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MAKRO

Estimation of the Price Elasticity of Oil

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Abstract

We estimate the oil price elasticity for import prices for the sectors present in MAKRO. In line with MAKRO, we assume price stickiness in the dynamics of import prices in order to allow for short-run and long-run effects. In order to estimate the oil price elasticity, we make use of a Kalman filter approach developed by Kastrup, Kronborg, and Stephensen (2022). We estimate the oil price elasticity for the combined sectors in MAKRO to approximately 0.21. However, we find heterogeneity across sectors. Not surprisingly, import prices in the energy and extraction sectors have the highest oil price elasticity, while changes in oil prices appear to have a minor impact on import prices in the production and service sectors. These estimates are robust to a set of robustness tests, such as changing the time period and applying different estimation approaches.

1 Introduction

In this note we estimate how shocks to oil prices pass through to import prices for sectors present in MAKRO. In MAKRO, we specify the import price as a function of two unknown parameters: The oil price and a scale parameter expressing all other factors that affect import prices. Thus, this definition allows the user of the model to analyze two different types of exogenous shocks to the import price.

We introduce price stickiness to allow for different short-run and long-run effects. This formulation is identical to the one applied in MAKRO. As the scale parameter is unobserved, assumptions are needed on this parameter to identify the oil price elasticity. We apply the framework from Kastrup, Kronborg, and Stephensen (2022) where the scale parameter is specified as a flexible and non-linear process estimated with the Kalman filter.

We find that the oil price elasticity is close to unity for the energy and extraction sectors and around 0.2 in the production and service sectors. These estimates are robust to a set of robustness tests, such as changing the time period and applying different levels of smoothing of the scale parameter.

2 Model

We first present how the import price is modeled in MAKRO. Second, we present how the parameters are estimated applying the state-space framework from Kastrup, Kronborg, and Stephensen (2022).

2.1 Import price in MAKRO

The import price for each sector modeled in MAKRO is specified as the following:

$$P^M_{s,t} = \left[\mu^{pm}_{s,t}\left(P^{oil}_t\right)^{\sigma^{pm}_s}\right]^{1-\varphi^F_s}\left[P^M_{s,t-1}\right]^{\varphi^F_s} \tag{1}$$

where $P^M_{s,t}$ is the current import price for sector s, $\mu^{pm}_{s,t}$ is an unobservable scale parameter, and P^{oil}_t is the current oil price. σ^{pm}_s is the price elasticity of oil while φ^F_s measures the price stickiness of the import price in sector s. This equation enables us to analyze two types of shocks: Oil price shocks and shifts in $\mu^{pm}_{s,t}$.

Equation 1 consists of three unknowns: $\mu^{pm}_{s,t}, \sigma^{pm}_s, \varphi^F_s$. The main objective of this paper is to estimate σ^{pm}_s and φ^F_s. Applying these estimates, $\mu^{pm}_{s,t}$ can be calibrated residually and forecasted based on the auto.arima forecast method applied in MAKRO to calibrate scale parameters. This unobserved variable reflects all factors net of oil prices that affect the import price. Such factors could be foreign producer price, exchange rate fluctuations, changes in the degree of pricing-to-market, and markup variations of foreign firms.

2.2 Estimation approach

In this section, we present the estimation framework. The presented framework and discussion is based on Kastrup, Kronborg, and Stephensen, 2022. Our main aim is to obtain an estimate for σ^{pm}_s based on 1. However, as the Kalman filter is linear in parameters, we need to obtain a linear model before we can apply the Kalman filter. Consequently, we first take logarithms of equation 1 and next rearrange it in its error-correction form:

$$\triangle log(P^M_{s,t}) = \alpha_1 \Delta log P^{oil}_t + \alpha_2\left[log P^M_{s,t-1} - log\mu^{pm}_{s,t} - \sigma^{pm}_s log P^{oil}_{t-1}\right] + \epsilon_t,\ \epsilon_t \sim N(0,\Sigma^{\epsilon}) \tag{2}$$

where α_1 is the short-run elasticity of oil prices and $\alpha_2 = (\varphi^F_s - 1)$ is the adjustment parameter. We estimate the parameters $(\alpha_1, \alpha_2, \sigma^{pm}_s, log\mu^{pm}_{s,t})$. While $\alpha_1, \alpha_2, \sigma^{pm}_s$ are constant over time, $log\mu^{pm}_{s,t}$ is time-varying and unobserved. Therefore, we need to make assumptions on the process of this parameter. In the following, we specify $log\mu^{pm}_{s,t}$ to satisfy two requirements: i) As both P^{oil}_{t-1} and $P^M_{s,t-1}$ are trending over time, we need to allow for a trend in $log\mu^{pm}_{s,t}$ to circumvent a potential spurious regression. ii) As $\mu^{pm}_{s,t}$ likely reflects factors that are non-linear over time, we allow it to deviate from a linear trend. Yet, $\mu^{pm}_{s,t}$ should not be flexible enough to capture all variations in $P^{M}_{s,t}$, placing less emphasis on oil price changes. A process that fits these requirements is an I(2) process of $log\mu^{pm}_{s,t}$:

$$\triangle log\mu^{pm}_{s,t} = \triangle log\mu^{pm}_{s,t-1} + \eta_t,\ \eta_t \sim N(0, \Sigma^{\eta}) \tag{3}$$

The smoothness of this process is determined by the so-called noise-to-signal ratio, $\lambda = \Sigma^{\varepsilon}/\alpha_2^2\Sigma^{\eta}$. When this ratio is low it implies that all variations, not described by the oil price, is subscribed to technical change. Oppositely, a high value of the ratio implies that $log\left(\mu^{pm}_{s,t}\right)$ is a linear trend and all deviations from the trend is ascribed to ϵ_t. λ is first estimated simultaneously with Σ^{ε} and next grid-searched in the range 20-500 with increment 10. The preferred value is the one that maximizes the likelihood and where it cannot be rejected that the error term is not autocorrelated. This approach also addresses the issue of having potentially multiple local minima of the likelihood function. As the parameters are specified as constant over time, we do not immediately obtain standard errors. Therefore, we apply a recursive bootstrapping procedure.

3 Data

The MAKRO database[1] is applied to estimate the price elasticity of oil. The dataset is on annual frequency and spans from 1967 until 2017. We apply the import price deflator for the sectors represented in MAKRO as measure of the impor price. The oil price is defined as the Brent crude oil price.[2] The oil price elasticity is estimated for the following four sectors: Energy, production, services, and extraction. We also estimate the elasticity for the goods and service sectors combined.

4 Results

4.1 Estimated results from the Kalman Filter

The estimated parameters are shown in Table 1. Overall, we estimate the oil price elasticity for the combined sectors in MAKRO to approximately 0.21. However, our sectoral estimations show major heterogeneity across sectors: Not surprisingly, import prices in the energy and extraction sectors have the highest oil price elasticity, around 0.8, i.e. they are the sectors in MAKRO for which import prices are the most affected by changes in oil prices. On the other hand, changes in oil prices appear to have a minor impact on import prices in the production and service sectors (elasticities on 0.12 and 0.16, respectively).

[1] The MAKRO database is primarily based on the ADAM database from Statistics Denmark: Economic Models
[2] For further explantion of the data and how the components are derived we refer to the ADAM note Bjornsted and Werner (2005).

In Table 1 we also report estimates for the time period 1983-2017 to only focus on the period with a fixed exchange rate. While we only observe minor differences in the import elasticity, we observe some differences in the price stickiness, φ_s^F. For example, in the production sector we find that this parameter declines from 0.51 to 0.40 implying a faster adjustment to the long run.

In some of the estimations, we observe considerable changes in the noise-to-signal ratio when adjusting the time period. This reflects changes in the smoothness of the scale parameter, $\mu_{s,t}^M$. To analyze how this change affects the estimated elasticity and price stickiness, in Appendix D we re-estimate equation (2) where we fix the value of λ to 100, irrespective of the sector and time period. We find that the estimates of the elasticity are closely related to the elasticities obtained in Table 1 (where we estimate λ freely), but the price stickiness is considerably higher and almost unaffected by changing the time period. Thus, the changes in price stickiness observed in Table 1 may be a result of changes in the noise-to-signal ratio.

Table 4.1.1: Estimated parameters from (2) using annual data

All sectors	Parameter	1967-2017	1983-2017	**Energy**	Parameter	1967-2017	1983-2017
Oil price elasticity	σ_{tot}^{pm}	$0.21^{\dagger}$ (0.02)	$0.22^{\dagger}$ (0.02)	Oil price elasticity	σ_s^{pm}	$0,80^{\ddagger}$ (0.02)	$0,82^{\ddagger}$ (0,04)
Price stickiness	φ_{tot}^{F}	0.36 (0.09)	0.33 (0.09)	Price stickiness	φ_s^F	0,27 (0.12)	0.35 (0,14)
Noice-to-signal ratio	λ	9.55	5.03	Noice-to-signal ratio	λ	1726	319,81
Production	Parameter	1967-2017	1983-2017	**Extraction**	Parameter	1967-2017	1983-2017
Oil price elasticity	σ_s^{pm}	$0,12^{\dagger}$ (0,02)	$0,12^{\dagger}$ (0,02)	Oil price elasticity	σ_s^{pm}	$0,86^{\ddagger}$ (0,03)	$0,89^{\ddagger}$ (0.04)
Price stickiness	φ_s^F	0,51 (0,06)	0.40 (0,08)	Price stickiness	φ_s^F	0,17 (0,12)	0.20 (0,14)
Noice-to-signal ratio	λ	15,19	6.14	Noice-to-signal ratio	λ	290	100
Services	Parameter	1967-2017	1983-2017	**G&S**	Parameter	1967-2017	1983-2017
Oil price elasticity	σ_s^{pm}	$0,16^{\dagger}$ (0,02)	$0,17^{\dagger}$ (0,02)	Oil price elasticity	σ_s^{pm}	$0,17^{\ddagger}$ (0,03)	$0,20^{\ddagger}$ (0.03)
Price stickiness	φ_s^F	0,51 (0,10)	0.45 (0,13)	Price stickiness	φ_s^F	0,68 (0,05)	0.69 (0,05)
Noice-to-signal ratio	λ	312	12117,87	Noice-to-signal ratio	λ	100	100

Notes: Parameters , σ_s^{pm}, φ_s^F and λ are estimated with the Kalman filter on annual data. Standard errors are in brackets and $\dagger$ represents the rejection of the hypothesis that the oil price elasticity is not significantly different from 0 while $\ddagger$ represents the rejection of the hypothesis that the oil price elasticity is not significantly different from 1. G&S stands for Goods and Services. The period 1983-2017 is included to solely capture the fixed-exchange-rate policy in Denmark.

4.2 Robustness check: Estimated results from linear regressions

In this subsection we conduct a robustness check of the estimated parameters obtained from the Kalman filter. Instead of assuming that the unobserved scale parameter $\mu_{s,t}^{pm}$ follow a Markov process as specified in 3, we let $\mu_{s,t}^{pm}$ have the following functional form:

$$\mu_{s,t}^{M} = e^{\mu_{0,s}+\mu_{1,s}t} \tag{4}$$

Applying a linear trend assumption for the scale parameter $\mu_{s,t}^{M}$ should be a good robustness check as import price deflators for certain sectors (e.g. energy and extraction) show a strong linear correlation with oil prices, see Figure 2 in Appendix A.[3]

The estimates of the oil price elasticity for energy, extraction and service sectors resembles those of estimated in the Kalman Filter. Table 2 emphasizes the results from the estimation in the previous section: Import prices from the energy and extraction sectors are sensitive to oil prices while the service sector is less so. The price stickiness parameter in the goods and service sectors are considerably higher than obtained with the Kalman filter in Table 1. This is well in accordance with the estimates in Appendix D where we apply $\lambda = 100$ which results in a more smooth trend compared to the estimates in Table 1. As a linear trend assumption corresponds to $\lambda = \infty$, it is reasonable that this estimation yields even higher price stickiness estimates.

[3] For further explanation of our estimation we refer to Appendix B.

Table 4.2.1: Estimated parameters from (7) using annual data

All sectors	Parameter	1967-2017	1983-2017	**Energy**	Parameter	1967-2017	1983-2017
Oil price elasticity	σ_{tot}^{pm}	0,53** (0.11)	0,09** (0.01)	Oil price elasticity	σ_s^{pm}	0,78** (0.03)	0,84** (0,03)
Price stickiness	φ_{tot}^{F}	0,92** (0.02)	0.09 (0.19)	Price stickiness	φ_s^F	0,38** (0.13)	0.31** (0,14)
Constant	$\mu_{0,tot}$	9.55* (0.49)	-0.09** (0.02)	Constant	$\mu_{0,s}$	0.08 (0.09)	-0.08 (0.06)
Trend	$\mu_{1,tot}^{pm}$	-0.02 (0.01)	0.00** (0.00)	Trend	$\mu_{1,s}^{pm}$	-0.00 (0.00)	-0.00 (0.00)
Production	Parameter	1967-2017	1983-2017	**Extraction**	Parameter	1967-2017	1983-2017
Oil price elasticity	σ_s^{pm}	0,50** (0,09)	0,07 (0,05)	Oil price elasticity	σ_s^{pm}	0,81** (0,03)	0,82** (0.04)
Price stickiness	φ_s^F	0,92** (0,012)	0.70** (0,13)	Price stickiness	φ_s^F	0,15 (0,03)	0.08 (0,19)
Constant	$\mu_{0,s}$	1.33** (0.42)	-0.08 (0.09)	Constant	$\mu_{0,s}$	1.33** (0.42)	-0.17** (0.08)
Trend	$\mu_{1,s}^{pm}$	-0.03** (0.01)	-0.00 (0.00)	Trend	$\mu_{1,s}^{pm}$	-0.03** (0.01)	0.00** (0.00)
Services	Parameter	1967-2017	1983-2017	**G&S**	Parameter	1967-2017	1983-2017
Oil price elasticity	σ_s^{pm}	0,26** (0,09)	0,04 (0,06)	Oil price elasticity	σ_s^{pm}	0,92** (0,02)	0,03** (0.01)
Price stickiness	φ_s^F	0,85** (0,07)	0.71** (0,13)	Price stickiness	φ_s^F	0,47** (0,02)	0.08 (0,19)
Constant	$\mu_{0,s}$	-1.13 (0.34)	-0.33** (0.10)	Constant	$\mu_{0,s}$	1.11** (0.45)	-0.09** (0.02)
Trend	$\mu_{1,s}^{pm}$	-0.01 (0.01)	0.01** (0.00)	Trend	$\mu_{1,s}^{pm}$	-0.02** (0.01)	0.00** (0.00)

Notes: Parameters σ_s^{pm}, φ_s^F,$\mu_{0,s}$ and $\mu_{1,s}^{pm}$ are estimated with help of non-linear estimation of equation (7) on annual data. Standard errors are in brackets. Significance level at 10% and 5 % are represented by * and **. G&S stands for Goods and Services. The period 1983-2017 is included to solely capture the fixed-exchange-rate policy in Denmark.

5 Conclusion

In this note we estimate the oil price elasticity for import prices. We estimate the sensitivity to oil price changes to import prices for the sectors present in MAKRO. As MAKRO treats external variables as exogenous, our expression for the dynamics of import prices is derived outside the model.

In order to estimate the oil price elasticity, we apply the Kalman Filter as suggested by Kastrup, Kronborg, and Stephensen (2022). Our estimation shows that the import prices for the energy and extraction sectors have relatively high price elasticity of oil (approximately 0.8) while for instance the import price for the service sector is relatively inelastic to changes in oil prices. Our estimations are confirmed by a linear regression approach.

References

Bjornsted, Erik and Morten. Werner (2005). “Olieprisrelationerne i ADAM”. In: *Danmarks Statistik* EMJ19505.

Kastrup, C. S., A. F. Kronborg, and P. P. Stephensen (2022). “Estimation of the Elasticity of Substitution when Several Shifts in Factor-Augmenting Technical Change are Present.” In: *DREAM working paper series*.

A Data

Figure A.0.1: Imported price deflator for each sector and oil price plotted for 1967-2017

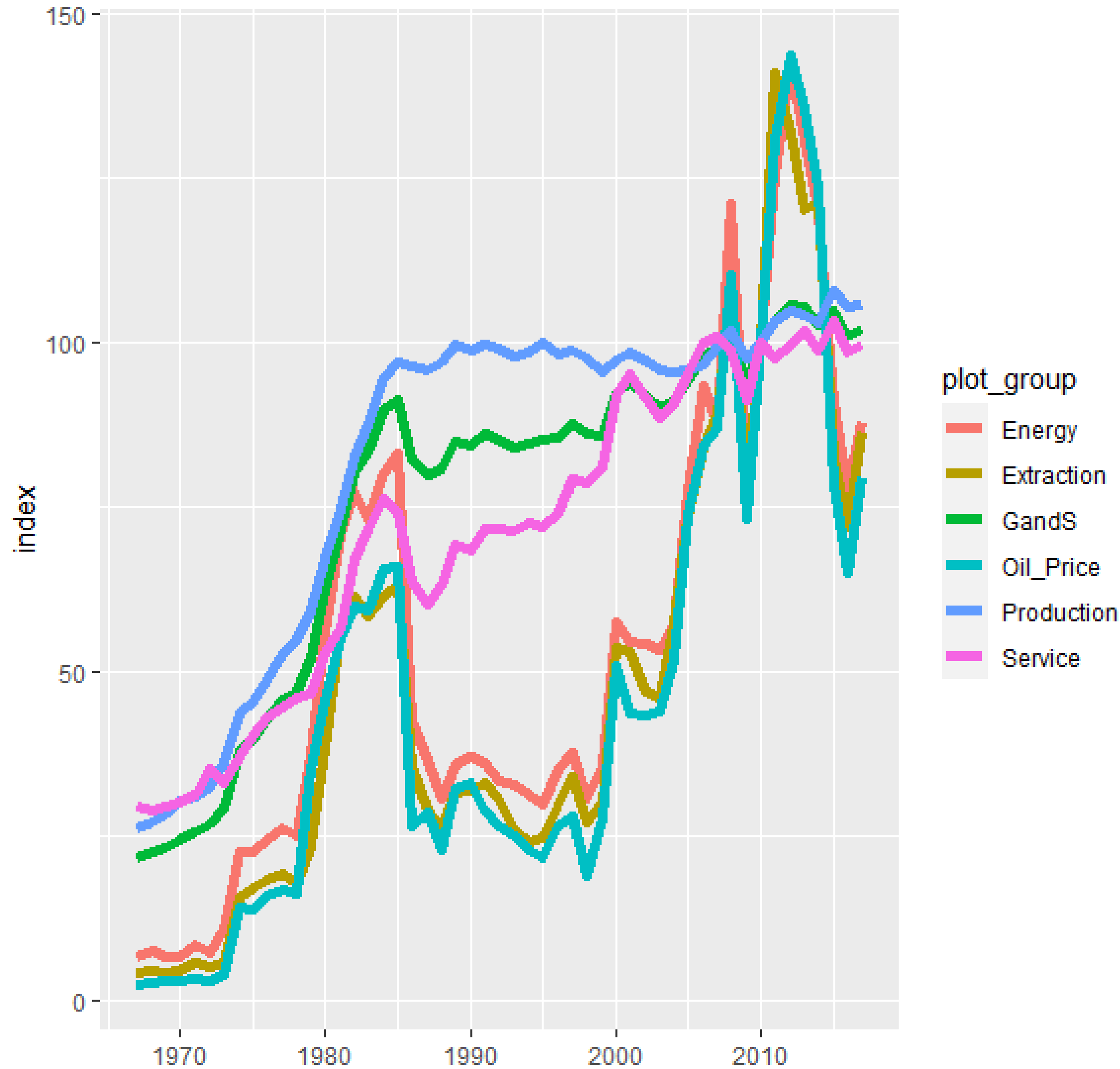
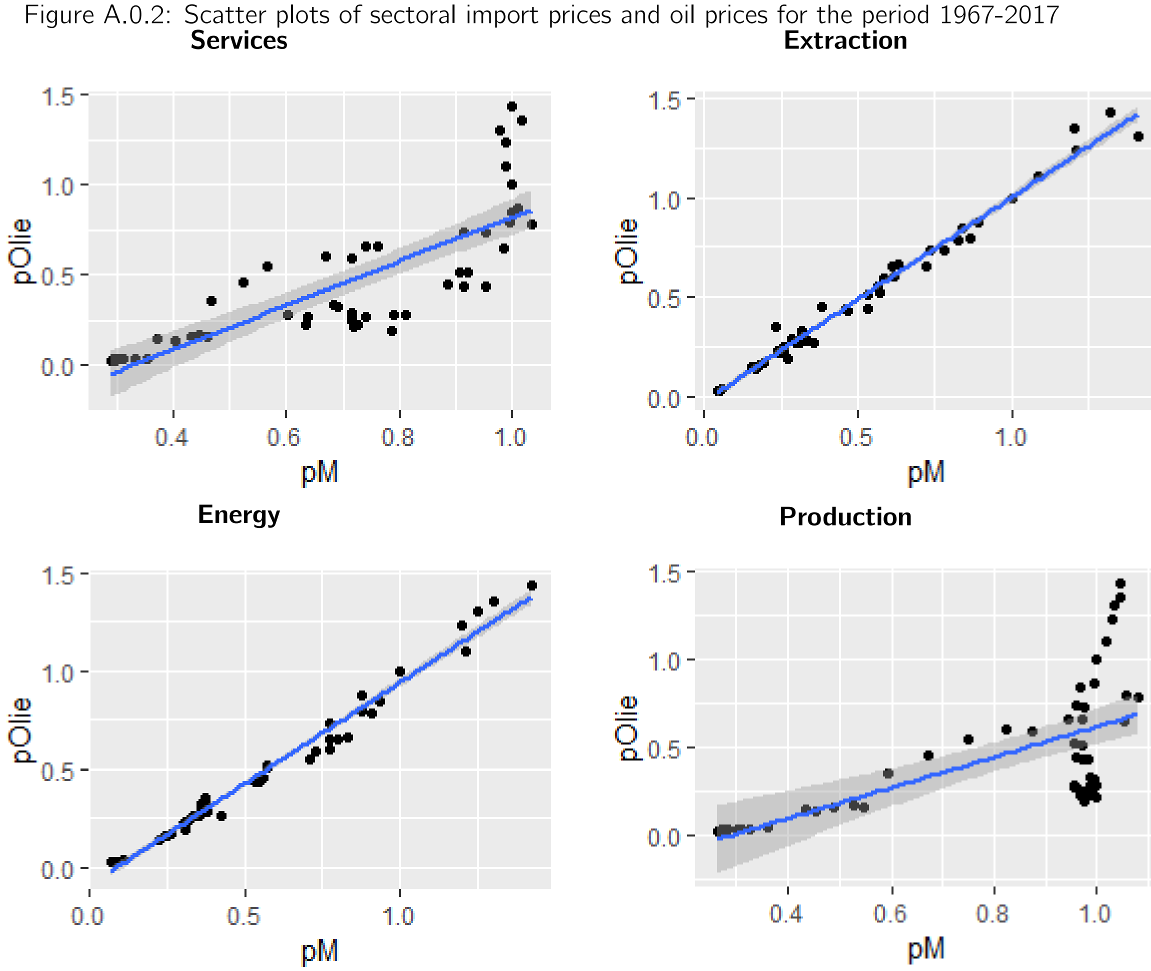


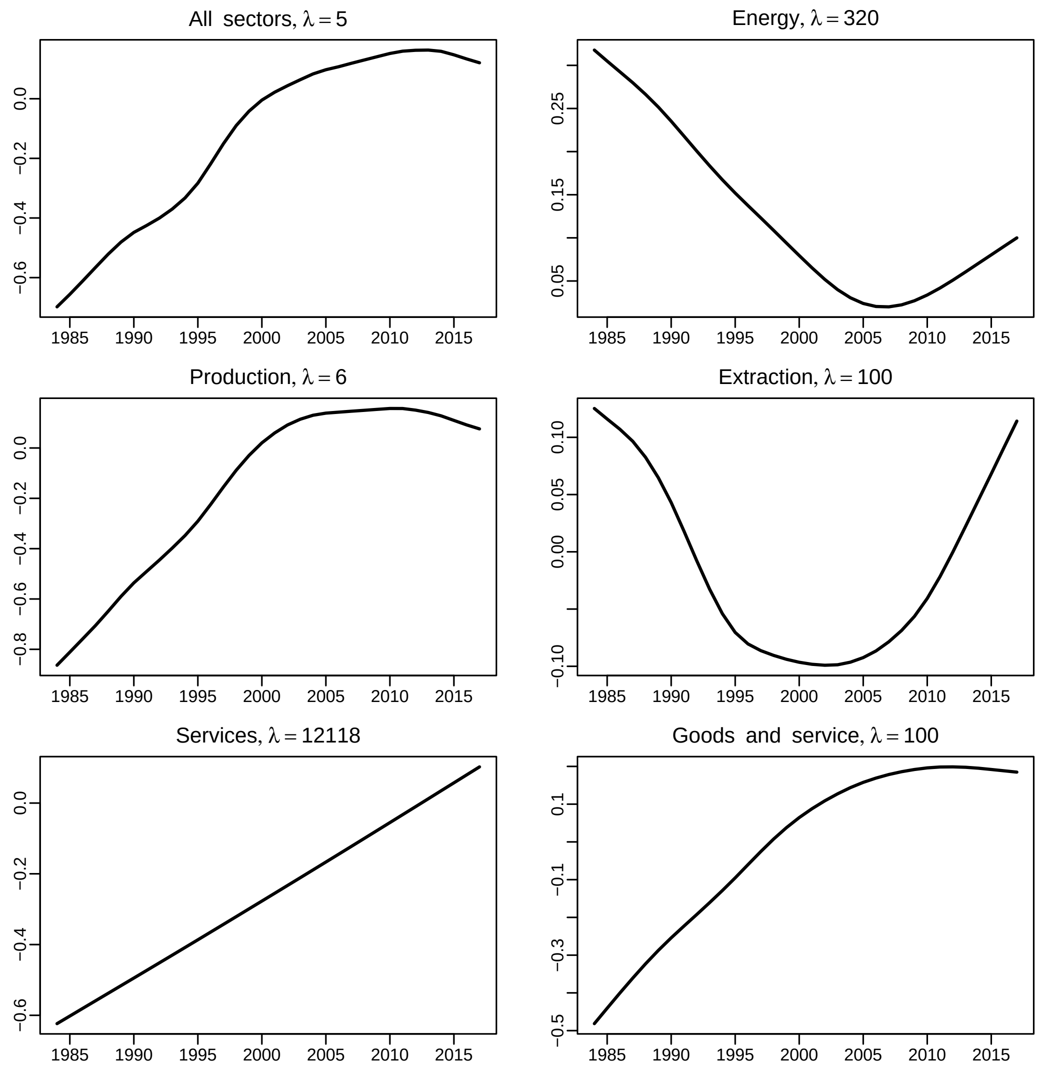
Figure A.0.2: Scatter plots of sectoral import prices and oil prices for the period 1967-2017



Note: Scatter plots for each sector plotted together with respective linear regression estimate. Sectoral imort prices are on the x-axis and oil price on the y-axis.

B Development of estimated scale parameters

Figure B.0.1: Estimated μ^{pm} from our preferred model



C Linear regressions

Given assumption (5) we get the following log-linear expression form from (1)

$$log(P^M_{s,t}) = (1 - \varphi^F_s)(\mu_{0,s} + \mu^{pm}_{1,s} t) + \sigma^{pm}_s (1 - \varphi^F_s) log P^{oil}_t + \varphi^F_s log P^M_{s,t-1} \tag{5}$$

which is then expressed in an error correction form:

$$\triangle log(P^M_{s,t}) = \alpha_1 \Delta log P^{oil}_t + \alpha_2 \left[\left[log P^M_{s,t-1} - \mu_{0,s} - \mu^{pm}_{1,s} t - \sigma^{pm}_s log P^{oil}_{t-1}\right]\right] + \epsilon_t,\ \epsilon_t \sim N(0, \Sigma^{\epsilon}) \quad (6)$$

where $\alpha_2 = (\varphi^F_s - 1)$. Equation (7) is estimated with help of a non-linear estimator where we minimize the sum of squared residuals.

The initial values we apply are the following: $\alpha = \varphi^F_s = \sigma^{pm}_s = \mu_{0,s} = \mu^{pm}_{1,s} = 0.5$.

D Estimates for fixed value of λ

Table D.0.1: Estimated parameters from (4) using annual data and $\lambda = 100$

G&S	Parameter	1967-2017	1983-2017
Oil price elasticity	σ^{pm}_s	0, 17 (0,03)	0, 20 (0,03)
Price stickiness	φ^F_s	0,68 (0,05)	0,69 (0,06)
Noice-to-signal ratio	λ	100	100

Production	Parameter	1967-2017	1983-2017
Oil price elasticity	σ^{pm}_s	0, 18 (0,04)	0, 20 (0,05)
Price stickiness	φ^F_s	0,76 (0,04)	0,76 (0,05)
Noice-to-signal ratio	λ	100	100

Services	Parameter	1967-2017	1983-2017
Oil price elasticity	σ^{pm}_s	0, 17 (0,02)	0, 21 (0,03)
Price stickiness	φ^F_s	0,45 (0,12)	0,43 (0,13)
Noice-to-signal ratio	λ	100	100

Energy	Parameter	1967-2017	1983-2017
Oil price elasticity	σ^{pm}_s	0, 81 (0,03)	0, 82 (0,04)
Price stickiness	φ^F_s	0,22 (0,13)	0,32 (0,15)
Noice-to-signal ratio	λ	100	100

Extraction	Parameter	1967-2017	1983-2017
Oil price elasticity	σ^{pm}_s	0, 86 (0,03)	0, 89 (0,04)
Price stickiness	φ^F_s	0,17 (0,12)	0,20 (0,14)
Noice-to-signal ratio	λ	100	100

Notes: Parameters , σ^{pm}_s, φ^F_s and λ are estimated with the Kalman filter on annual data. Standard errors are in brackets and † represents the rejection of the hypothesis that the oil price elasticity is not significantly different from 0 while ‡ represents the rejection of the hypothesis that the oil price elasticity is not significantly different from 1. G&S stands for Goods and Services. The period 1983-2017 is included to solely capture the fixed-exchange-rate policy in Denmark.