
01 Jan 2009	price	price	price	price
01 Jan 2010	price	price, coverage	price, coverage	price, coverage
01 Jan 2011	price	price	price	price, coverage
01 Jul 2011		price		
01 Jan 2012	price	price	price	price
01 Jul 2012	price		price	
01 Jan 2013	price	price, coverage	price	price, coverage
01 Feb 2013	price	price	price	
01 Jan 2014	price	price	price	price, coverage
01 Jan 2015	price	price, coverage	price	price, coverage
01 Jan 2016	price	price	price	price
01 Jan 2017	price	price	price	price
01 Jan 2018	price	price	price	price
01 Jan 2019	price	price	price	price

Table B1: Changes in price and coverage of explicit and implicit carbon taxes in Denmark. Data is collected to the author's best understanding of the tax histories provided in local language. Changes in price and coverage are incomplete towards the mid and beginning of the sample due to availability of information from official administration sources. Note that distinctions into changes in prices and changes in coverage can be ambiguous. Source: Skat (Danish Customs and Tax Administration).

	Explicit and implicit carbon taxes in Finland	Implicit carbon taxes in Finland	
Date	**Energy content and carbon dioxide tax**	**Strategic stockpile fees**	**Oil pollution fees**
01 Jan 2005			price
01 Jul 2005	coverage		
01 Jan 2008	price, coverage		
01 Jan 2010			price
01 Jan 2011	price, coverage		
01 Jan 2012	price		
01 Jan 2013	price		
01 Jan 2014	price		
01 Jan 2015	price		
01 Jan 2016	price, coverage	coverage	
01 Mar 2016	price		
01 Jan 2017	price		
01 Jan 2018	price		
01 Jan 2019	price		

Table B2: Price changes and some changes in coverage of explicit and implicit carbon taxes in Finland. Data is collected to the author's best understanding of the available tax histories. Information about changes in the coverage by the taxes are not available from official administration sources. Source: Statistics Finland.

	Explicit carbon taxes in Norway				
Date	**Avgift på mineralolje**	**Avgift på kull og koks mv.**	**CO2-avgift på mineralske produkter**	**Engangsavgift - beregnet CO2-komponent**	**Miljøavgift på klimagassene HFCs og PFCs**
01 Jan 1995	price, coverage	price			
01 Jan 1996	price	price			
01 Jan 1997	price, coverage	price, coverage			
01 Jan 1998	price	price			
01 Jan 1999	abolished	abolished	introduction		
01 Jan 2000			price, coverage		
01 Jan 2001			price, coverage		
01 Jan 2002			price		
01 Jan 2003			price, coverage		introduction
01 Jan 2004			price		price
01 Jan 2005			price		price
01 Jan 2006			price		price
01 Jan 2007			price	introduction	price
01 May 2007				coverage	
01 Jan 2008			price	price	price
01 Jan 2009			price, coverage	price, coverage	price
01 Jan 2010			price	price, coverage	price
01 Sep 2010			coverage		
01 Jan 2011			price, coverage	price, coverage	price
01 Jan 2012			price, coverage	price	price, coverage
01 Jan 2013			price	price, coverage	price
01 Jan 2014			price, coverage	price, coverage	price
01 Jan 2015			price	coverage	price
01 Jul 2015			price, coverage		
01 Jan 2016			price	price, coverage	price
01 Jan 2017			price	price, coverage	price
01 Jul 2017				coverage	
01 Jan 2018			price, coverage	price, coverage	price
01 Jan 2019			price	price	price
01 Jul 2019				coverage	

Table B3: Changes in price and coverage of explicit carbon taxes in Norway. Data is collected to the author's best understanding of the tax histories provided in local language. Note that distinctions into changes in prices and changes in coverage can be ambiguous. Source: Skatteetaten (Norwegian Tax Authorities).

	Implicit carbon taxes in Norway				
Date	**Veibruksavgift på drivstoff**	**Veibruksavgift på bensin**	**Veibruksavgift på autodiesel**	**Avgift på smøreolje mv.**	**Grunnavgift på mineralolje mv.**
01 Jan 1995		price, coverage	price		
01 Jan 1996		price	price	price	
01 Jan 1997		price	price, coverage	price, coverage	
01 Jan 1998		price	price, coverage	price	
01 Jan 1999		price, coverage	price, coverage	price, coverage	
01 Jan 2000		price, coverage	price, coverage	price, coverage	introduced
01 Jul 2000		price	coverage		
01 Jan 2001		price	price	price	price
01 Jul 2001		price	price		
01 Jan 2002		price	price	price	price
01 Jan 2003		price	price	price	price
01 Jan 2004		price	price	price	price
01 Jan 2005		price	price	price	price
01 Jan 2006		price, coverage	price	price	price
01 Jan 2007		price	price	price	price
01 Jan 2008		price	price	price	price
01 Jul 2008		price	price		
01 Jan 2009		price	price	price	price
01 Jan 2010		price	price, coverage	price, coverage	price
01 Jul 2010					coverage
01 Jan 2011	introduced	abolished	abolished	price	price
01 Jan 2012	price			price	price
01 Jan 2013	price			price	price
01 Jan 2014	price			price, coverage	price, coverage
01 Jan 2015				price	price
01 Jul 2015	price				
01 Jan 2016	price, coverage			price	price
01 Jul 2016	coverage				
01 Jan 2017	price			price	price
01 Jan 2018	price			price	price
01 Jan 2019	price			price	price

Table B4: Changes in price and coverage of implicit carbon taxes in Norway. Data is collected to the author's best understanding of the tax histories provided in local language. Note that distinctions into changes in prices and changes in coverage can be ambiguous. Source: Skatteetaten (Norwegian Tax Authorities).

	Implicit carbon taxes in Sweden		Explicit carbon taxes in Sweden
Date	**Dieseloljeskatt**	**Energiskatt bränslen**	**Koldioxidskatt**
01 Jan 1993			price
01 Oct 1993		price	
01 Jan 1994		price	price
01 Jul 1994	price	price	
01 Jan 1995	abolished	price	price
01 Jan 1996		price	price
01 Sep 1996		price	
01 Jan 1997			price
01 Jul 1997		price	price
01 Jan 1999		price	price
01 Jan 2000		price	price
01 Jan 2001		price	price
01 Jan 2002		price	price
15 Nov 2002		price	
01 Jan 2003		price	price
01 Jan 2004		price	price
01 Jan 2005		price	price
01 Jan 2006		price	price
01 Jan 2007		price	price
01 Jan 2008		price	price
01 Jan 2009		price	price
01 Jan 2010		price	price
01 Jan 2011		price	price
01 Jan 2012		price	price
01 Jan 2013		price	price
01 Jan 2014		price	price
01 Jan 2015		price	price
01 Jan 2016		price	price
01 Jan 2017		price	price
01 Jan 2018		price	price
01 Jul 2018		price	price
01 Jan 2019		price	price
01 Jul 2019		price	

Table B5: Changes in price and coverage of explicit and implicit carbon taxes in Sweden. Data is collected to the author's best understanding of the tax histories provided in local language. Information about changes in the coverage of the taxes are not available from official administration sources. Source: Skatteverket (Swedish Tax Agency).

C Variance-Covariance Matrix

I follow Metcalf and Stock (2020) in obtaining the variance-covariance matrix $\boldsymbol{V}_{\boldsymbol{\beta_k}}$ of the vector $\boldsymbol{\beta}_k$. To simplify notation and provide more intuition, the Frisch-Waugh theorem is applied to equation (1). At first, project a single variable of interest $y_{k,i,t+h}$ and the tax rate $\tau_{i,t,h}$ on all control variables $\mathbf{x}_{i,t}$ to obtain their error terms $y^{\perp}_{k,i,t,h}$ and $\eta_{i,t,h}$, so

$$y_{k,i,t+h} = \mathbf{x}_{i,t}\mathbf{d}_{k,h} + y^{\perp}_{k,i,t,h}, \tag{C1}$$

and

$$\tau_{i,t,h} = \mathbf{x}_{i,t}\mathbf{d}_{\tau,h} + \eta_{i,t,h}. \tag{C2}$$

Afterwards, project $y^{\perp}_{k,i,t,h}$ on $\eta_{i,t,h}$ to obtain the coefficient $\beta_{k,h}$ and the error term $u_{k,i,t,h}$ from equation (1), that is,

$$y^{\perp}_{k,i,t,h} = \beta_{k,h}\eta_{i,t,h} + u_{k,i,t,h}.$$

As the number of observations differs at the various horizons, the variance-covariance matrix $V_{\boldsymbol{\beta}_k}$ is computed manually through

$$V_{\boldsymbol{\beta}_{k,lj}} = \left(\eta'_{i,t,l}\eta_{i,t,l}\right)^{-1}\left(\eta_{i,t,l} \circ u_{k,i,t,l}\right)' \sqrt{\frac{n_l}{n_l - q_l}}\sqrt{\frac{n_j}{n_j - q_j}}\left(\eta_{i,t,j} \circ u_{k,i,t,j}\right)\left(\eta'_{i,t,j}\eta_{i,t,j}\right)^{-1},$$

where $V_{\boldsymbol{\beta}_{k,lj}}$ denotes the l-th row and j-th column of $\boldsymbol{V}_{\boldsymbol{\beta_k}}$ and $\circ$ is the Hadamard product. $\eta_{i,t,l}$, $\eta_{i,t,j}$, $u_{k,i,t,l}$ and $u_{k,i,t,j}$ are the error terms of equation (C1) and (C2) at horizon $l = 1, ..., H$ and $j = 1, ..., H$, and n_l and n_j are the number of observations, and q_l and q_j are the number of regressors used in these regressions.

D All Data Sources and Transformations

Variable	Source	Frequency	Conversion/Use	Sample
Explicit and implicit carbon tax revenue; LCU	Statistics Denmark (2021); Statistics Finland (2021); Statistics Norway (2020-2022); Statistics Sweden (2021-2022)	annual	Converted to monthly explicit, implicit and effective carbon tax rates.	DK: 1990M01-2019M12 FI: 2004M01-2019M12 NO: 1995M01-2019M12 SE: 1993M01-2019M12
Coverage-unadjusted real explicit carbon tax rate	World Bank (2021)	annual	Converted to local currencies with nominal exchange rates and to monthly rates as explicit and implicit rates. Deflated with CPI.	All: 1990M01-2019M12
(Consumer) Pump price for gasoline (95 Octane) including taxes	Drivkraft Danmark (2021); Statistics Finland (2021); Statistics Norway (2020-2022); Macrobond (2022)	monthly	Seasonally adjusted with X11-X13 method in JDemetra+. Deflated with CPI.	All: 1990M01-2019M12
Greenhouse gas emissions without LULUCF	UNFCCC (2021)	annual	Temporally disaggregated to monthly levels with Chow-Lin method.	All: 1990M01-2019M12
Consumer price index for all items, 2015=100	OECD (2021*a*)	monthly	Seasonally adjusted with X11-X13 method in JDemetra+.	All: 1990M01-2019M12
Consumer price index for energy items, 2015=100	OECD (2021*a*)	monthly	Seasonally adjusted with X11-X13 method in JDemetra+.	All: 1990M01-2019M12
GDP (output based) and gross value added by various sectors (NACE Level 1 classification); LCU; current prices; seasonally and calendar adj.	Eurostat (2021)	quarterly	Temporally disaggregated to monthly levels with Chow-Lin method.	DK: 1995M01-2019M12 FI: 1990M01-2019M12 NO: 1990M01-2019M12 SE: 1993M01-2019M12
GDP deflator; 2015=100; LCU; seasonally and calendar adjusted	Eurostat (2021)	quarterly	Used to deflate GDP and gross value added before the temporal disaggregation.	DK: 1995M01-2019M12 FI: 1990M01-2019M12 NO: 1990M01-2019M12 SE: 1993M01-2019M12
Unemployment rate; all persons; seasonally adjusted	OECD (2021*b*)	monthly	-	All: 1990M01-2019M12
Interbank interest rate yield, 3-month maturity	OECD (2021*b*)	monthly	Missing value for Sweden in 2001M11 replaced with the average of the previous and subsequent month's value.	All: 1990M01-2019M12
Real effective exchange rate index, 2015=100	OECD (2021-2024)	monthly	-	All: 1990M01-2019M12

Table D1: Data description of variables used in the main analysis.

Variable	Source	Frequency	Conversion/Use	Sample
Nominal exchange rates	Eurostat (2021); Bank for International Settlements (2021)	monthly	Used to rescale or convert monetary variables to other currencies.	All: 1990M01-2019M12
Settlement price of futures on carbon price from EU ETS, in Euro	Datastream (2021) (Ticker: LEXC.01), same as in Känzig (2021)	monthly	Price before implementation of EU ETS is set to zero. Converted to local currencies.	All: 2005M04-2019M12
Long term interest rates, 10-year maturity	OECD (2021-2024)	monthly	-	All: 1990M01-2019M12
Government Expenditure; LCU; current prices; seasonally and calendar adjusted	OECD (2021-2024)	quarterly	Temporally disaggregated to monthly levels with Chow-Lin method just like GDP.	DK: 1995M01-2019M12 FI: 1990M01-2019M12 NO: 1990M01-2019M12 SE: 1993M01-2019M12
Real electricity tax rates in LCU	Statistics Denmark (2021); Statistics Finland (2021); Statistics Norway (2020-2022); Statistics Sweden (2021-2022); Eurostat (2021)	annual	Electricity tax revenues are divided by electricity consumption to obtain average electricity tax rates paid. Deflated and disaggregated to monthly data in the same way as effective carbon tax rates using the timing feature.	DK: 1990M01-2019M12 FI: 2004M01-2019M12 NO: 1995M01-2019M12 SE: 1993M01-2019M12
Commodity terms of trade net export price index	Gruss and Kebhaj (2019)	monthly	-	All: 1990M01-2019M12
Industrial production (excluding construction), 2015=100, seasonally adjusted	OECD (2021-2024)	monthly	Used as indicator to temporally disaggregate GDP, GVA and GHG emissions with the Chow-Lin method.	All: 1990M01-2019M12
Share price index, 2015=100	OECD (2022*a*)	monthly	Deflated with CPI.	All: 1990M01-2019M12
Total tax revenue as a share of GDP, in percent	OECD (2022*b*)	annual	Disaggregated to monthly data in the same way as effective carbon tax rates assuming the same timing feature.	All: 1990-2019
Greenhouse gas emissions by sector (NACE Level 1 classification)	Eurostat (2021)	annual	Average across sample used in Table 1.	All: 2008-2018
Gross value added by sector (NACE Level 1 classification); current prices	Eurostat (2021)	annual	Average across sample used in Table 1.	All: 2008-2018

Table D2: Data description of variables used in robustness checks, in tables and for the construction of other variables.

E Plots of Variables

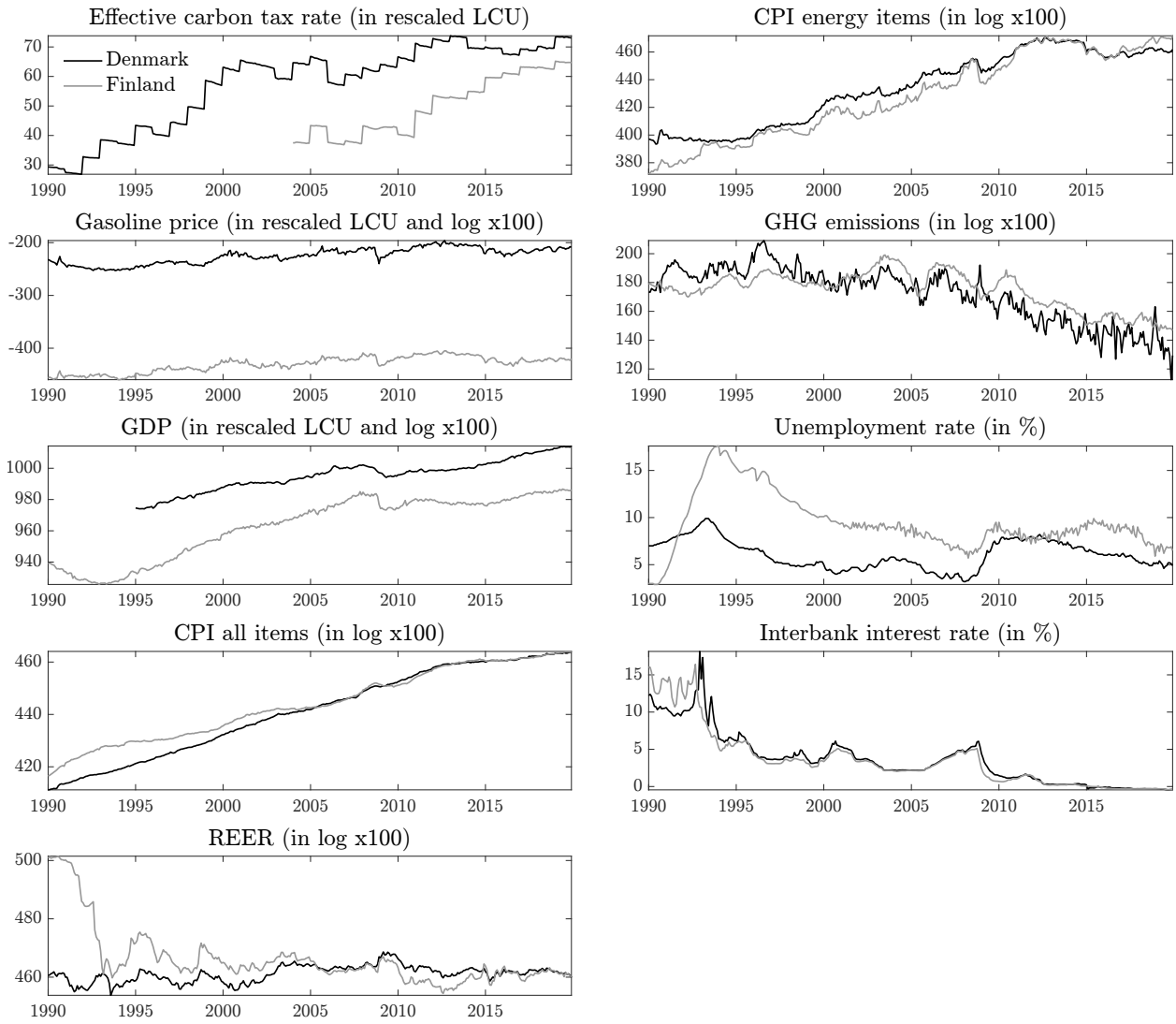

Figure E1: Plots displaying the employed variables for Denmark and Finland.

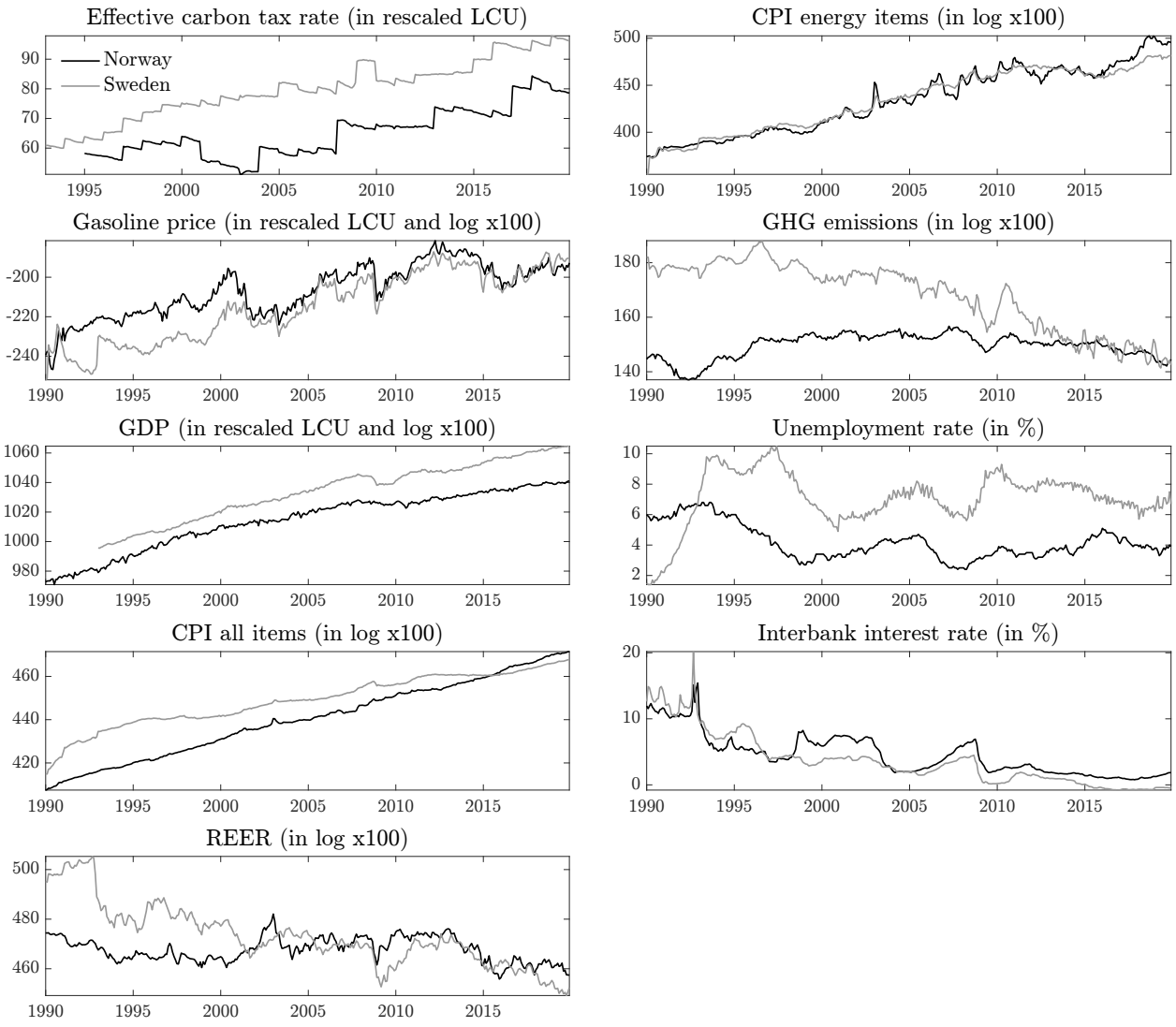

Figure E2: Plots displaying the employed variables for Norway and Sweden.

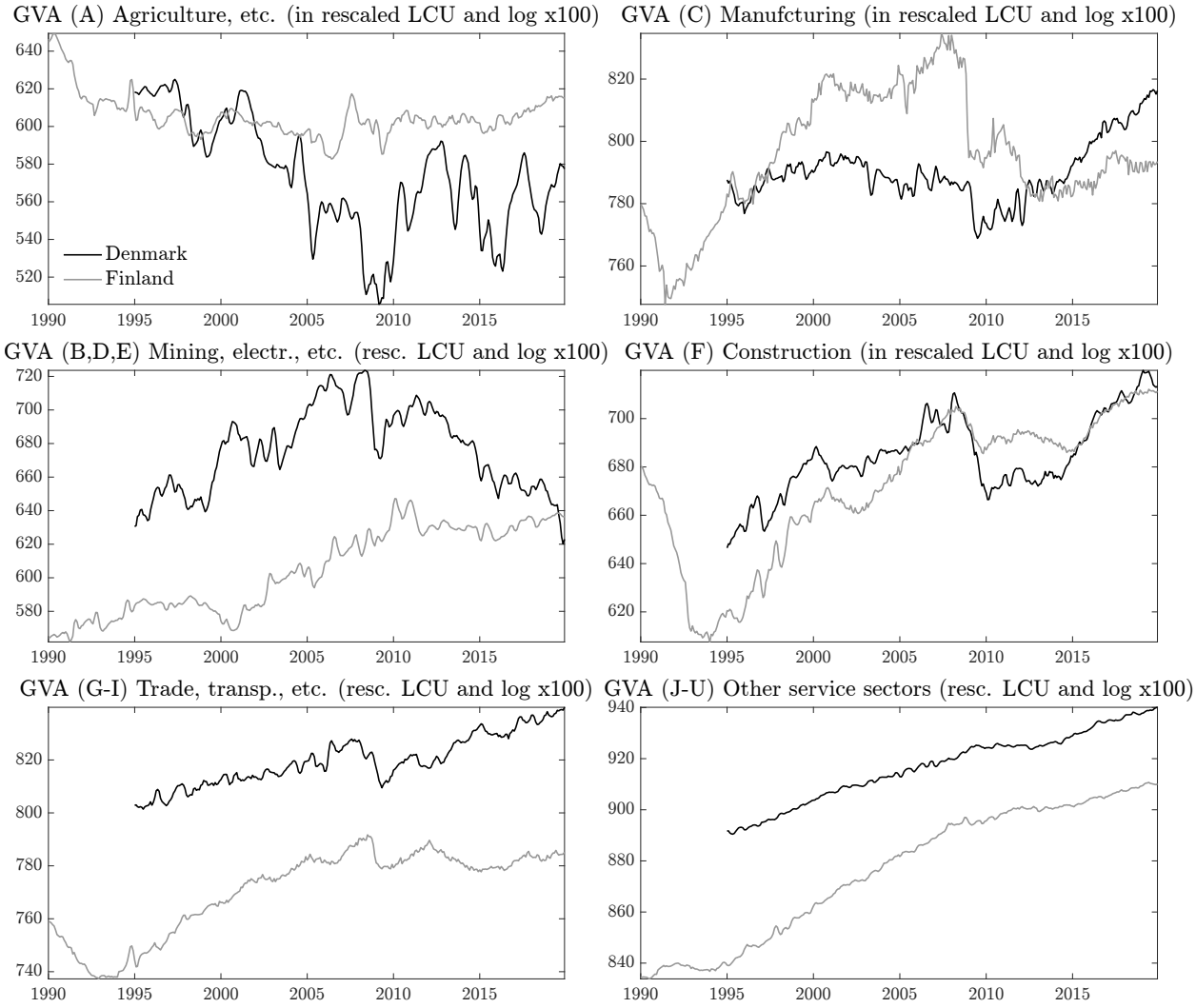

Figure E3: Plots of gross value added (GVA) of various sectors in Denmark and Finland.

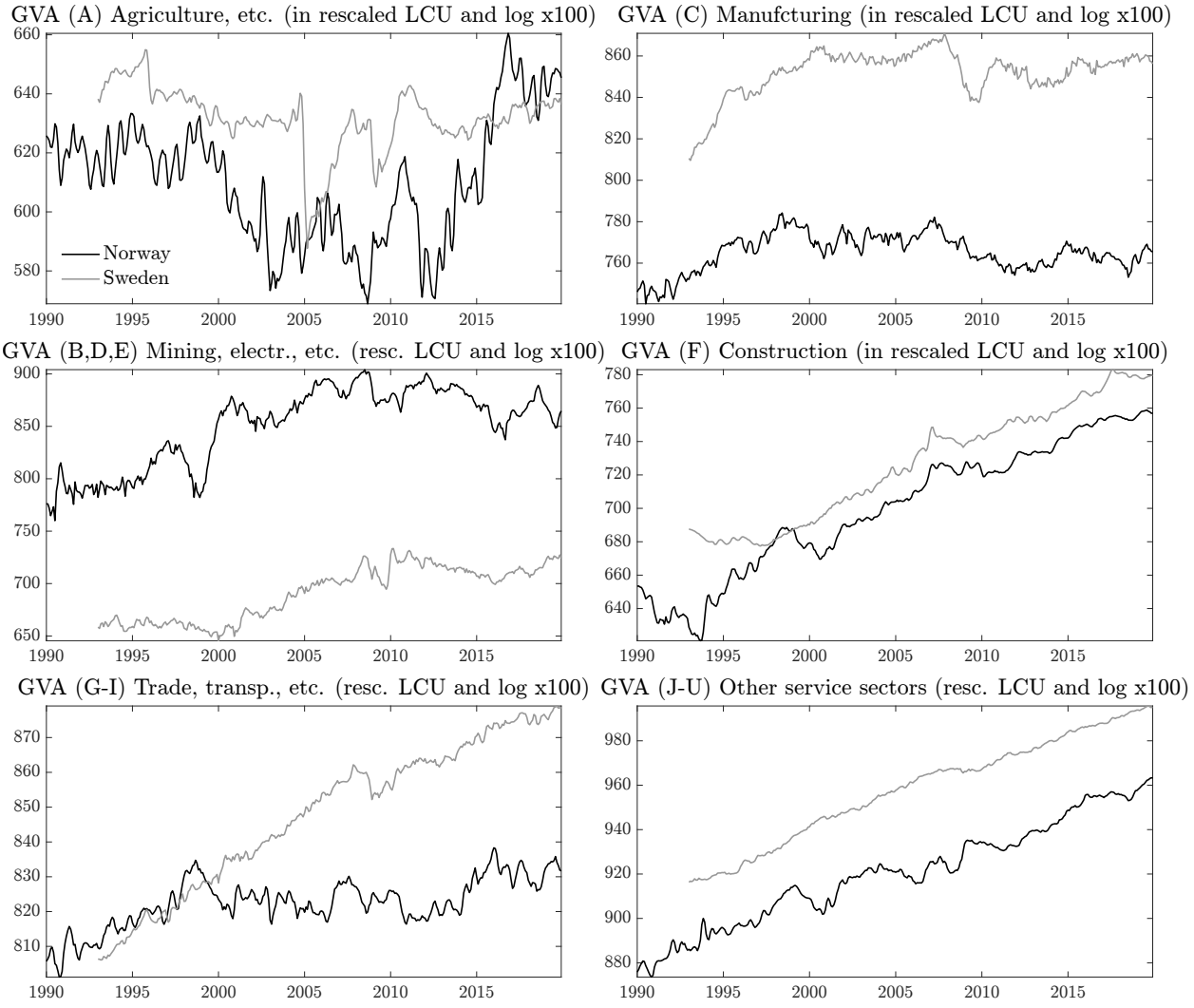

Figure E4: Plots of gross value added (GVA) of various sectors in Norway and Sweden.

F Additional Results

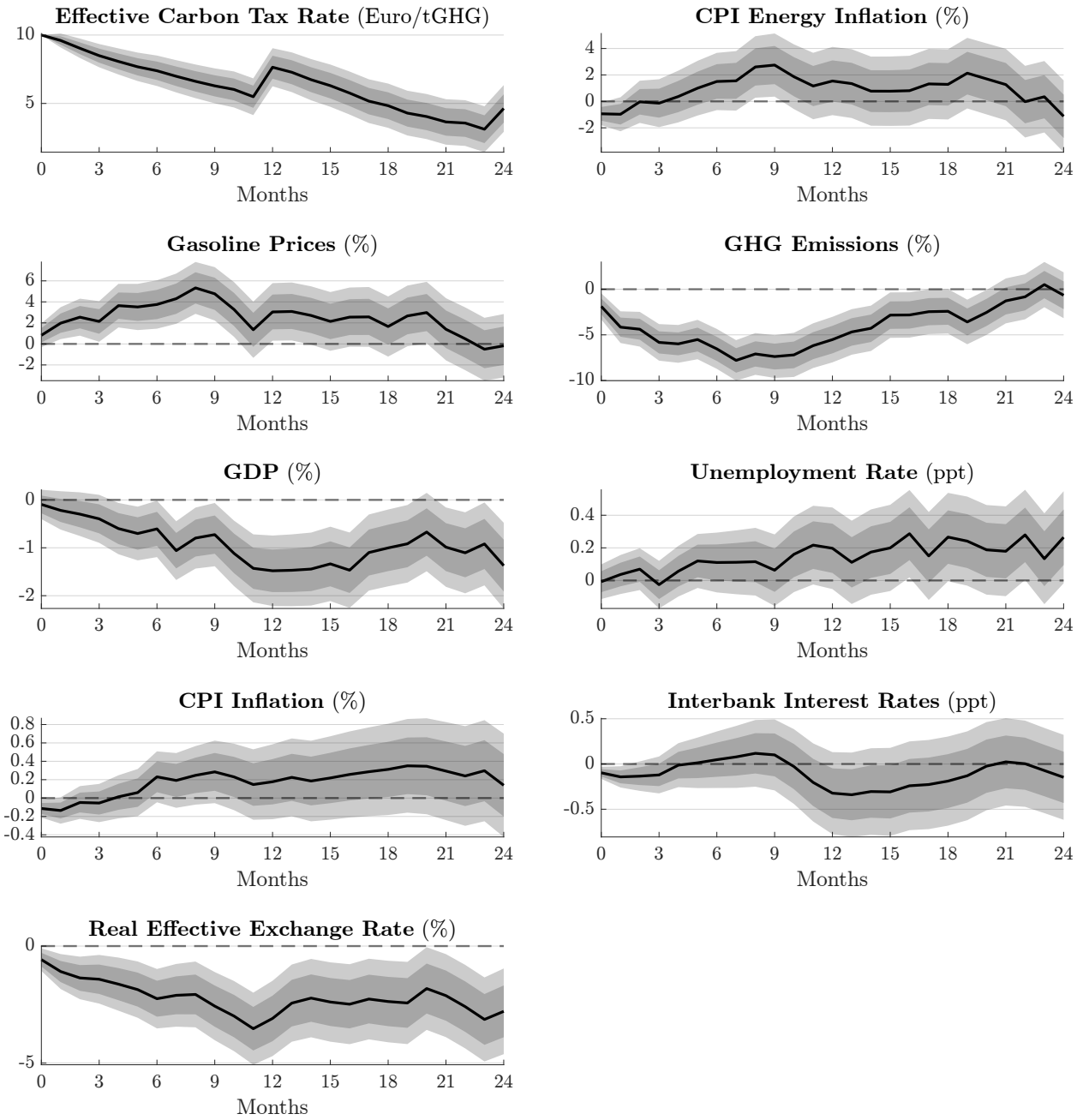

Figure F1: Impulse responses resulting from conventional local projections. Impulse responses of all variables of interest in the 24 months after a temporary increase in the effective carbon tax rate by ten euros. In the underlying analysis, the feature of permanent tax changes, as described in section II, is removed and the conventional approach of local projections is adopted. The dark and light grey areas indicate the 68% and 90% confidence bands.

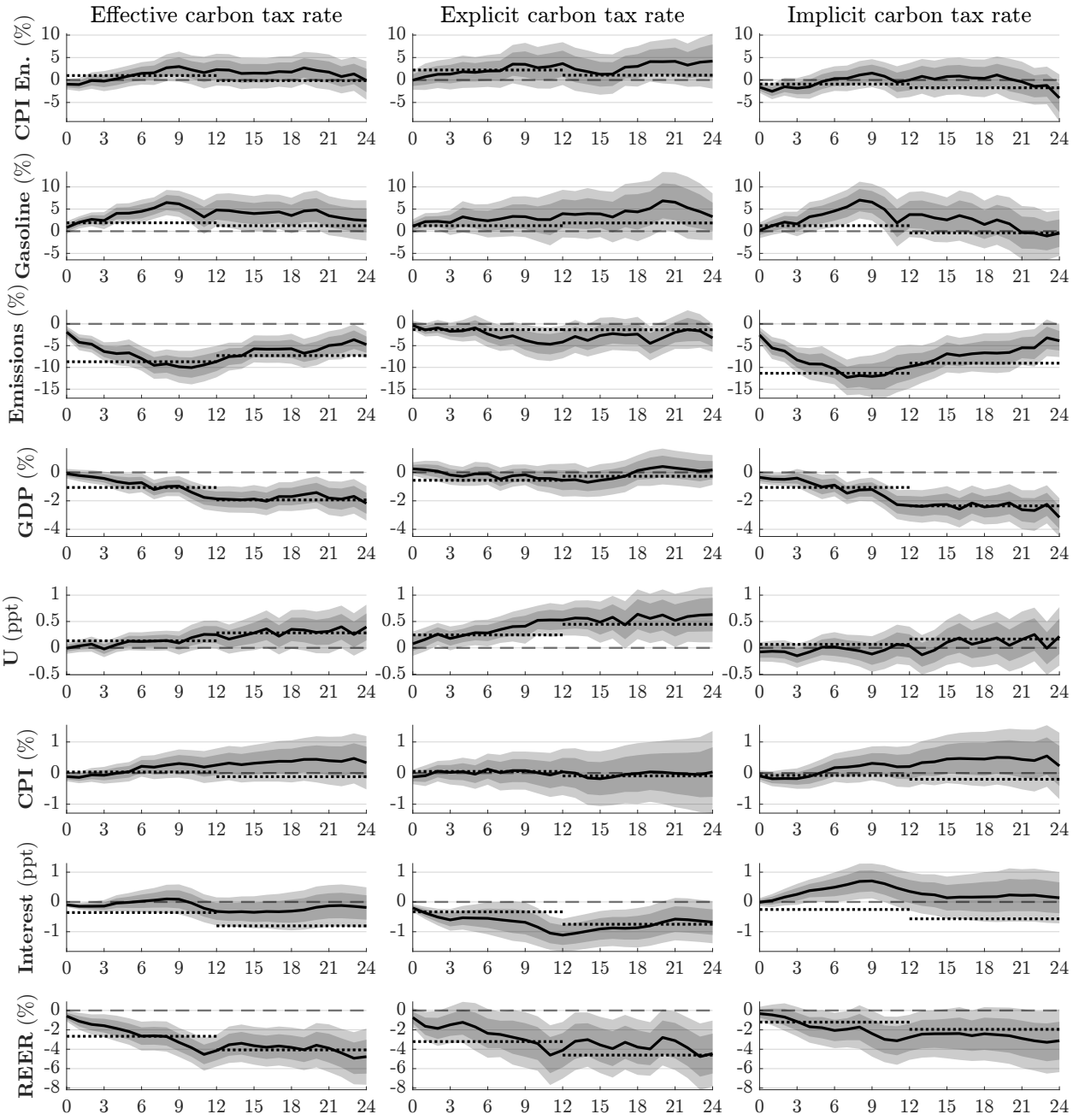

Figure F2: Comparison of impulse responses resulting from monthly and annual data. Impulse responses of all variables of interest (sorted by row) in the 24 months after an increase in the effective, explicit or implicit carbon tax rate (sorted by column) by ten euros. The dark and light grey areas indicate the 68% and 90% confidence bands. The dotted lines show the same impulse response for the first and second year when the empirical model is re-estimated with annual instead of monthly data.

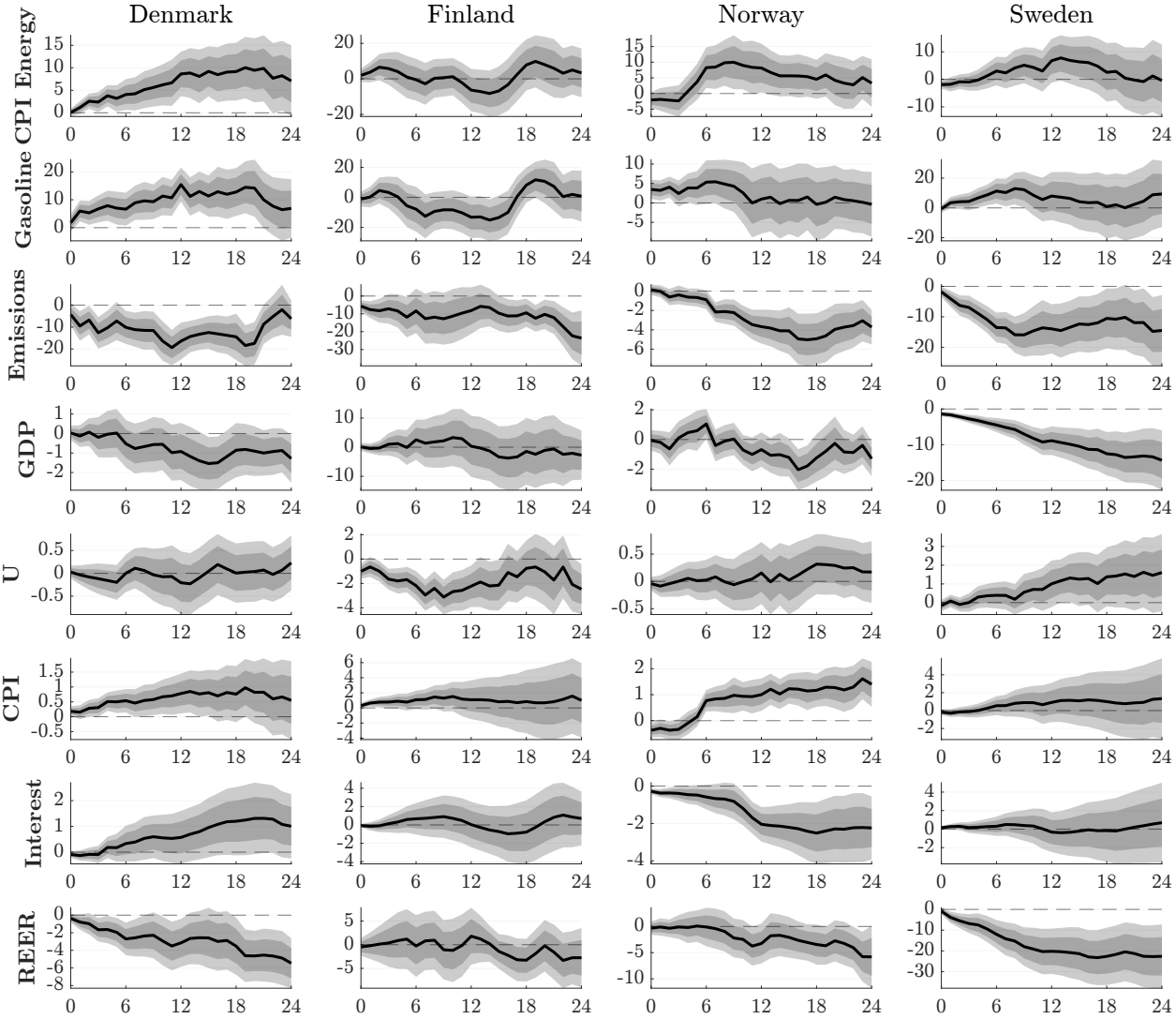

Figure F3: Impulse responses of all variables across the Nordic countries. Impulse responses of all variables of interest (sorted by row) in the 24 months after an increase in the effective carbon tax rate by ten euros for each country separately (sorted by column). The dark and light grey areas indicate the 68% and 90% confidence bands.

G Robustness Tests

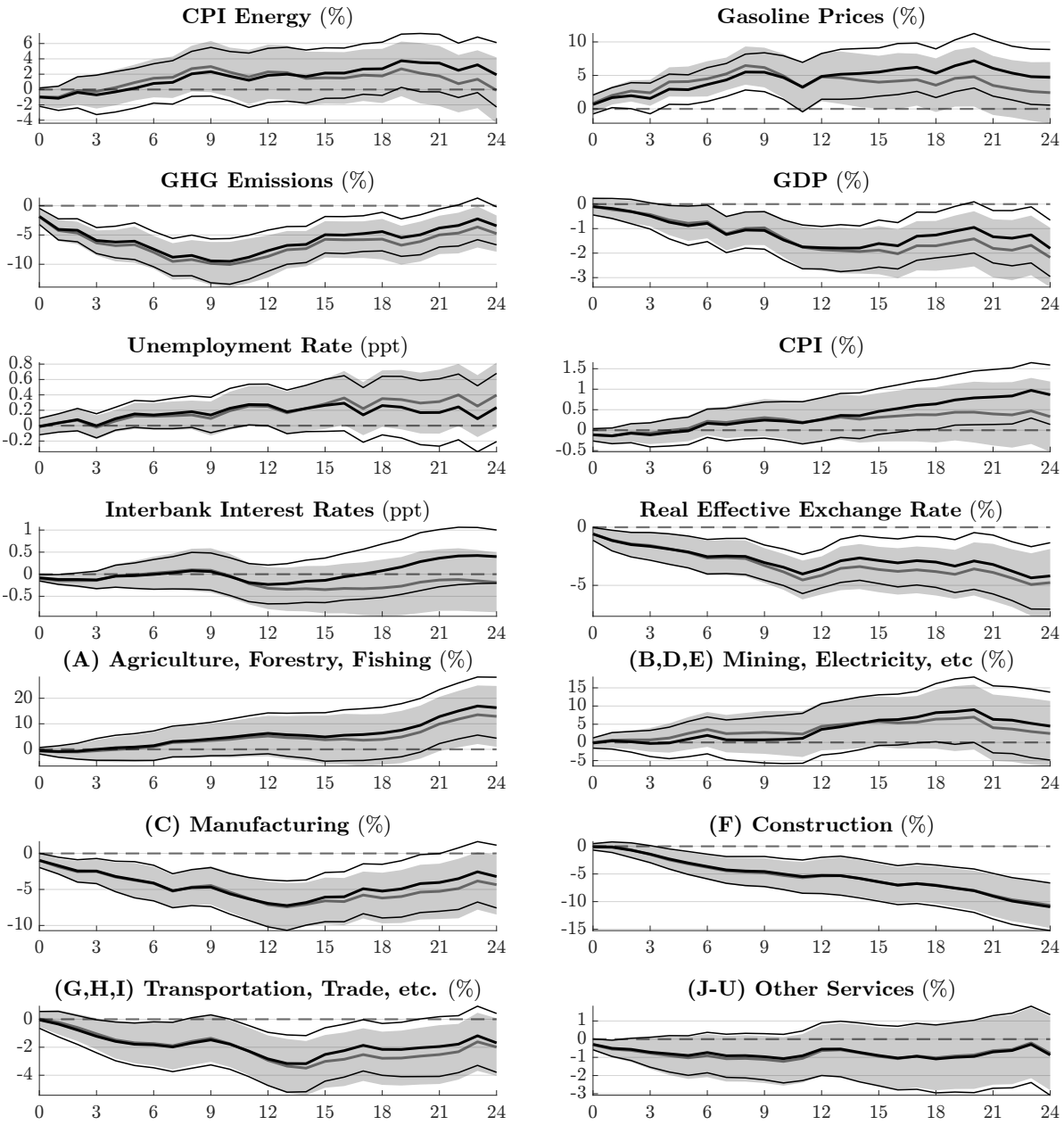

Figure G1: Robustness of impulse responses to the emission permit price of the EU ETS. Results from sections III.C and III.E (dark grey line, shaded area indicates 90% confidence interval) and their robustness to augmenting the model with the emission permit price of the European Union Emissions Trading System (thick black line, area between thin black lines indicates 90% confidence interval).

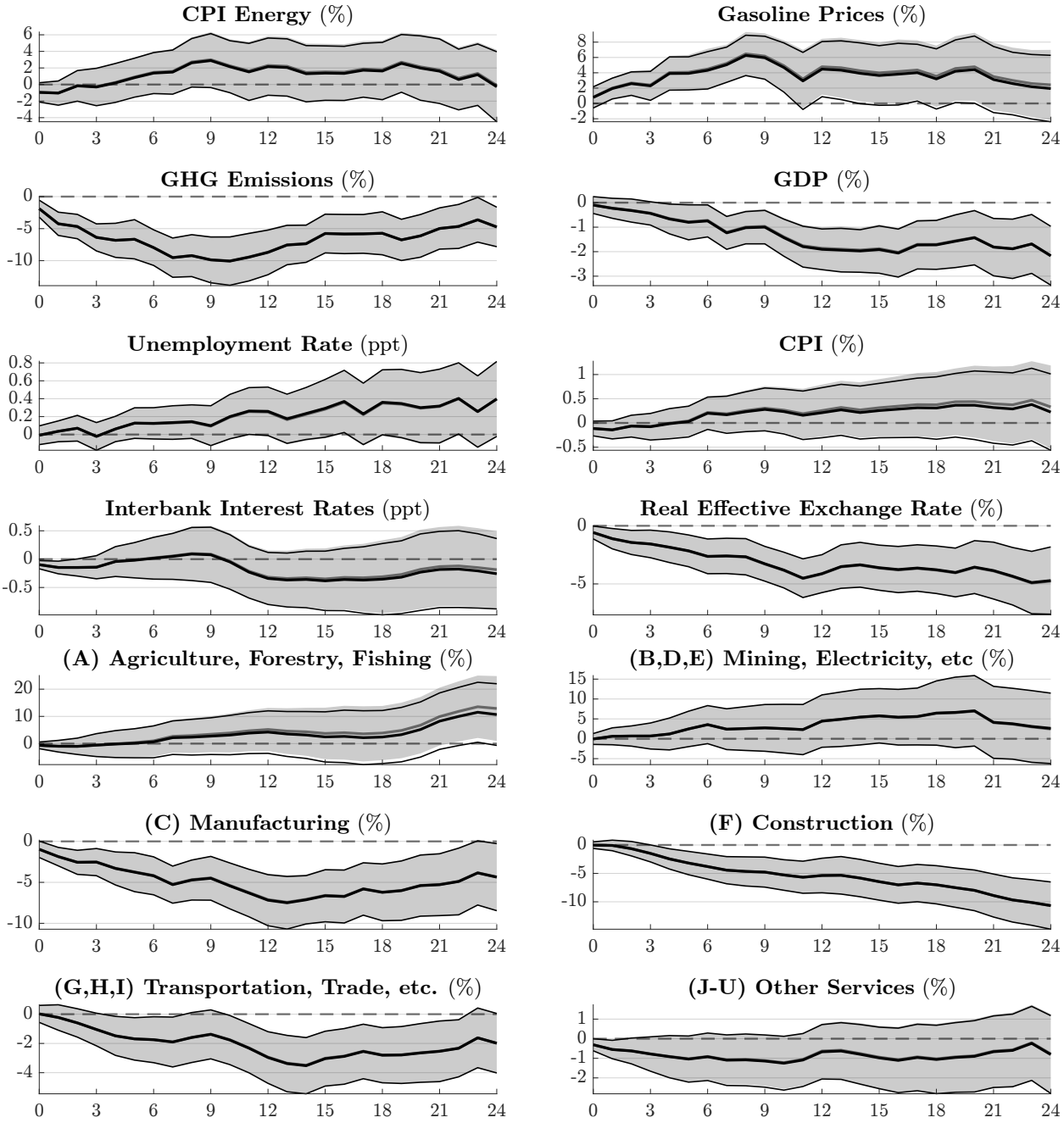

Figure G2: Robustness of impulse responses to the presence of the EU ETS. Results from sections III.C and III.E (dark grey line, shaded area indicates 90% confidence interval) and their robustness to augmenting the model with a dummy for the European Union Emissions Trading System from 2005-2019 (thick black line, area between thin black lines indicates 90% confidence interval).

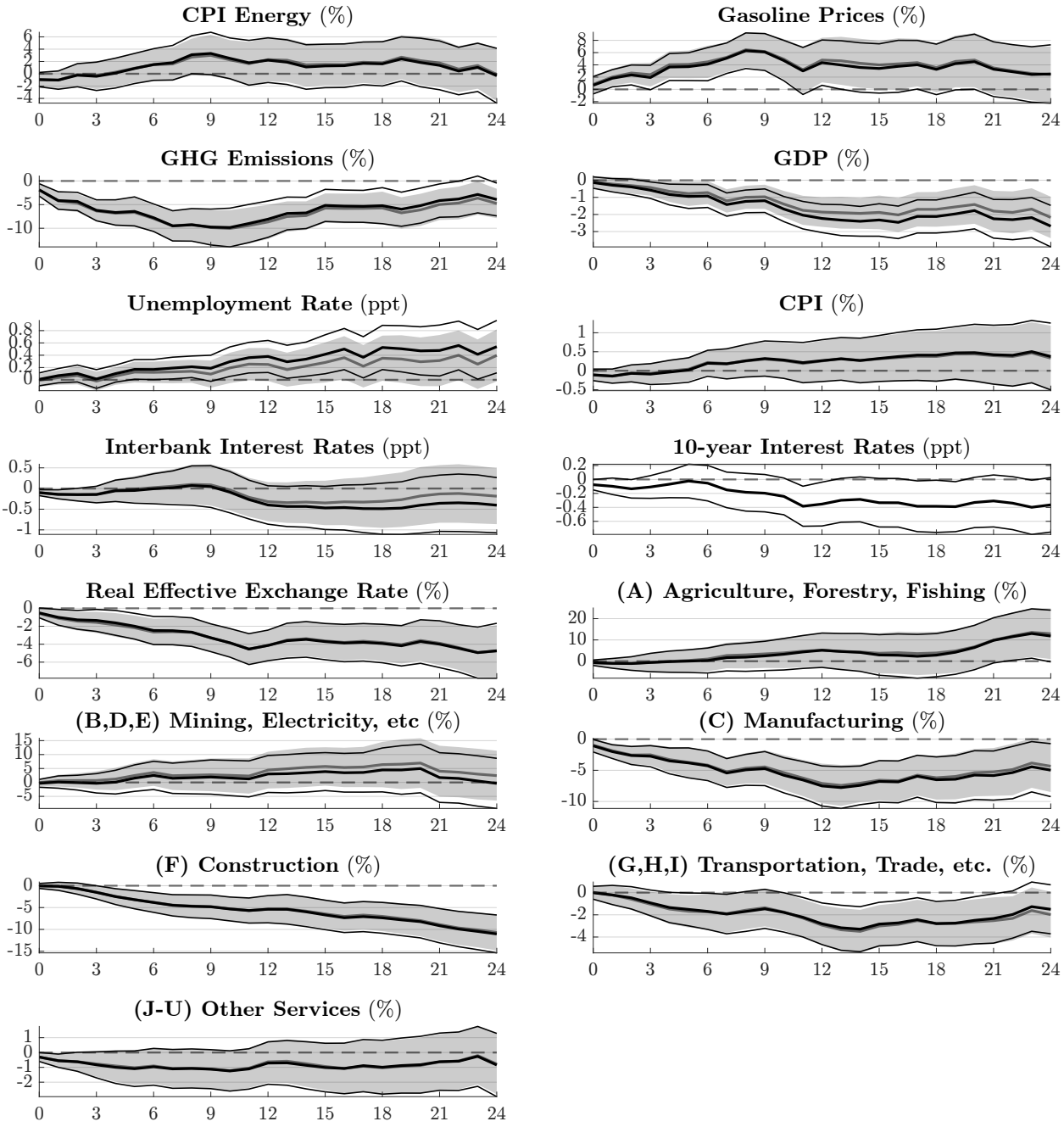

Figure G3: Robustness of impulse responses to the effective lower bound of monetary policy. Results from sections III.C and III.E (dark grey line, shaded area indicates 90% confidence interval) and their robustness to the effective lower bound of monetary policy, which is checked by adding the long-term 10-year interest rate as a ninth variable to the base model (thick black line, area between thin black lines indicates 90% confidence interval).

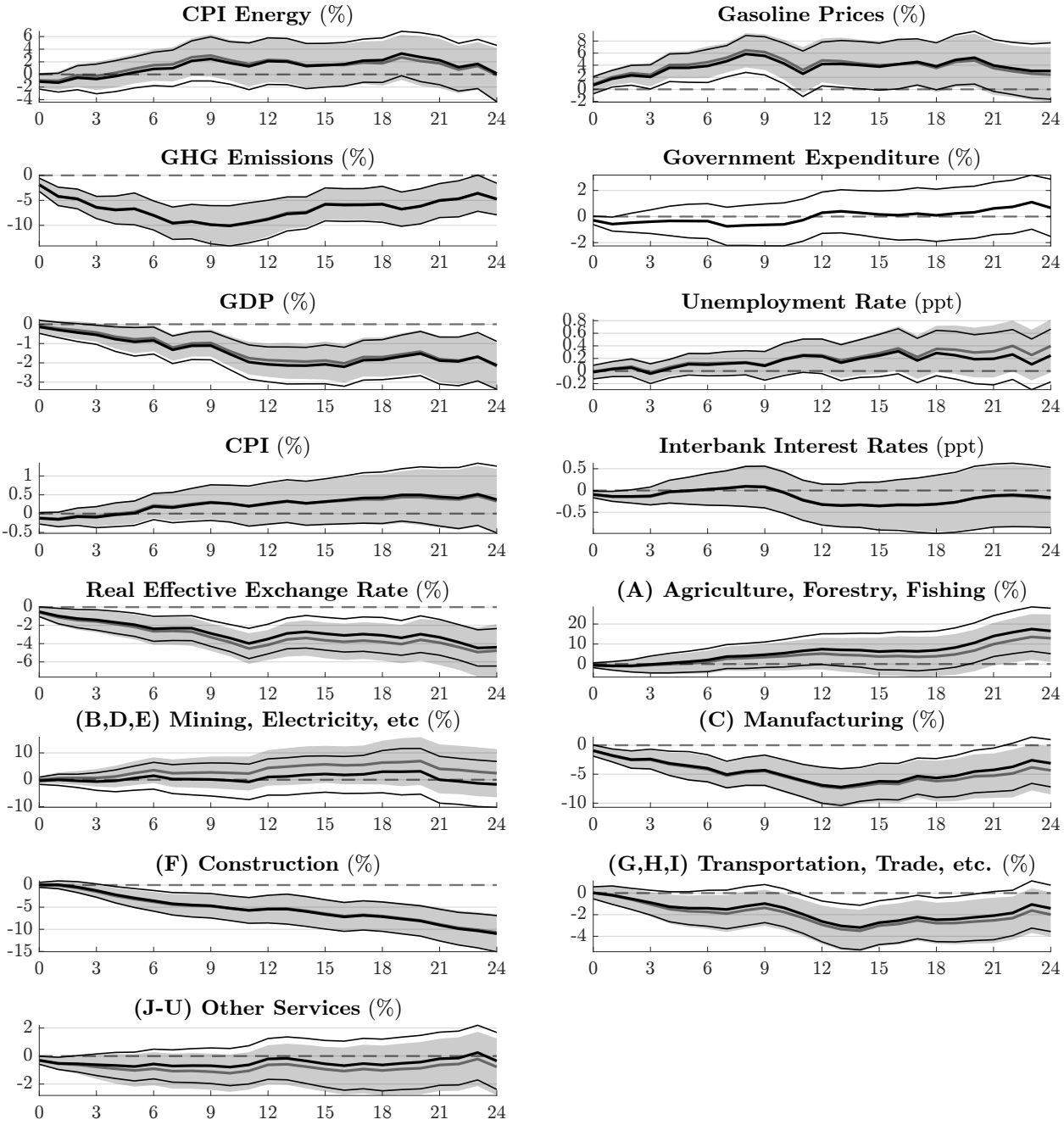

Figure G4: Robustness of impulse responses to fiscal spending. Results from sections III.C and III.E (dark grey line, shaded area indicates 90% confidence interval) and their robustness to augmenting the base model with government expenditure (thick black line, area between thin black lines indicates 90% confidence interval).

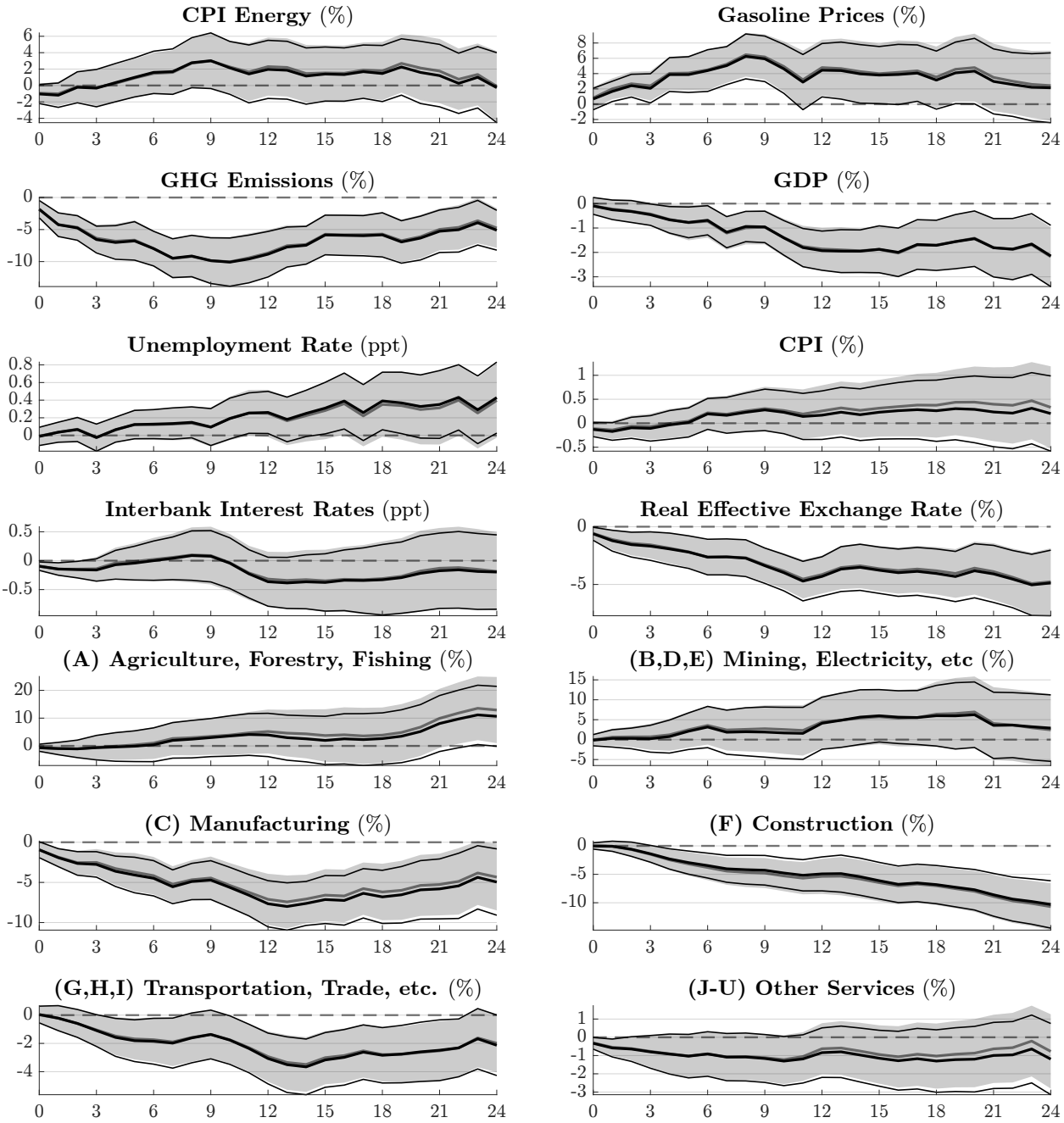

Figure G5: Robustness of impulse responses to a potential anticipation of carbon tax rates. Results from sections III.C and III.E (dark grey line, shaded area indicates 90% confidence interval) and their robustness to the anticipation of carbon tax rate by adding the log of the real stock price index as additional variable in the system ordered above the tax rate (thick black line, area between thin black lines indicates 90% confidence interval).

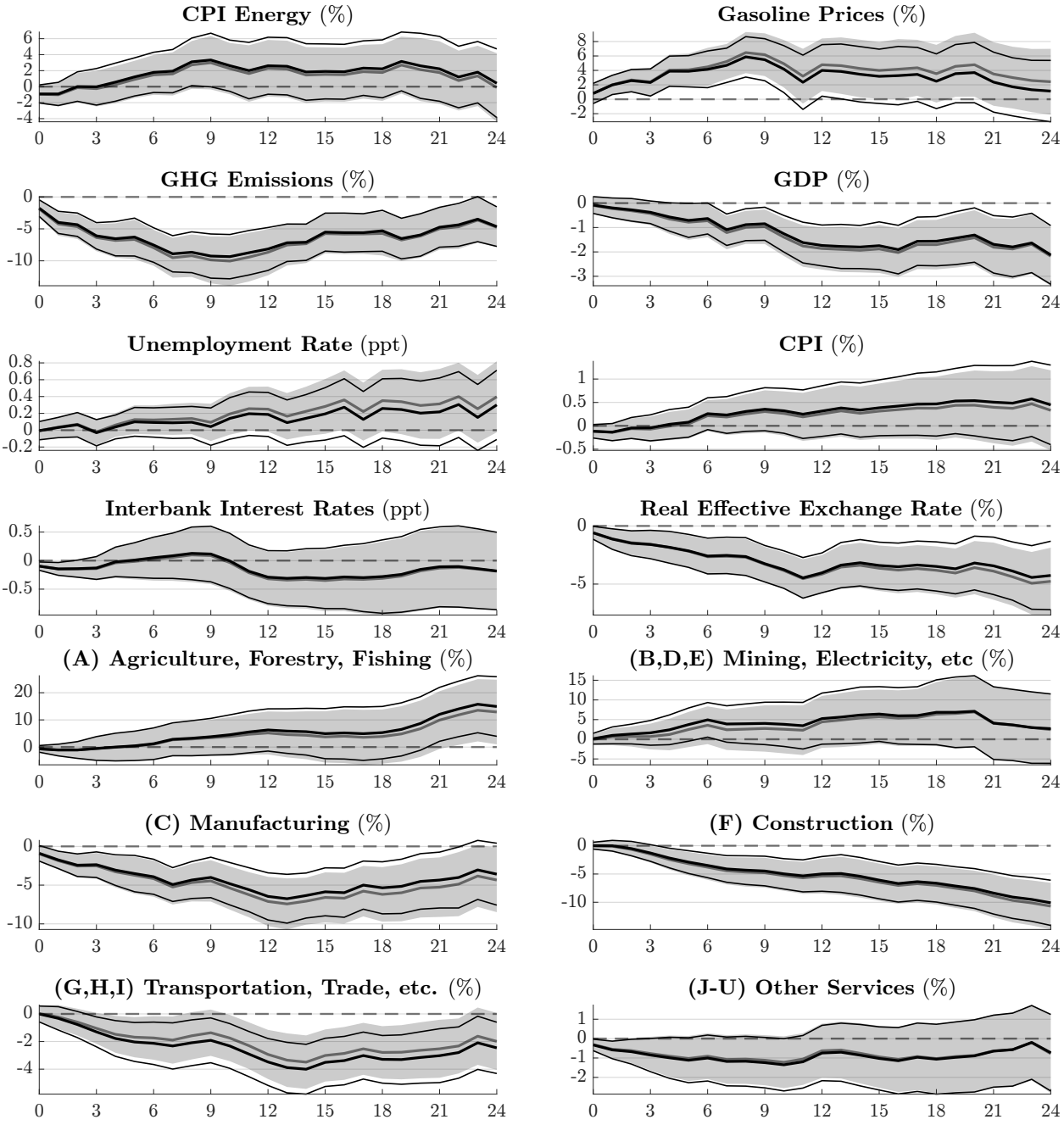

Figure G6: Robustness of impulse responses to the general tax burden of the economy. Results from sections III.C and III.E (dark grey line, shaded area indicates 90% confidence interval) and their robustness to augmenting the model with the total tax revenue as a share of GDP (thick black line, area between thin black lines indicates 90% confidence interval).

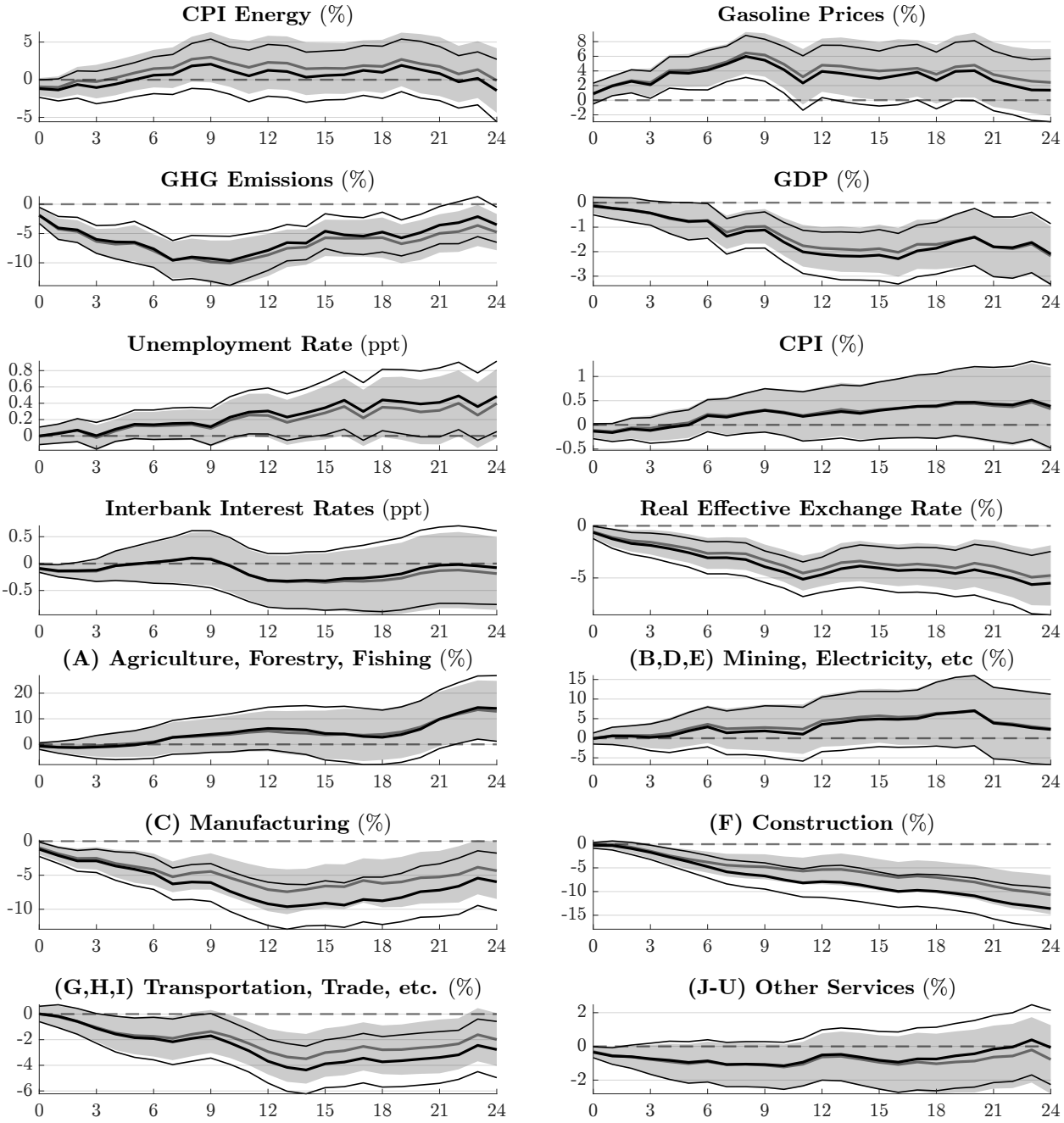

Figure G7: Robustness of impulse responses to simultaneous adjustments of electricity taxes. Results from sections III.C and III.E (dark grey line, shaded area indicates 90% confidence interval) and their robustness to augmenting the model with average tax rates on electricity (thick black line, area between thin black lines indicates 90% confidence interval).

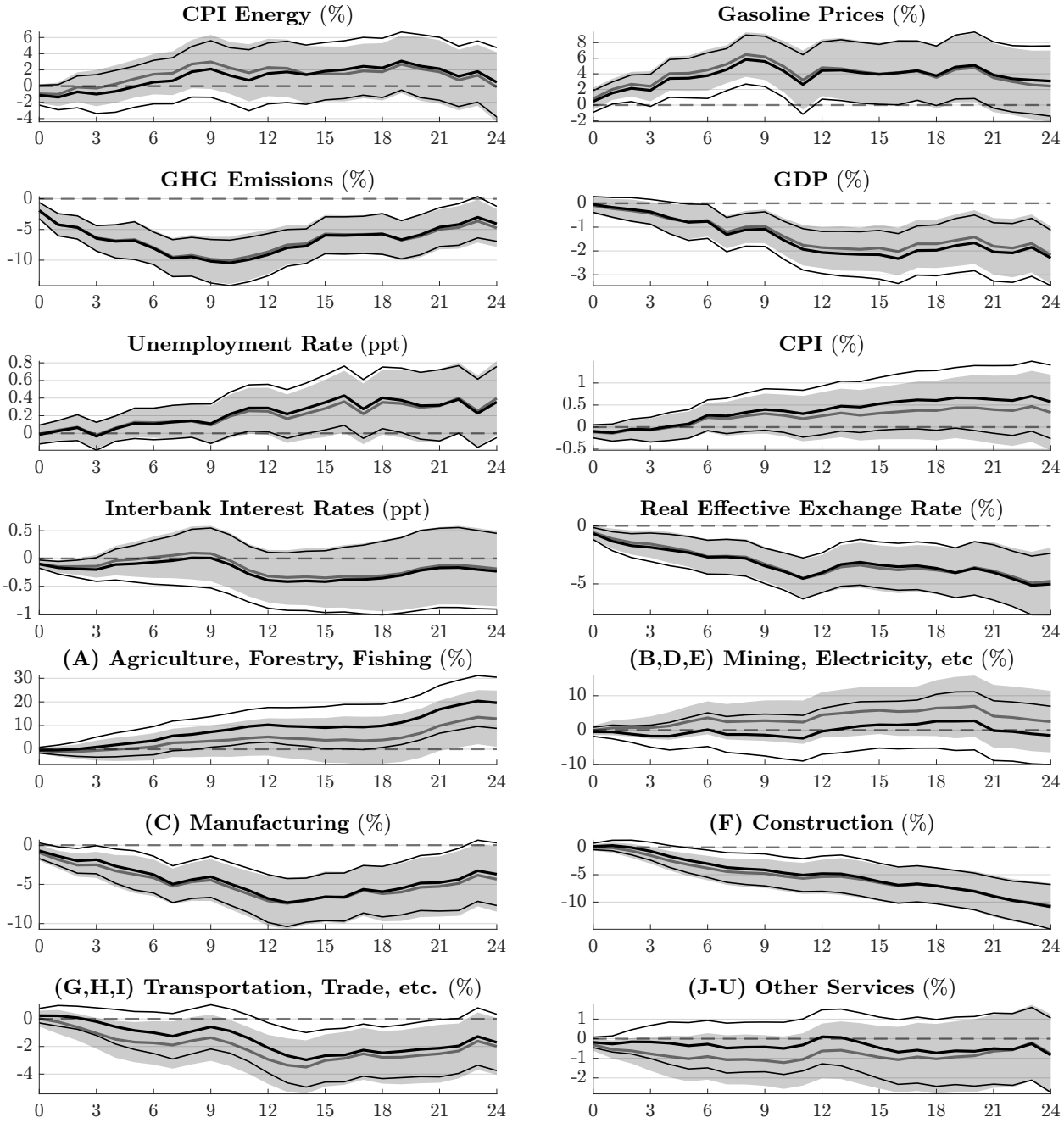

Figure G8: Robustness of impulse responses to changes in commodity prices. Results from sections III.C and III.E (dark grey line, shaded area indicates 90% confidence interval) and their robustness to augmenting the model with the commodity terms of trade net export price index (thick black line, area between thin black lines indicates 90% confidence interval).

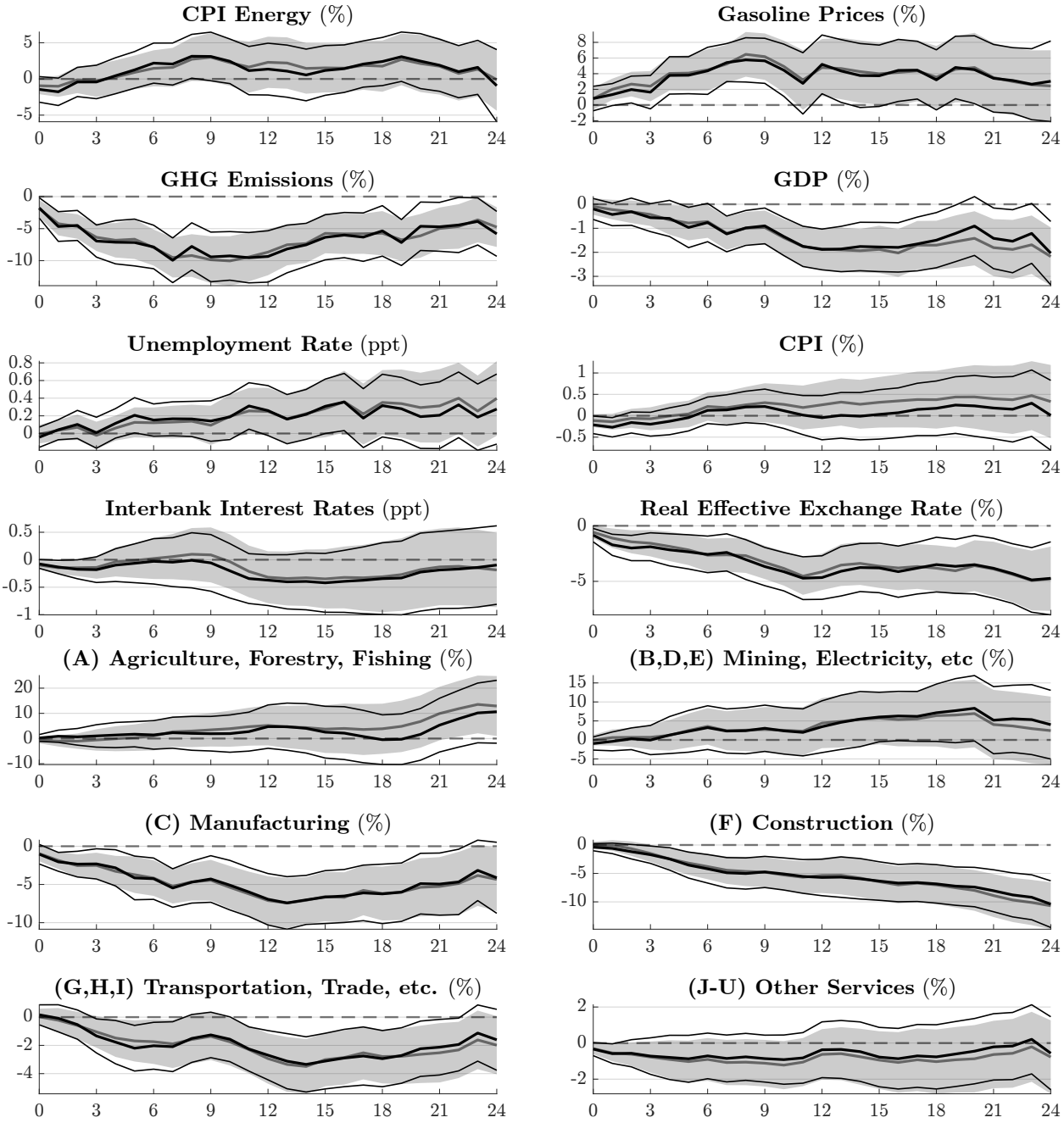

Figure G9: Robustness of impulse responses to seasonality. Results from sections III.C and III.E (dark grey line, shaded area indicates 90% confidence interval) and their robustness to augmenting the model with monthly dummies to check for seasonality (thick black line, area between thin black lines indicates 90% confidence interval).

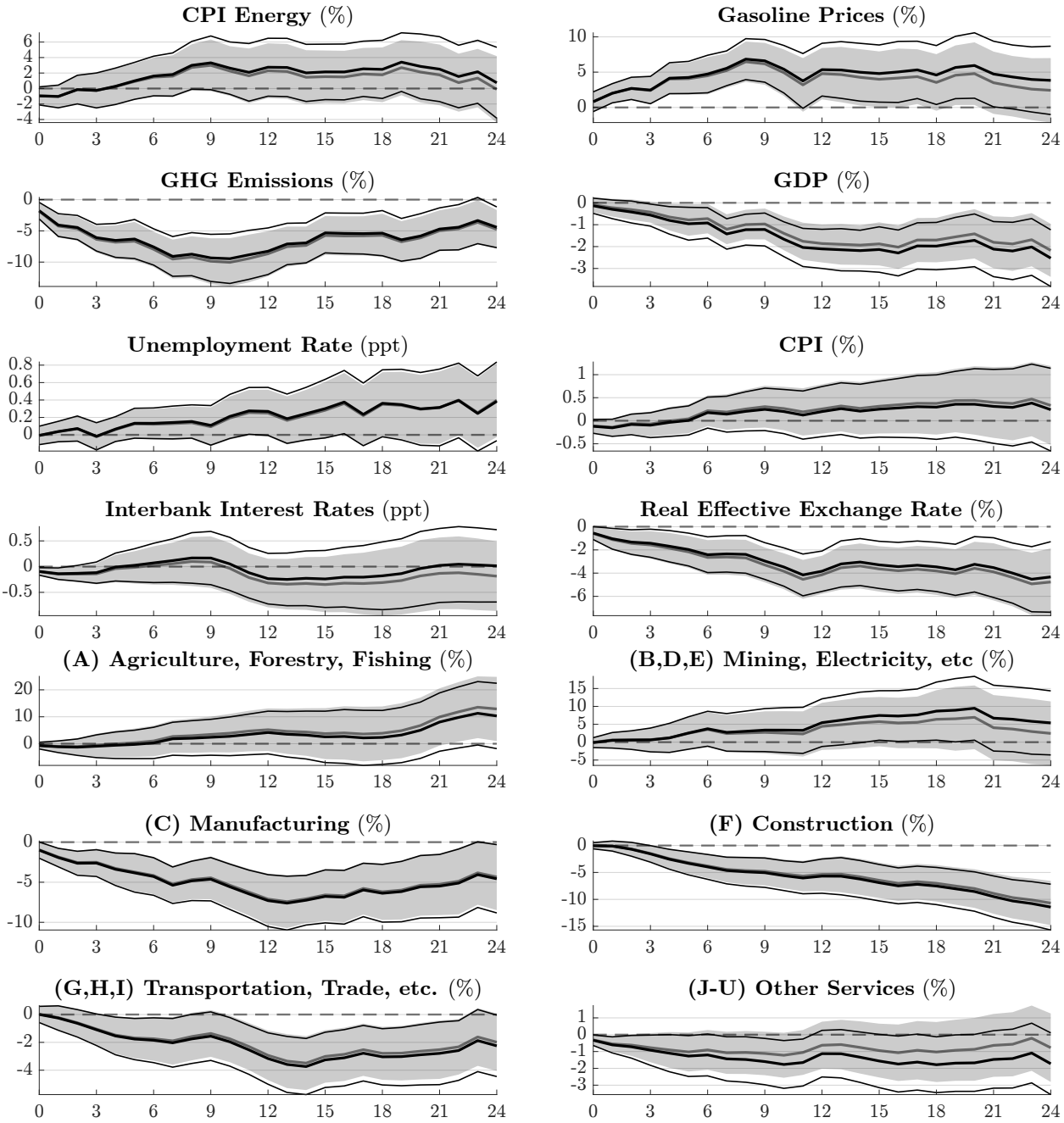

Figure G10: Robustness of impulse responses to trends in the variables. Results from sections III.C and III.E (dark grey line, shaded area indicates 90% confidence interval) and their robustness to augmenting the model with a trend (thick black line, area between thin black lines indicates 90% confidence interval).

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