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## Article

# Green tax shocks and economic growth

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## Green Tax Shocks and Economic Growth

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### ABSTRACT

The purpose of this paper is to examine the long-run relationship between green tax and economic growth. Specifically, it utilizes the sign-restrictions structural vector autoregressions (VAR) to examine whether green tax is growth-enhancing or growth-inhibiting. Using data on the Danish economy for the period 1975-2017, the results reveal that green tax shocks trigger opposite movements in non-renewable and renewable energy consumption, and a mild transitory decrease in economic growth. The study also compares green tax shocks in the pre- and post-Carbon tax periods and finds that how the Danish economy experiences green tax shocks has not fundamentally changed since the introduction of Carbon tax in 1992. Taken together, the findings suggest that green tax is effective in increasing reliance on renewable energy while decreasing non-renewable energy consumption without seriously inhibiting economic growth.

**Keywords:** Green Tax, Carbon Tax, Economic Growth, Structural Var

**JEL Classifications:** E62, O44, Q43

### 1. INTRODUCTION

There has been a growing recognition that energy-related taxes play a crucial role in transforming economies to become greener. By reflecting externalized costs from high-carbon fossil fuel production and consumption, energy-related taxes signal the market to shift production, consumption, and investments to lower-carbon alternatives. While this corrective ability of energy-related taxes is well-documented in the environmental taxation literature (William, 2016), not much is known about their long-run macroeconomic effects. Are energy-related taxation, such as green tax, growth-enhancing or growth-inhibiting? Earlier studies on this issue have been theoretical, either using green (environmental) taxes in an endogenous growth framework (Bovenberg and de Mooij, 1994, 1997; Hettich, 1998; Musu, 1996; Ricci, 2007; Schou, 2000) or as a general measure of green energy policy (Koskela and Schob, 1999; Nielsen et al., 1995; Schneider, 1997). Recent studies have mainly been empirical or simulation-based and focus on examining the causal effect of green (environmental) taxes on growth by modeling green taxes

as exogenous. For example, Metcalf (2015) used difference-in-difference regressions of provincial gross domestic product (GDP) in Canada from 1999 to 2013 to test whether growth rates in British Columbia differed from the rest of Canada after the imposition of the carbon tax. The study finds no statistically significant effect of carbon tax on the province's economic growth. Brannlund et al. (2014) used a two-step regression analysis and find that carbon tax played a significant role in explaining the low emission intensity manufacturing output growth that occurred in Sweden between 1990 and 2004. Conefrey et al. (2012) analyzed the medium-term effects of a carbon tax on economic growth and CO<sub>2</sub> emissions in Ireland using the HERMES macroeconomic simulation model, and find that the volume of GDP decreases as a result of the carbon tax. Another simulation study by Cao et al. (2013) examined the economics of environmental policies in China. The study finds that on the one hand, sulphur tax policy negatively affects aggregate output under a flue gas desulfurization (FGD) scenario but positively affects aggregate output under a shutdown policy and a combined shutdown and FGD scenarios. On the other hand, carbon tax policy negatively impacts aggregate output under

all scenarios (lump sum transfer and reduced other taxes). In a comprehensive review of studies that apply computable general equilibrium models to environmental taxation and economic growth, Freire-Gonzalez (2018) concluded that the relationship between environmental taxes and economic growth remains an ambiguous question that needs further research.

These empirical and simulation-based studies provide very important insights about the relationship between green (environmental) taxes and economic growth. But because taxes in general or green taxes in particular are themselves likely to be influenced by the very factors they seek to explain, exogenously specified empirical or simulation-based models reduces the information set about the endogenous nature of the relationship between green taxation and economic growth. Thus, this study departs from recent empirical studies by electing to use the innovation-accounting techniques of structural vector autoregressive (VAR) model which is potentially more informative, because it endogenizes the taxation-economic growth relationship. The choice of VAR modeling is also influenced by a growing literature that employs VARs to analyze the impact of fiscal policy shocks on the macroeconomy (see for example Blanchard and Perotti, 2002; Burnside et al., 2003; Eichenbaum and Fisher, 2004; Fatas and Mihov, 2001; Favero, 2002; Gali et al., 2007; Mountford and Uhlig, 2009).

This paper adds to existing literature by opening a new window towards modeling the long-run macroeconomic effects of green (environmental) taxes. Specifically, it utilizes the sign restrictions structural VAR model to examine whether green tax shocks are growth-enhancing or growth-inhibiting. To account for the mediatory role of energy consumption, non-renewable energy and renewable energy consumption are included in the VAR model. The model is operationalized using data on the Danish economy for the period 1975-2017.

Several interesting results emerge from the analysis. First, a green tax shock trigger opposite movements in non-renewable energy and renewable energy consumption, and a mild transitory decrease in real output growth. Second, non-renewable energy shock is contractionary while renewable energy shock is expansionary. Third, both non-renewable and renewable energy shocks depress green tax revenue, although the latter's effect is temporary. Fourth, there is a reverse asymmetric relationship between the two measures of energy consumption. In particular, following a non-renewable energy shock, renewable energy consumption increases with a delay of about 2 years whereas the decline in non-renewable energy consumption following a renewable energy shock is instantaneous. Finally, comparisons of green tax shocks in the pre- and post-Carbon tax periods show that the way the Danish economy experiences green tax shocks has not fundamentally changed since the introduction of Carbon tax in 1992. All together, the findings suggest that green tax is effective in increasing reliance on renewable energy while decreasing non-renewable energy consumption without seriously inhibiting economic growth.

The rest of the paper is organized as follows. Section 2 provides a brief overview of the empirical model for examining the

relationship between green tax and economic growth. Section 3 operationalizes the empirical model using data on the Danish economy. Section 4 presents and discusses the results. Conclusions are summarized in Section 5.

## 2. METHODOLOGY

There exists no “typical” empirical model for examining the relationship between green tax and economic growth. However, in the taxation-economic growth literature, it is common to specify a growth model based on some form of a production function and then add the tax variables of interest to examine the effects of taxation on economic growth (Adkisson and Mohammed, 2014; Arnold et al., 2011). But because of potential simultaneity between tax variables and economic growth, such specification reduces the information set about the endogenous nature of the relationship between taxation and economic growth. Thus, this study utilizes the innovation-accounting techniques of structural VAR model which are potentially more informative.

The study elected for a VAR containing four variables. Here, the variables are described only briefly. Full details and sources of all series are provided in Section 3. Real GDP growth is the annual rate of economic growth. The three other series in the VAR are non-renewable energy consumption, renewable energy consumption, and government revenue from green tax. The primary interest of the study is to examine the effect of green tax on economic growth. Non-renewable energy consumption and renewable energy consumption are included in the model to permit green tax to operate indirectly on economic growth through changes in non-renewable and renewal energy consumption. Additionally, to account for endogeneity, the effect of economic growth on green tax is examined. Also examined is how non-renewable and renewable energy consumption affect and are each affected by green tax and economic growth.

The analysis is based on the following structural VAR model:

$$A_0 y_t = \alpha + \sum_{i=1}^n A_i y_{t-i} + \varepsilon_t \quad (1)$$

where  $y_t$  denotes a vector time series consisting of the growth rates of real GDP ( $RGDP_t$ ), non-renewable energy consumption ( $NREC_t$ ), renewable energy consumption ( $REC_t$ ), and government revenue from green tax ( $GRNT_t$ ). The vector  $\varepsilon_t$  consists of four structural shocks. The first shock is an output shock common in macroeconomic shocks literature (Bargain, et al., 2012; Campbell and Mankiw, 1987; Keating and Nye, 1998; Mohammed, 2018; Rogers, 1995). The second and third shocks are new shocks introduced by the study and respectively referred to as non-renewable energy consumption shock and renewable energy consumption shock. These shocks are designed to capture unexpected changes in non-renewable energy and renewable energy consumption. The study also introduces a fourth shock referred to as green tax shock designed to capture unexpected green tax policy shifts.

To identify the shocks, the study uses the sign restrictions approach in Uhlig (2005) and Mountford and Uhlig (2009) which allows the identification of shocks by directly restricting the signs of their impulse responses. The identifying sign restrictions on the impulse responses are provided in Table 1, each of which is discussed as follows. First, an output shock (such as increases in real output) will increase economic growth, non-renewable consumption, and renewable energy consumption. This shock is also expected to positively co-move with green tax revenue since economic growth drives non-renewable energy consumption on which the green tax is levied. Second, a non-renewable energy shock (such as exogenous oil shocks) will lower economic growth, lower non-renewable energy consumption but increase renewable energy consumption and decrease green tax revenue because of the decrease in non-renewable energy consumption. Third, a renewable energy shock (which may result from a new green energy technology) will increase renewable energy consumption and economic growth but lower non-renewable energy consumption. The impact of renewable energy shock on green tax revenue will be negative since it decreases non-renewable energy consumption. Finally, a green tax shock (such as a sudden increase in the tax rate for fossil-based energy consumption) will lower non-renewable energy consumption, increase renewable energy consumption, decrease green tax revenue, but may or may not affect economic growth. Consequently, no restriction is imposed on economic growth's response to green tax shock. These set of identifying restrictions imposed in Table 1 implies a unique response pattern for each structural shock and are used to operationalize the VAR model in Equation (1).

### 3. UNDERSTANDING THE EFFECTS OF GREEN TAX SHOCKS ON ECONOMIC GROWTH

A question of considerable interest is how green energy tax shocks relates to economic growth. Denmark is one of the early adopters

**Table 1: Sign restrictions**

Shock/Variable	RGDP	NREC	REC	GRNT
Output shock	+	+	+	+
Non-renewable energy shock	-	-	+	-
Renewable energy shock	+	-	+	-
Green tax shock		-	+	-

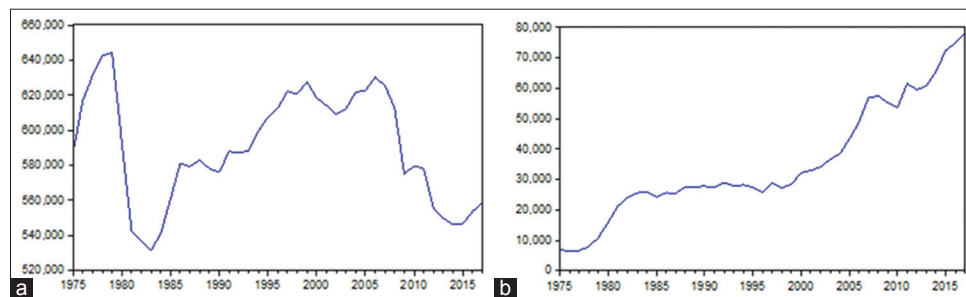
Missing entries mean that no sign restriction is imposed. RGDP: Real GDP, NREC: Non-renewable energy consumption, REC: Renewable energy consumption, GRNT: Government revenue from green tax

of green energy taxes. Thus, the study addresses this question using data on the Danish economy. Annual energy consumption data is obtained from the Danish Energy Agency (DEA) Energy Statistics. The DEA reports final energy consumption and categorizes it into non-renewable and renewable sources. Green tax revenue data is collected from the Danish Ministry of Taxation. Green tax comprises of energy taxes, motor vehicle taxes, and environmental taxes. Energy taxes includes tax on coal, oil, natural gas, and electricity. Motor vehicle taxes include fuel consumption tax, registration and insurance tax, and road toll. Environment taxes spans a wide range of items; most notable are CO<sub>2</sub> tax, NO<sub>x</sub> tax, and CFC tax. Carbon tax was passed in 1991 and took effect in 1992. When the Carbon tax passed, it increased environmental taxes. To maintain the overall tax rate, policymakers included a subsequent decrease in energy taxes (Sumner et al., 2009). The real GDP data is obtained from the World Bank World Development Indicators. Both green tax revenue and real GDP are expressed in Danish krone.

As indicated in Figure 1, energy consumption in Denmark since 1975 is very different across non-renewable energy (oil, coal, and natural gas) and renewable energy (wind, solar, and biomass). Non-renewable energy consumption are considerably higher than renewable energy consumption despite the sharp decline in the former following the 2008 downturn. Figure 2 displays Denmark's real GDP. Until the 2008 recession, real GDP increased steadily. Moreover, the initial decline in real GDP in 2007 that led to the 2008 downturn coincided with the peak of non-renewable energy consumption. During the downturn, while both real GDP and non-renewable energy consumption declined, renewable energy consumption soared. Green tax revenue is depicted in Figure 3. Although it does not vary much with movements in non-renewable and renewable energy consumption, its pattern since 1975 is remarkably identical to real GDP. Could changes in green tax explain changes in real economic activity or vice versa? Do renewable and non-renewable energy consumption play a role in the green tax-economic growth nexus?

To empirically examine these questions, the study operationalizes the model in Equation (1) using the annual data on Denmark's energy consumption (non-renewable and renewable), green tax revenue, and real GDP from 1975-2017 (Data sources are discussed at the beginning of this Section). The sample period is dictated by the availability of energy consumption data. All variables are transformed to annual growth rate by taking their logs. To estimate Equation (1), one must limit the lag lengths. With 43 years of annual data and  $n = 4$ ,

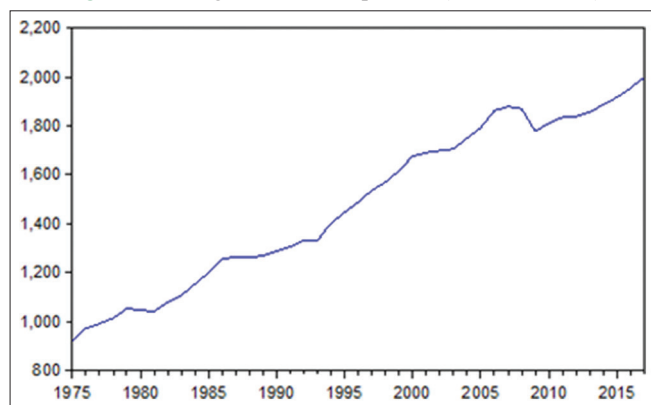
**Figure 1: Energy consumption (in thousand joules). (a) Non-renewable energy; (b) Renewable energy**



Source: Danish energy agency energy statistics

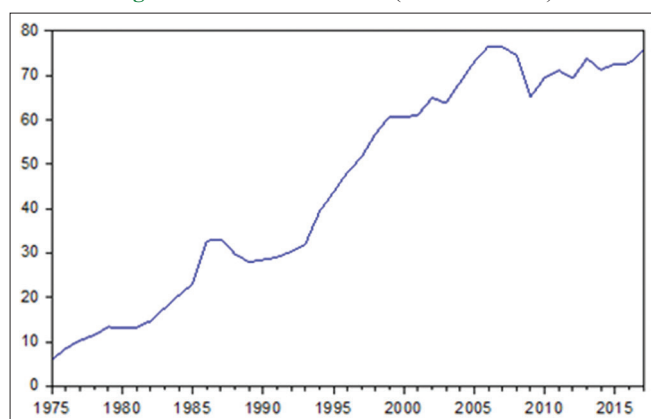


**Figure 2:** Real gross domestic product (in billion DKK)



Source: World Bank World Development Indicators

**Figure 3:** Green tax revenue (in billion DKK)



Source: Danish ministry of taxation.

the study experimented with lag lengths up to six and found that little was gained by allowing for longer than three lags. Thus, the VAR is estimated using three lags for the sample period under consideration. Results for lags longer than three are reported in the Appendix.

## 4. RESULTS

### 4.1. Main Results

Figures 4-7 show the estimated impulse responses of economic growth, non-renewable energy consumption, renewable energy consumption, and green energy tax revenue to a 1% structural innovation in each of the four shocks, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands. The vertical axis is the direction and magnitude of the response and the horizontal axis is the time elapsed, in annual frequency following the shock. The main results are the following. First, from Figure 4, output shock has a statistically significant positive effect on economic growth, renewable energy consumption, and green tax revenue. The increase in renewable energy consumption following an output shock is transitory and wears off after 5 years. In addition, this shock causes a statistically significant increase in non-renewable energy consumption upon impact, followed by a sharp reversal within the 3<sup>rd</sup> year.

Second, from Figure 5, a non-renewable energy shock triggers a persistent statistically significant contraction in economic growth. The economic contraction following non-renewable energy shock is consistent with findings in the energy-growth literature (Cologni and Manera, 2008; Dasgupta and Heal, 1974; Dogrul and Soytaş, 2010; Hamilton, 1983 and 2013; Jimenez-Rodriguez and Sanchez, 2005; Kilian, 2009; Li and Lin, 2016; Mork et al., 1994; Peersman

**Figure 4:** Impact of output shock

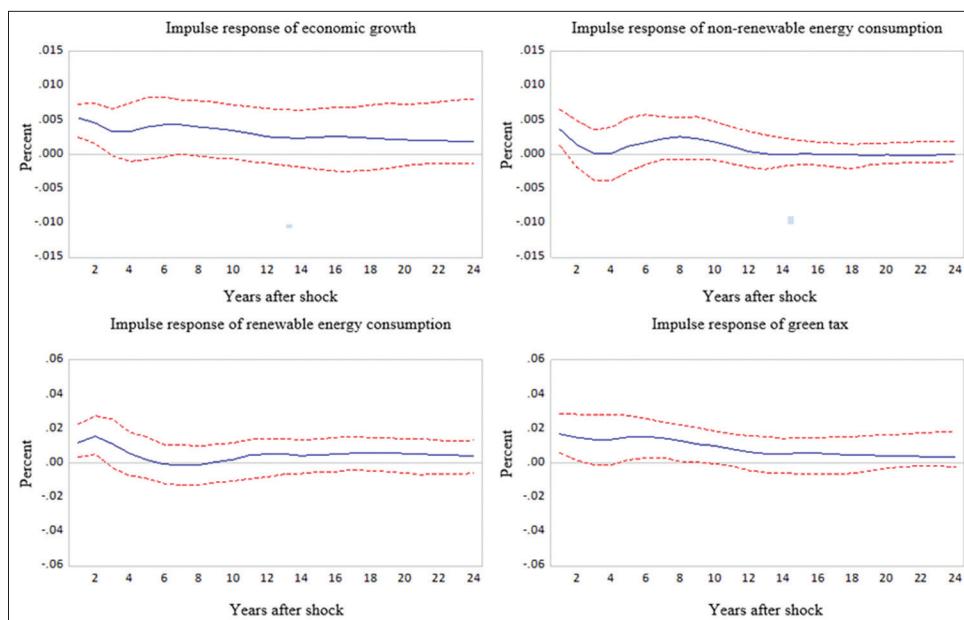


Figure shows median impulse responses to a 1% structural innovation in output, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

and Van Robays, 2012; Rotemberg and Woodford, 1996; Solow, 1974; Stern, 2004; Sachs, 1982). At the same time, this shock causes a transitory decline in non-renewable energy consumption and a transitory increase in renewable energy consumption although much of the increase in the latter is delayed by about 2 years. The delay in renewable energy's response to non-renewable energy shock could result from low elasticity of substitution from non-renewables to renewables as documented in the inter-fuel substitution literature (Adao et al., 2017; Bello et al., 2018; Pelli, 2012; Stern, 2012; Wesseh et al., 2013). Also, as expected, green tax revenue declines following non-renewable energy shock.

The responses to renewable energy shock is shown in Figure 6. Renewable energy shock causes a statistically significant immediate and persistent increase in renewable energy consumption but a sharp transitory decline in non-renewable energy consumption that is also statistically significant. Unlike the delayed response of renewable energy consumption to nonrenewable energy shock, the response of non-renewables to renewable energy shock is instantaneous. This indicates a reverse asymmetric relationship between renewable and non-renewable energy consumption. Also, renewable energy shock is associated with a relatively mild increase in economic growth and a temporary decline green tax revenue.

**Figure 5:** Impact of non-renewable energy shock

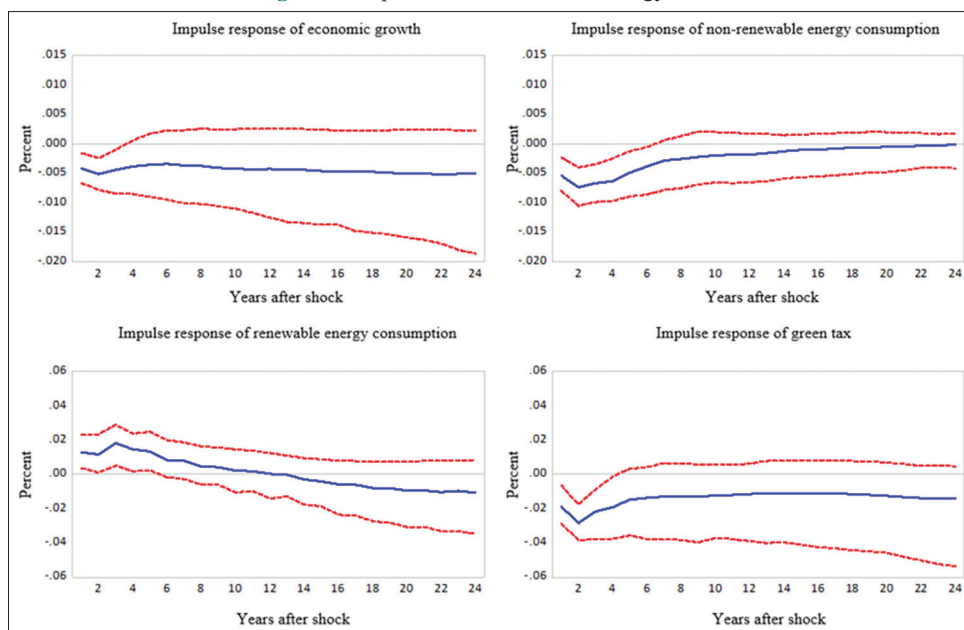


Figure shows median impulse responses to a 1% structural innovation in non-renewable consumption, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

**Figure 6:** Impact of renewable energy shock

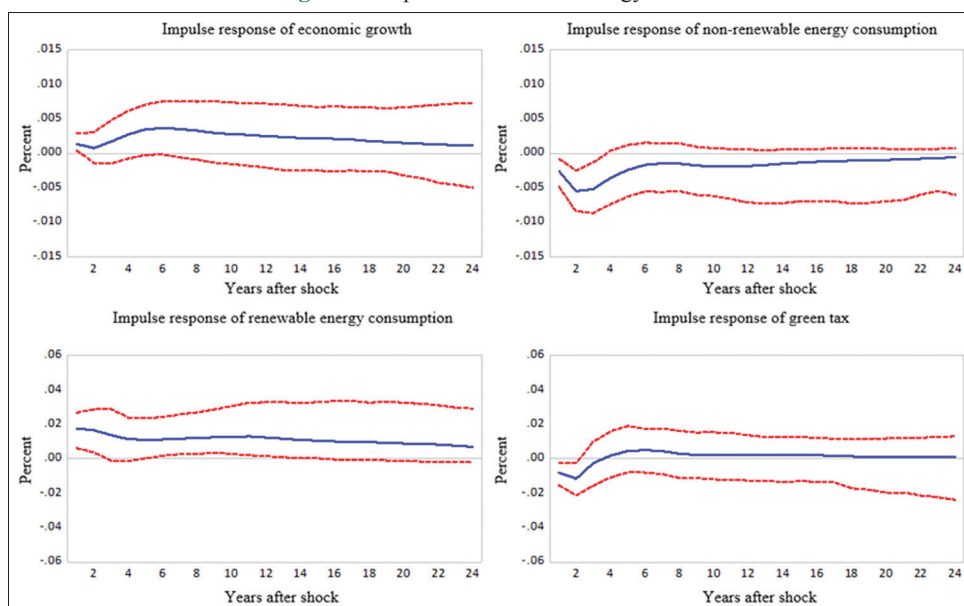


Figure shows median impulse responses to a 1% structural innovation in renewable consumption, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

Lastly, the responses to green tax shock, our principal shock of interest, are displayed in Figure 7. Green tax shock triggers a mild transitory statistically significant decrease in economic growth. Furthermore, this shock moves renewable energy and non-renewable energy consumption in opposite directions. In particular, it increases renewable energy consumption and decreases non-renewable energy consumption. Also, green tax shock lowers green tax revenue. These results suggest that green tax stimulates renewable energy consumption and discourages non-renewable energy consumption without seriously hampering economic growth. Some CGE stimulation studies that do not

explicitly account for energy consumption have found similar results. They conclude that green (environmental) taxes has small negative transient influence on real output growth (Bosquet, 2000; Cao et al., 2013; Sajeewani et al., 2015). A common explanation from these studies is that green (environmental) taxation, at the initial stage, raises consumer prices and wages, which depresses economic activity due to reduction in domestic and external demand. Over time, cuts in labor taxes offset the negative impact on demand leading to employment gains, demand resurgence, and output expansion. In the case of Denmark, the mild transitory negative effect of green tax shocks on output growth is not

**Figure 7:** Impact of green energy tax shock

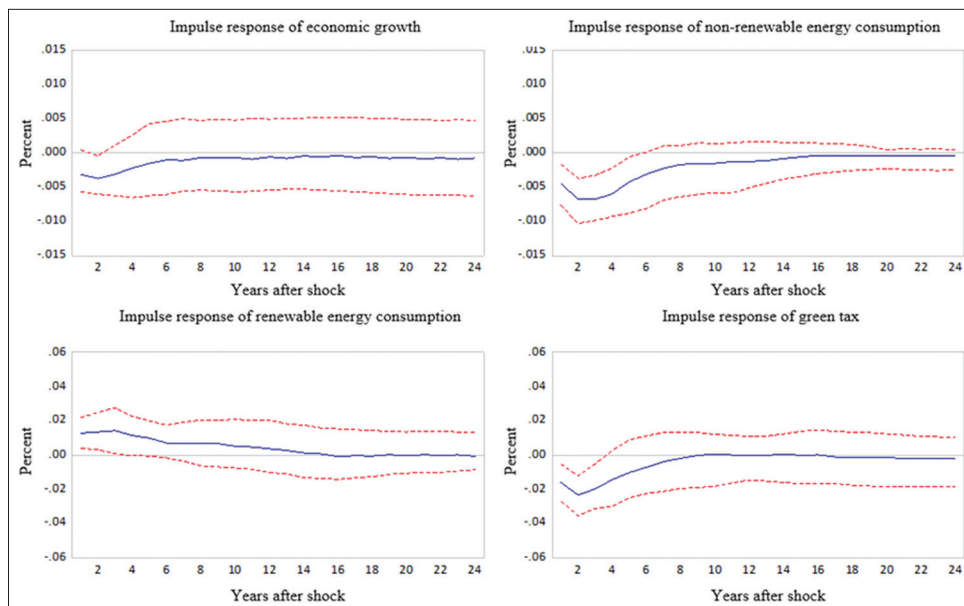


Figure shows median impulse responses to a 1% structural innovation in green tax, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually.

**Figure 8:** Impact of green tax shocks before and after Carbon tax

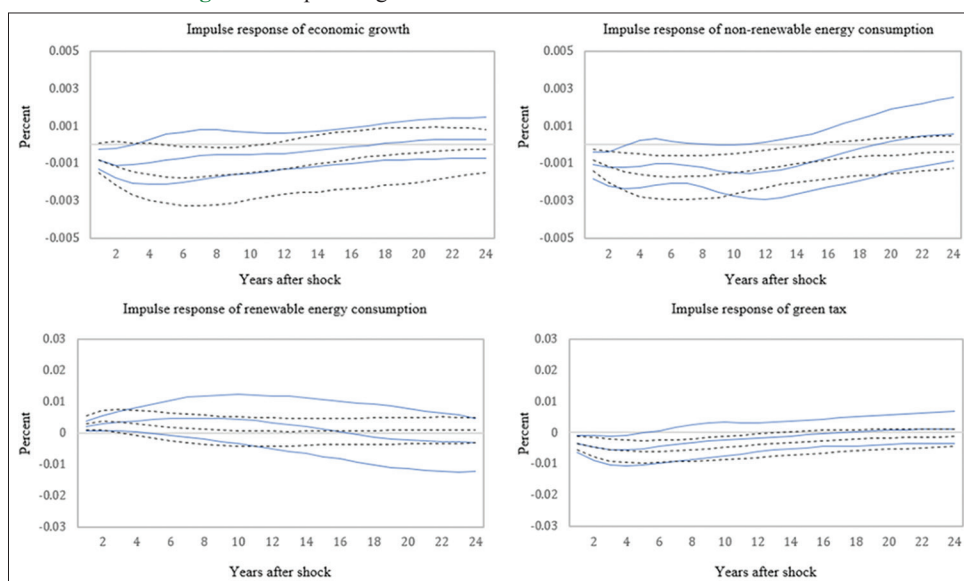


Figure shows the median impulse responses to a 1% structural innovation in green tax before and after Carbon tax, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually. Before carbon tax (1975–1991): solid blue lines. After Carbon tax 1992–2017: dotted black lines.

**Table 2: Chow breakpoint test**

Breakpoint test year: 1992			
Null Hypothesis: No breaks at specified breakpoints			
F-statistic	49.76305	Prob. F(3,37)	0.000
Log likelihood ratio	69.50443	Prob. Chi-square(3)	0.000
Wald Statistic	124.6368	Prob. Chi-square(3)	0.000

necessarily driven by reduction in taxes on labor income, but reflects the cumulative benefits of prolonged and sustained efforts towards green energy that has increased the economy's resilience to energy-related fiscal policy shocks.

#### 4.2. Robustness Checks

It is common practice for researchers to check the robustness of the VAR results to alternative identifying assumptions. Thus, in addition to changing the lag lengths, the study examines the sensitivity of the results to another identification technique that recovers the structural shocks from a recursive VAR model. Results from these robustness checks – changes in lag lengths and structural shocks recovery from recursive VAR – are reported in the Appendix. The results show that the main findings of the paper, i.e., green tax shocks trigger opposite movements in non-renewable energy and renewable energy consumption and a mild transitory decrease in economic growth are not sensitive to these changes. The one exception is that in the case of recursive structural VAR identification, green tax shock has no statistically significant effect on economic growth and non-renewable energy consumption.

#### 4.3. Has the Way the Danish Economy Experiences Green Tax Shocks Changed Since the Introduction of Carbon Tax?

From 1977 until 1991, green taxes in Denmark primarily consisted of energy taxes on coal, oil, natural gas, and electricity; motor vehicle taxes on fuel consumption, auto registration and insurance, and road toll; and environmental taxes on NO<sub>x</sub> and CFC. In 1991, Denmark passed the Carbon Tax Act which took effect in 1992. When the Carbon tax passed, it increased environmental taxes. Consequently, lawmakers included a subsequent decrease in other energy taxes to maintain the overall tax rate. While the subsequent decrease in other energy taxes may maintain the overall tax rate, green tax revenue may change due to changes in energy consumption. To test whether there exist no structural break in green tax revenue when the Carbon tax took effect in 1992, the study run a Chow breakpoint test. The test results reported in Table 2 indicate that the null hypothesis of no structural break in green tax can be rejected.

The existence of structural break implies that green taxation in Denmark is characterized by two different heteroskedasticity regimes. Thus, the way the Danish economy experiences green tax shocks is likely to change overtime across these two regimes. To examine whether the structural break in green tax triggers differential responses across regimes, the structural VAR in Equation (1) is estimated before and after the introduction of Carbon tax. Figure 8 plots the impulse responses under the two different regimes. Clearly, the responses do not vary much over time, indicating that the estimated coefficients do not show much time variation and that how the Danish economy experiences green

tax shocks has not changed fundamentally since the introduction of Carbon tax. Some difference is detectable in the response of renewable energy consumption which exhibits a consumption puzzle, i.e., a strong persistent increase in renewable energy consumption in the pre-Carbon tax period in contrast to a weak transitory increase in the Carbon tax period.

## 5. CONCLUSION

This paper evaluates the long-run relationship between green tax and economic growth. In particular, it utilizes the sign restrictions structural VARs to examine whether green tax is growth-enhancing or growth-inhibiting. To account for the mediatory role of energy consumption, non-renewable energy and renewable energy consumption are included in the analysis. Using data on the Danish economy for the period 1975-2017, the estimations indicate that green tax shocks trigger an increase in renewable consumption, a decline in non-renewable energy consumption, and a transitory decrease in economic growth. Furthermore, comparison of the impacts of green tax shocks in the pre- and post-Carbon tax periods reveal that the way the Danish economy experiences green tax shocks has not fundamentally changed since the introduction of Carbon tax in 1992. Taken together, the findings support the advantages of green tax policies. Specifically, they show that green tax is effective in stimulating reliance on renewable energy while decreasing non-renewable energy consumption without seriously hindering economic growth.

The evidence provided in this study obviously does not discount that other macroeconomic indicators are also crucial in explaining the macroeconomic consequences of green tax shocks. Whereas the study analyzed the relationship between green tax and economic growth, other macroeconomic indicators such as inflation, unemployment, and interest rate could matter in explaining the overall macroeconomic implications of green tax shocks. The importance of these and other macroeconomic indicators can be explored in future studies.

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## APPENDIX

### Appendix A: Robustness Check Results from Lags Longer than Three

The study tests whether the main results with three lags are sensitive to changes in the lag length by experimenting with different lag lengths using the structural VAR model in Eq. (1). As reported in Figures A1-A12 below, from lags four to six the results remained quite similar to the main results with three lags. Hence, little is gained by allowing for lags longer than three.

### Appendix B: Robustness Check Results from Recursive Structural VAR Identification

To recover the structural shocks from a recursive VAR and test their impacts, the study specifies the following structural VAR model:

$$A_0 z_t = \alpha + \sum_{i=1}^3 A_i z_{t-i} + \varepsilon_t \quad (2)$$

where  $z_t$  denotes a vector time series consisting of the growth rates of real GDP ( $RGDP_t$ ), non-renewable energy consumption ( $NREC_t$ ), renewable energy consumption ( $REC_t$ ), and government revenue from green taxes ( $GRNT_t$ ). The error term  $\varepsilon_t$  is a vector of serially and mutually uncorrelated structural innovations, which are obtained from the vector of reduced-form VAR innovations,  $e_t$ ,  $e_t = A_0^{-1} \varepsilon_t$  by imposing the following recursive restrictions on  $A_0^{-1}$ :

$$e_t = \begin{pmatrix} e_t^{RGDP} \\ e_t^{NREC} \\ e_t^{REC} \\ e_t^{GRNT} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{output\ shock} \\ \varepsilon_t^{non-renewable\ energy\ shock} \\ \varepsilon_t^{renewable\ energy\ shock} \\ \varepsilon_t^{green\ tax\ shock} \end{pmatrix} \quad (3)$$

We can think of Eq. (3) as being composed of three blocks. The first row describes the output block; the second and third rows (which comprises non-renewable and renewable energy) describe the energy consumption block; and the last block, i.e. the last row, consists of one equation for green tax revenue changes. Output shock is defined as unexpected innovations to real GDP. The restrictions on the first row imply that real GDP or economic growth does not respond to innovations to consumption of non-renewable energy and renewable energy consumption and green taxes within the same year. Non-renewable energy shock captures changes in fossil-based energy consumption. The restriction on the second row imply that changes in renewable energy consumption influences non-renewable energy consumption only with a delay since it takes time for non-renewable energy to adjust. Renewable energy shock captures changes in renewable energy consumption and is assumed not to contemporaneously respond to green tax changes. The last shock, i.e., green tax shock, captures changes in green tax revenues that cannot be explained based on output shock, non-renewable energy shock, and renewable energy shock, and are attributed to changes in green tax policy shifts. For comparison to the results obtained from the main sign-restriction model, Eq. (3) is estimated using three lags.

Figures B1-B4 show the impulse responses to a 1% standard deviation in structural innovations implied by the recursive VAR model. As the plots indicate, with the exception that green tax shock has no statistically detectable impact on economic growth and non-renewable energy consumption, all results are identical to those from the main sign-restrictions VAR model.

Figure A1: Impact of output shock (4 lags)

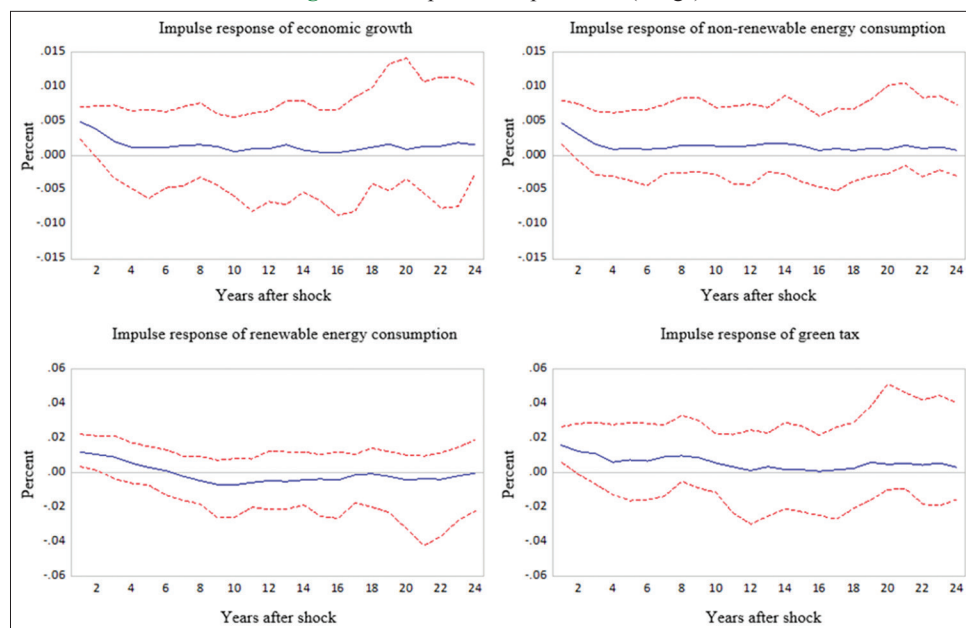


Figure shows median impulse responses to a 1% structural innovation in output, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

**Figure A2:** Impact of output shock (5 lags)

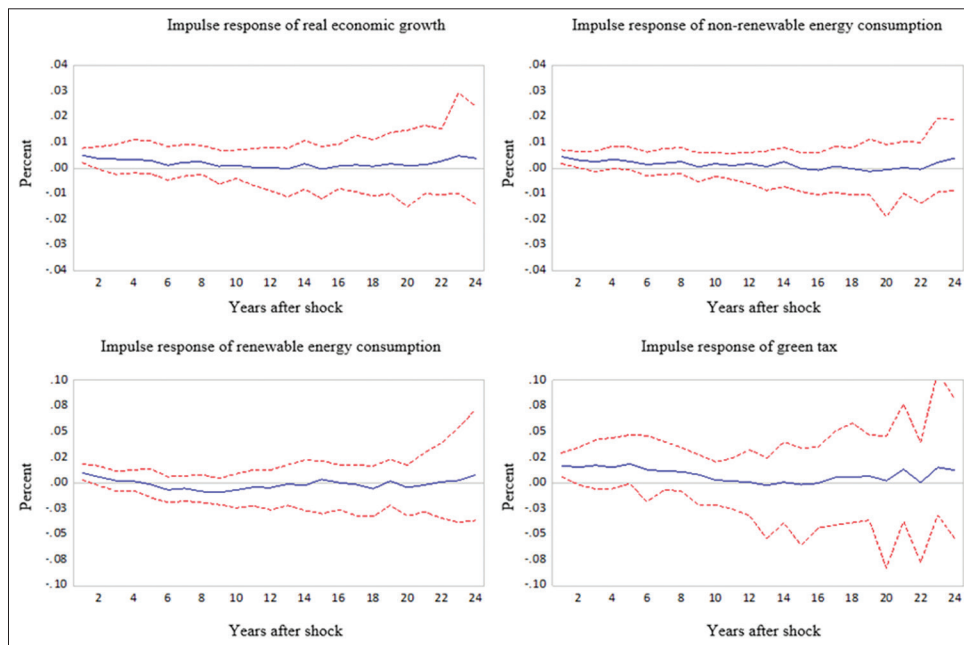


Figure shows median impulse responses to a 1% structural innovation in output, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

**Figure A3:** Impact of output shock (6 lags)

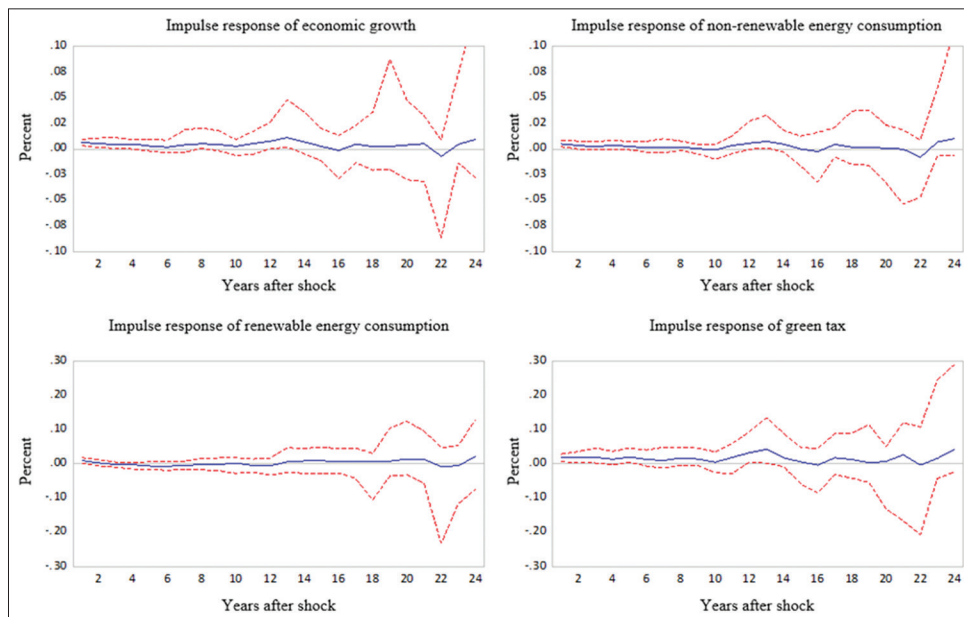


Figure shows median impulse responses to a 1% structural innovation in output, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

**Figure A4:** Impact of non-renewable energy shock (4 lags)

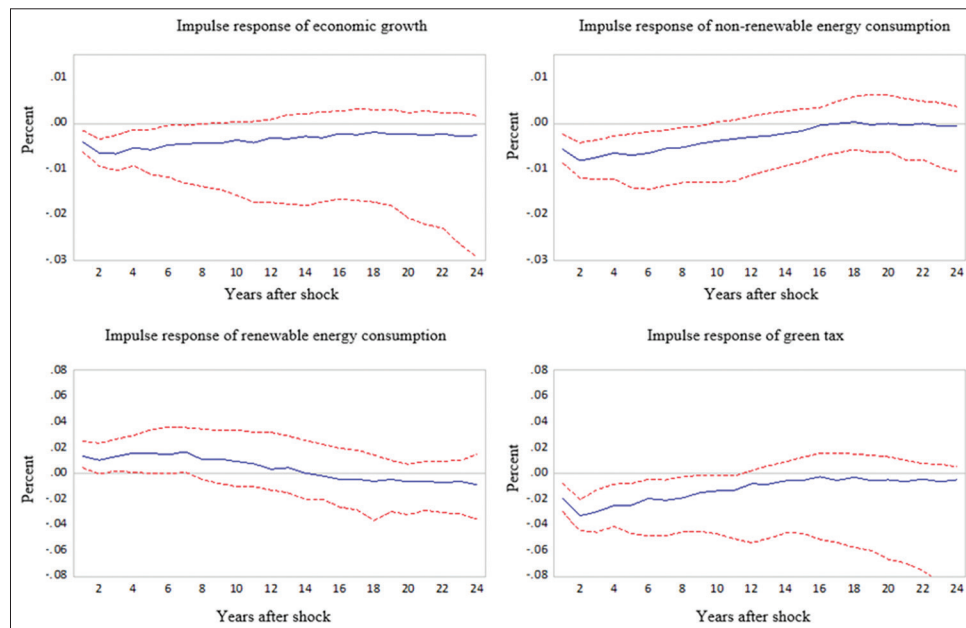


Figure shows median impulse responses to a 1% structural innovation in non-renewable energy consumption, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

**Figure A5:** Impact of non-renewable energy shock (5 lags)

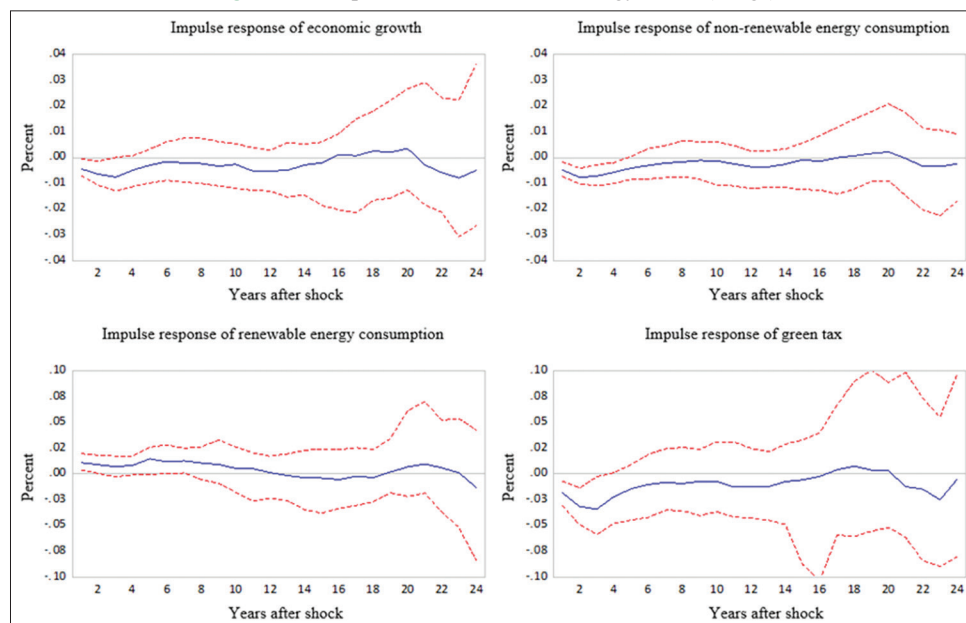


Figure shows median impulse responses to a 1% structural innovation in non-renewable energy consumption, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually



**Figure A6:** Impact of non-renewable energy shock (6 lags)

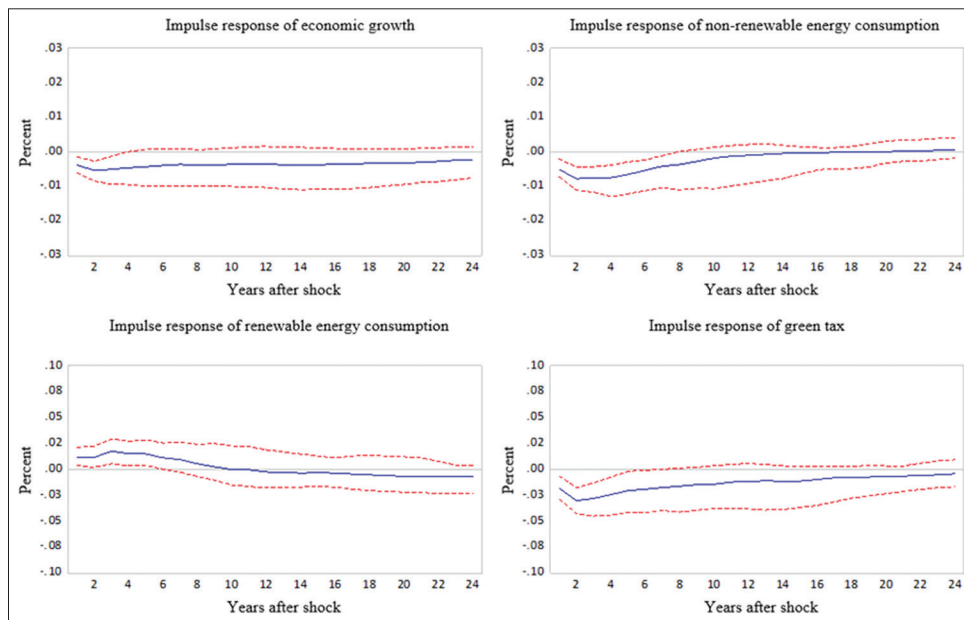


Figure shows median impulse responses to a 1% structural innovation in non-renewable energy consumption, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

**Figure A7:** Impact of renewable energy shock (4 lags)

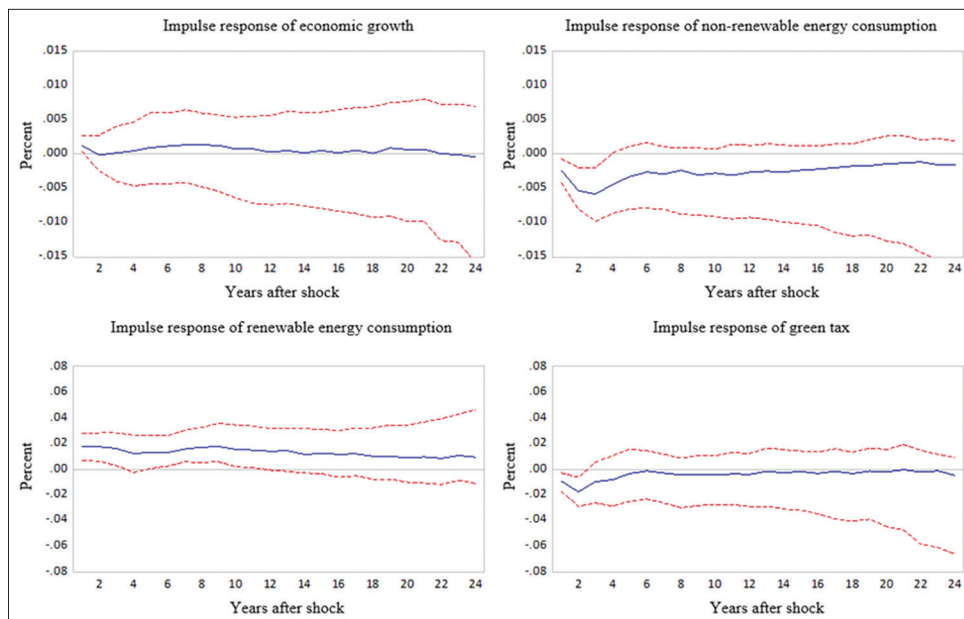


Figure shows median impulse responses to a 1% structural innovation in renewable energy consumption, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

**Figure A8: Impact of renewable energy shock (5 lags)**

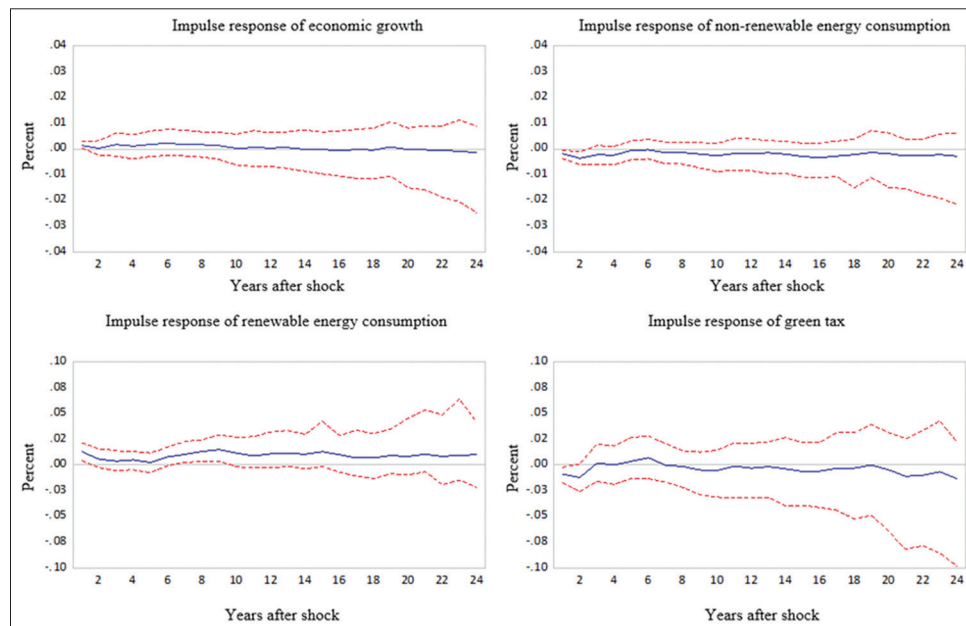


Figure shows median impulse responses to a 1% structural innovation in renewable energy consumption, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

**Figure A9: Impact of renewable energy shock (6 lags)**

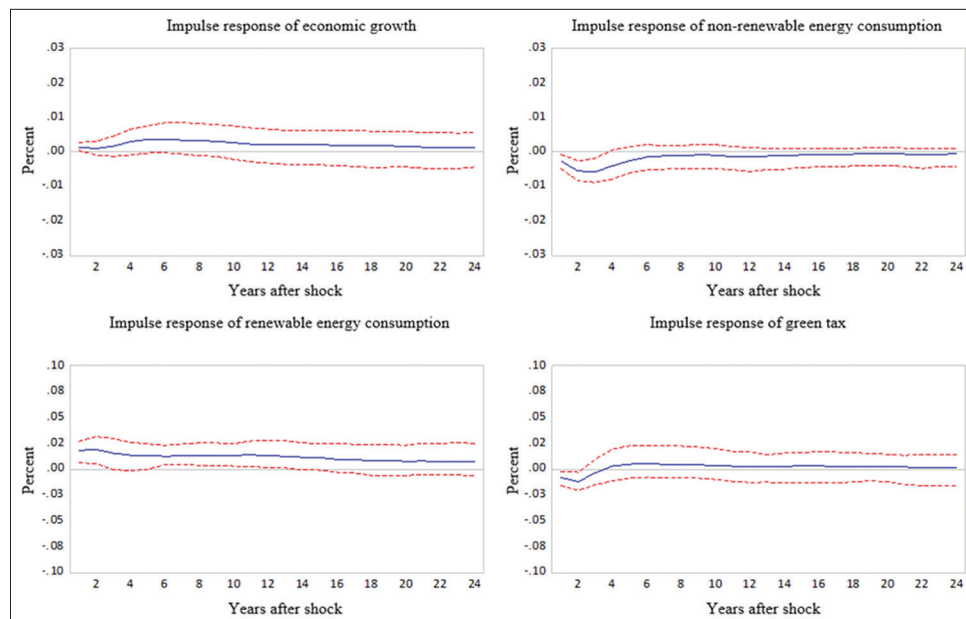


Figure shows median impulse responses to a 1% structural innovation in non-renewable energy consumption, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

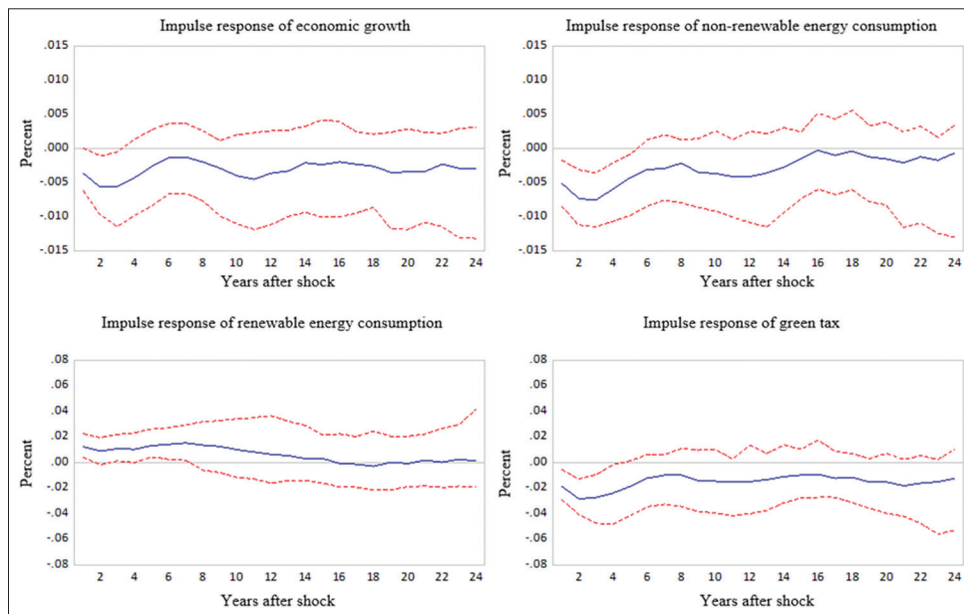
**Figure A10:** Impact of green tax shock (4 lags)

Figure shows median impulse responses to a 1% structural innovation in green tax, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

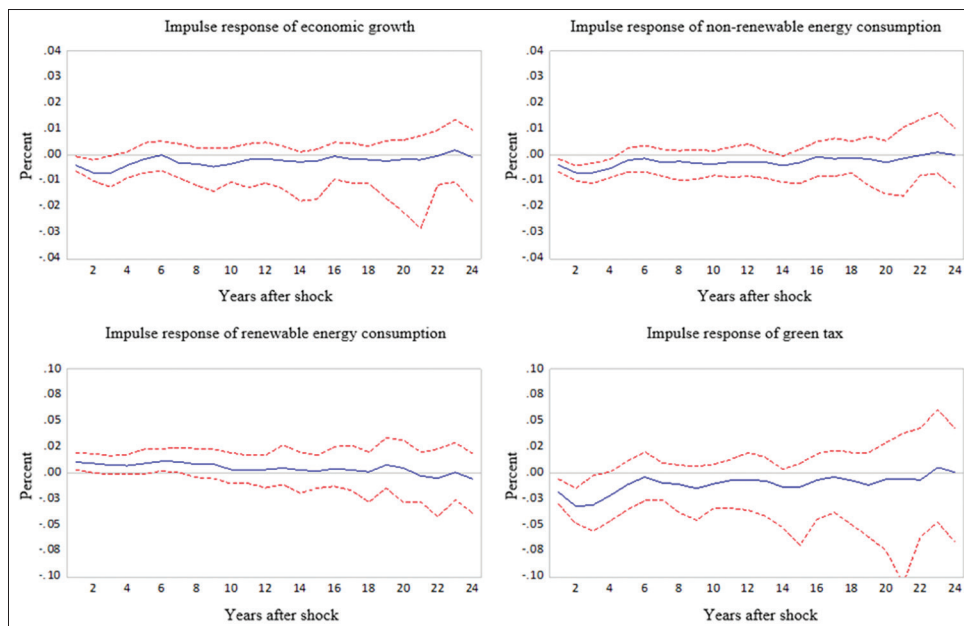
**Figure A11:** Impact of green tax shock (5 lags)

Figure shows median impulse responses to a 1% structural innovation in green tax, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

**Figure A12:** Impact of green tax shock (6 lags)

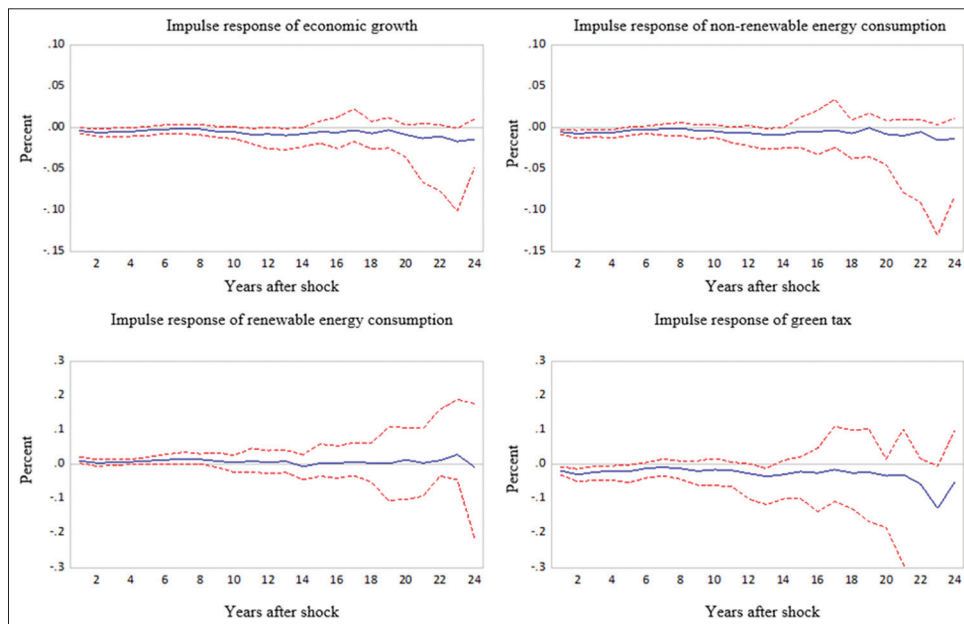


Figure shows median impulse responses to a 1% structural innovation in green tax, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

**Figure B1:** Impact of output shock

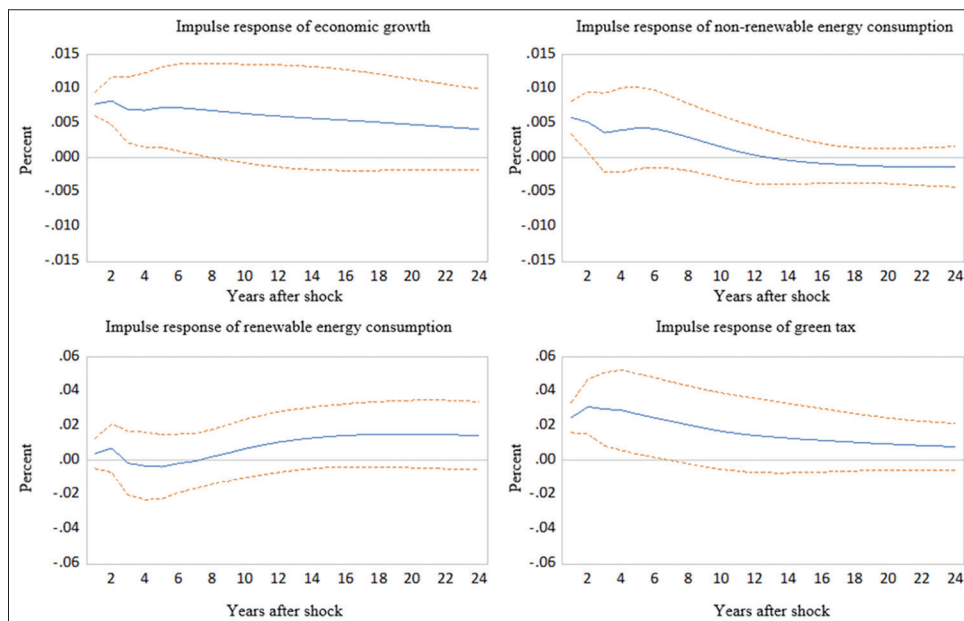


Figure shows median impulse responses to a 1% structural innovation in output, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually



**Figure B2:** Impact of non-renewable energy tax shock

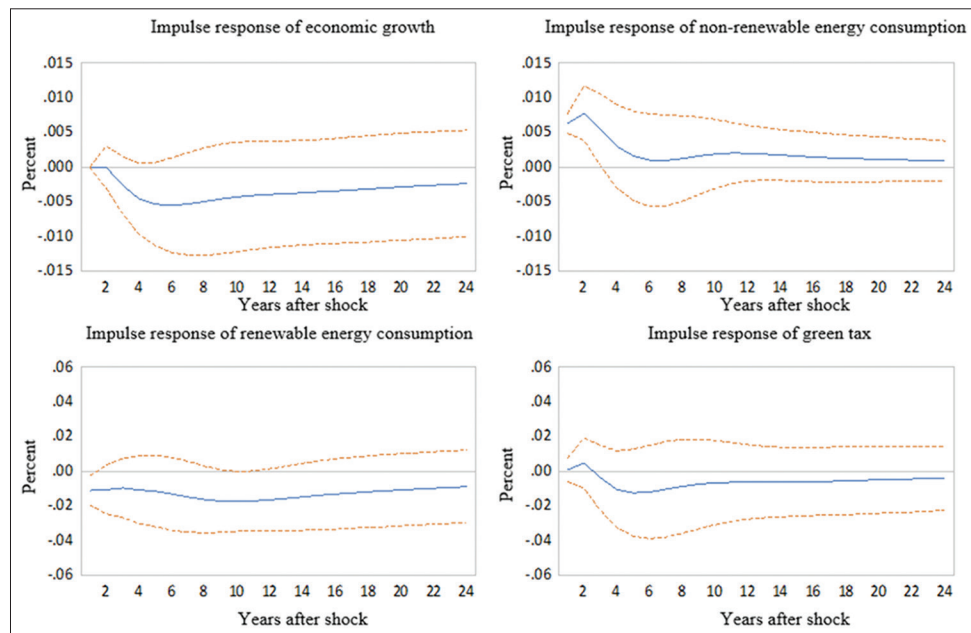


Figure shows median impulse responses to a 1% structural innovation in non-renewable energy consumption, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

**Figure B3:** Impact of renewable energy shock

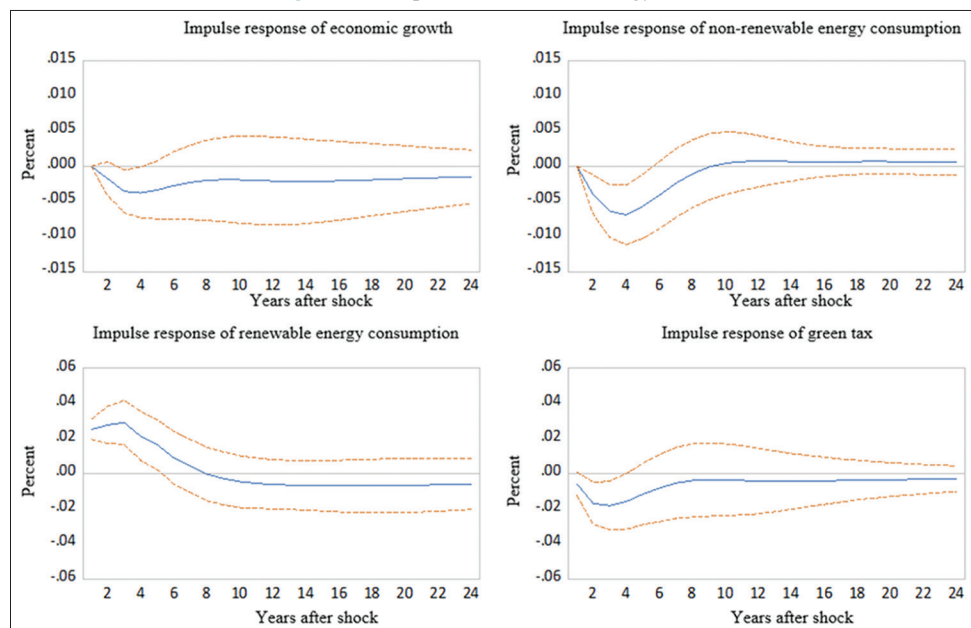


Figure shows median impulse responses to a 1% structural innovation in renewable energy consumption, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually

**Figure B4: Impact of green tax shock**

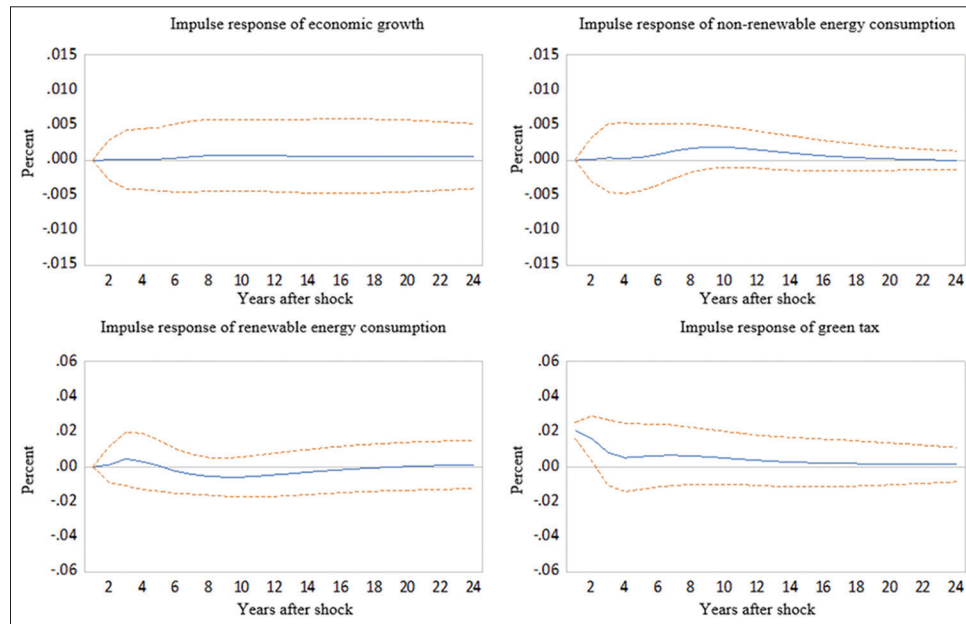


Figure shows median impulse responses to a 1% structural innovation in green tax, together with the 16<sup>th</sup> and 84<sup>th</sup> percentile error bands; horizon is annually