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## 1 Econometric approach

In this section I will describe the econometric model that I will use to identify the structural shocks using the Structural vector autoregression with instruments variables (SVAR-IV). In the formalisation of my model I will follow in the footsteps of Känzig (2022) and Montiel Olea et al. (2021).

### 1.1 VAR

Presume a standard VAR-model with a lag length of  $p$ .

$$y_t = b + B_1 y_{t-1} + \dots + B_p y_{t-p} + u_t \quad (1)$$

Where the  $y_t$  refers to a  $n \times 1$  vector of the observed endogenous variables at time step  $t$ . The  $B_1, \dots, B_p$  are  $n \times n$  coefficient matrices.  $u_t$  is an  $n \times 1$  vector of the reduced form innovations with a covariance matrix of  $\Sigma$ .

### 1.2 Identification of the structural shocks

An integral assumption in using SVAR-models that, the one-step-ahead prediction errors i.e. the innovations  $u_t$  are a linear combination of a vector of mutually orthogonal structural shocks  $\varepsilon_t$ :

$$u_t = S\varepsilon_t$$

Where  $S$  is a nonsingular  $n \times n$  structural impact matrix. Due to the orthogonality the structural the  $n \times n$  covariance matrix of  $\text{var}(\varepsilon_t) = \Omega$  is diagonal. Thus due the linear mapping of the innovations and structural shocks described in the equation x, we can describe the covariance matrix of the innovations as:

$$\Sigma = S\Omega S'$$

For the sake of clarity, the  $\varepsilon_{1,t}$  is defined to describe the shock of interest, the carbon policy shock. Latter part of this chapter will present how by using an external instrument approach we can identify the structural impact vector  $s_1$  which is analogous to the first column of the structural impact matrix  $S$ .

### 1.3 External instrument

For an external instrument  $z_t$  to be useful in identifying structural shocks it has to satisfy the following two conditions:

$$\begin{aligned}\mathbb{E}(z_t \varepsilon_{1,t}) &= \alpha \neq 0 \\ \mathbb{E}(z_t \varepsilon_{i \neq 1,t}) &= 0\end{aligned}$$

The equation x is the relevance condition and the equation y is the exogeneity condition. If these conditions in tandem with the invertibility requirement are met the sign and the and scale of the  $s_1$  can be identified by:

$$s_1 \propto \frac{\mathbb{E}(z_t u_t)}{\mathbb{E}(z_t u_{1,t})} \quad (2)$$

The size of  $\alpha$  is the strength of the external instrument and it can be tested with the XXX elaborated in the nörnörnöös (2018) article. After the structural impact vector has been identified the estimation of the confidence bands in IRF can be done with a moving block bootstrap method, also used in the Känzig (2022).

### 1.4 Comparing other identification strategies

Other possible strategies to identify the structural shocks would be to use heteroscedasticity based identification of structural vector autoregressions or local projections. In an interesting article Plagborg-Møller and Wolf (2021) offer a proof that local projections and SVARs are estimating the same impulse responses, but they have different finite-sample properties (Plagborg-Møller and, Wolf 2021).

When comparing the results of SVAR-IV to ones produced with local projection the variance of the impulse response functions are lower, but with a trade off of bias in the results if the VAR is noninvertible (Wolf, 2020). In the appendix XX I will provide the impulse responses that are produced via Local projection-instrument variable approach, as an robustness check for the results of the baseline SVAR-IV model. The results we see are at least notionally similar and thus provide additional evidence that the baseline model can be trusted.

Even though these both would have been a valid choice as an instrument, but as one the main tasks of this thesis is to quasi-replicate the findings of Känzig I will continue with the SVAR-IV that my findings are as comparable as possible. Additional reasons why I selected the SVAR-IV as my approach was for the reliability and the efficiency, which are paramount in estimating the responses to a shock from a short sample.