The Exchange rate in a small open commodity exporting economy

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CATE workshop: Økonometriske modeller og økonomisk politikkanalyse

Objectives: Several

- Not to answer why the euro-nok krone exchange rate is so weak
- To investigate whether it is possible to find support for some features typically related to New-Keynesian rational expectation model by resorting to a purely frequentist estimation approach, not imposing restrictions on the parameters (distributional or otherwise)
- How one may go about operationalizing forward looking expectations in a wider macro econometric model environment

Results

- In certain cases possible to freely estimate a structural model that comes close to being consistent with some features of a New-Keynesian rational expectation model
- In the framework of a general equilibrium model of a two-country two-markets economy we do find in fact some support for the existence of a New Keynesian Phillips curve.
- The inherent problem of stability may be circumventet by both utilising
  1. An adaptive expectation formation scheme (VARS)
  2. Incorporating the saddle path solution of a rational expectation general equilibrium model for the variables that according to theory are directly affected by the expectation formation.

Motivation

- Much recent econometric work concerning exchange rate modelling revolves around models based on uncovered interest parity - or rather deviations from it.
- Problem: Empirical models based on one equation at the-time design processes do not take properly into account the fact that the exchange rate is the outcome of a simultaneous causal interaction process, involving a set of interdependent endogenous variables.
- Exchange rates, prices and real interest rates are all endogenous macroeconomic variables depending on the simultaneous structure of an underlying hypothetical data generating process (DGP).

Motivation

- There are differences in the dynamic simultaneous structure of the Dornbuschs/Mundell Flemming model versus the New Keynesian model.
- Dornbuschs model is behavioral and derived under perfect foresight with no shocks, except an initial monetary policy surprise.
- The New Keynesian models are derived from optimizing behavior by households and firms under uncertainty
- Here: We are going to use a New Keynesian model framwork as a point of departure for modelling the exchange rate.
- In a setting where it is determined jointly with prices and interest rates based on a rational expectation general equilibrium framework

New-Keynesian model of a two-country two-markets economy

- Aggregate relationships derived from the decisions of utility-maximizing households and profit-maximizing monopolistic firms in two countries.
- Symmetrical model with equal preferences (No home bias in consumption) and technologies.
- Firms are monopolistic and produce imperfect substitutes and when they are allowed to change their prices (price rigidity)
- Prices set so that the discounted present value of their total future expected profit is maximized

New-Keynesian model of a two-country two-markets economy continued

- Starting point: Model with deviations from UIP

$$i_t - i_t^* = E_t(q_{t+1}) - q_t + E_t(\pi_{t+1} - \pi_{t+1}^*) - \lambda_t$$

- Monetary policy is determined at home and out by two similar reaction functions where the Taylor principle is met

$$i_t - i_t^* = \sigma(\pi_t - \pi_t^*) + \rho(u_t - u_t^*) + \alpha(i_{t-1} - i_{t-1}^*) + \varepsilon_t - \varepsilon_t^*$$

- Companies set prices to maximize the expected discounted value of all future profits

$$\pi_t - \pi_t^* = \delta q_t + \beta E_t(\pi_{t+1} - \pi_{t+1}^*)$$

New-Keynesian model of a two-country two-markets economy continued

- The simultaneous structure

$$E_t \begin{pmatrix} \pi_{t+1} - \pi^*_{t+1} \\ q_{t+1} \\ i_t - i^*_t \end{pmatrix} = \begin{bmatrix} \frac{1}{\beta} & -\frac{\delta}{\beta} & 0 \\ \frac{\sigma\beta-1}{\beta} & \frac{\beta+\delta}{\beta} & \alpha \\ \sigma & 0 & \alpha \end{bmatrix} \begin{pmatrix} \pi_t - \pi^*_t \\ q_t \\ i_{t-1} - i^*_{t-1} \end{pmatrix}$$

$$+ \begin{bmatrix} 0 & 0 \\ -1 & \rho \\ 0 & \rho \end{bmatrix} \begin{pmatrix} \lambda_t \\ u_t - u^*_t \end{pmatrix} + \begin{pmatrix} 0 \\ \varepsilon_t - \varepsilon^*_t \\ \varepsilon_t - \varepsilon^*_t \end{pmatrix}$$

Multiplying by: $\begin{bmatrix} \frac{1}{\beta} & -\frac{\delta}{\beta} & 0 \\ \frac{\sigma\beta-1}{\beta} & \frac{\beta+\delta}{\beta} & \alpha \\ \sigma & 0 & \alpha \end{bmatrix}^{-1} =>$

New-Keynesian model of at two-country two-markets ecomomy continued

$$\begin{pmatrix} \pi_t - \pi_t^* \\ q_t \\ i_t - i_t^* \end{pmatrix} = \begin{bmatrix} \beta+\delta & \delta & -\delta \\ 1 & 1 & 1 \\ \frac{1}{\alpha}\sigma(\beta+\delta) & -\frac{1}{\alpha}\sigma\delta & \frac{1}{\alpha}(\sigma\delta+1) \end{bmatrix} E_t \begin{pmatrix} \pi_{t+1} - \pi_{t+1}^* \\ q_{t+1} \\ i_{t+1} - i_{t+1}^* \end{pmatrix}$$

$$+ \begin{bmatrix} \beta+\delta & \delta & -\delta \\ 1 & 1 & 1 \\ \frac{1}{\alpha}\sigma(\beta+\delta) & -\frac{1}{\alpha}\sigma\delta & \frac{1}{\alpha}(\sigma\delta+1) \end{bmatrix} \begin{bmatrix} 0 & 0 \\ -1 & \rho \\ 0 & \rho \end{bmatrix} \begin{pmatrix} \lambda_t \\ u_t - u_t^* \end{pmatrix}$$

$$+ \begin{bmatrix} \beta+\delta & \delta & -\delta \\ 1 & 1 & 1 \\ \frac{1}{\alpha}\sigma(\beta+\delta) & -\frac{1}{\alpha}\sigma\delta & \frac{1}{\alpha}(\sigma\delta+1) \end{bmatrix} \begin{pmatrix} \omega_{\pi(t+1)} \\ \omega_{q(t+1)} \\ \varepsilon_t - \varepsilon_t^* \end{pmatrix}$$

New-Keynesian model of a two-country two-markets economy continued

Written in equation form:

$$\pi_t - \pi_t^* = \delta(s_t + p_t^* - p_t) + \beta E_t(\pi_{t+1} - \pi_{t+1}^*),$$

$$s_{t+1} + p_{t+1}^* - p_{t+1} = (\frac{\beta + \delta}{\beta})(s_t + p_t^* - p_t)_t + \alpha((i_{t-1} - \pi_t) - (i_{t-1}^* - \pi_t^*)) \\ + \rho(u_t - u_t^*) - \lambda_t + \varepsilon_t - \varepsilon_t^*$$

$$i_t - i_t^* = \sigma(\pi_t - \pi_t^*) + \rho(u_t - u_t^*) + \alpha(i_{t-1} - i_{t-1}^*) + \varepsilon_t - \varepsilon_t^*$$

From theory to a SVECM

$$\Delta s_t = -\phi_s\{(s_{t-1}+p^*_{t-1}-p_{t-1})+\alpha_s(i_{t-1}-i^*_{t-1})-\omega_s(\Delta p_{t-1}-\Delta p^*_{t-1})$$
$$-\gamma_s(u_{t-1}-u^*_{t-1})\}+c_s+\lambda_{t-1}+\sum_{i=0}^{k}\Gamma_i\Delta\bar{Z}_{t-i}+\sum_{i=1}^{k}\rho_i\Delta s_{t-i}+\Theta_s D_t+\epsilon^s_t$$

$$\Delta i_t = -(\alpha_i)\{(i_{t-1}-i^*_{t-1})-\psi_i(\Delta p_{t-1}-\Delta p^*_{t-1})+\gamma_i(u_{t-1}-u^*_{t-1})\}$$
$$+c_i+\sum_{i=0}^{k}\Upsilon_i\Delta\bar{X}_{t-i}+\sum_{i=1}^{k}\psi_i\Delta i_{t-i}+\Theta_i D_t+\epsilon^i_t$$

$$\Delta p_t = \Delta p^*_t+c_\pi+\delta(p_{t-1}-(s_{t-1}+p^*_{t-1}))+\beta E_t(\Delta p_{t+1}-\Delta p^*_{t+1})+\epsilon^p_t$$

SVECM: Estimation period: 2001(1) to 2017(2)

$$\Delta s_{t-1} = \underset{(0.04)}{0.09} + \underset{(0.089)}{0.229}\Delta s_{t-2} + \underset{(0.003)}{0.007}\Delta(p_t - p_t^*) - \underset{(0.001)}{0.003}\Delta(p_{t-1} - p_{t-1}^*)$$
$$- \underset{(0.001)}{0.004}\Delta(p_{t-2} - p_{t-2}^*) - \underset{(0.013)}{0.067}\Delta poil_t - \underset{(0.001)}{0.004}\Delta(i_t - i_t^*)$$
$$- \underset{(0.056)}{0.174}(s_{t-1} + p_{t-1}^* - p_t) - \underset{(0.0007)}{0.0019}((i_{t-1} - \Delta p_{t-1}) - (i_{t-1}^* - \Delta p_{t-1}^*))$$
$$- \underset{(0.021)}{0.054}(vogava_{t-1}) + \underset{(0.056)}{0.174}\,\mathrm{SDUM081084} + \epsilon_t^s$$

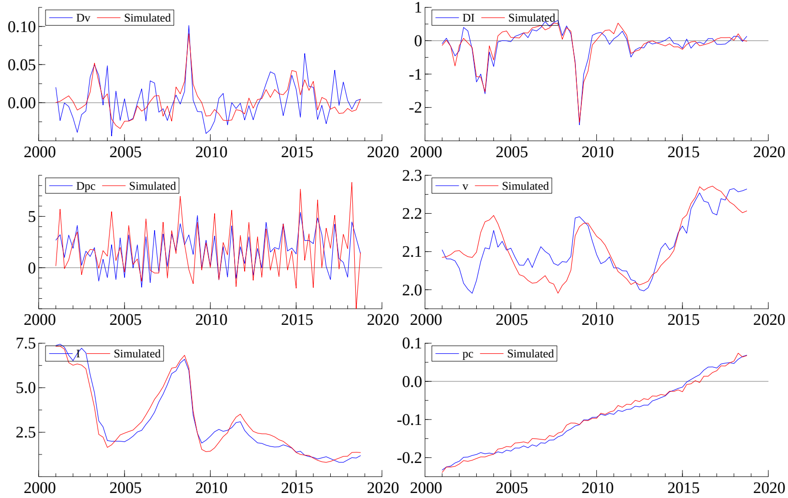
$$\Delta i_t = \underset{(0.11)}{0.168} + \underset{(0.05)}{0.97}\Delta i_t^* + \underset{(0.035)}{0.134}\Delta i_{t-1} + \underset{(0.038)}{0.147}\Delta\Delta_4(p_t)$$
$$- \underset{(0.023)}{0.083}(i_{t-1} - i_{t-1}^*) - \underset{(0.028)}{0.074}u_{t-1} + \underset{(0.033)}{0.203}\Delta_4 p_{t-1}$$
$$- \underset{(0.095)}{0.519}\,\mathrm{SDUM031032}) - \underset{(0.12)}{1.09}(\mathrm{DUM033}) - \underset{(0.12)}{0.39}(\mathrm{DUM041})$$
$$- \underset{(0.075)}{0.398}\,\mathrm{SDUM082093} - \underset{(0.049)}{0.247}\,\mathrm{SDUM133} - \underset{(0.049)}{0.247}\,\mathrm{CS1} + \epsilon_t^i$$

$$\Delta p_t = -\underset{(2.96)}{6.51} + \Delta p_t^* - \underset{(4.08)}{8.98}(p_{t-1} - (s_{t-1} + p_{t-1}^*)) + \underset{(0.137)}{0.534}\Delta_2(p_{t+2} - p_{t+2}^*)$$

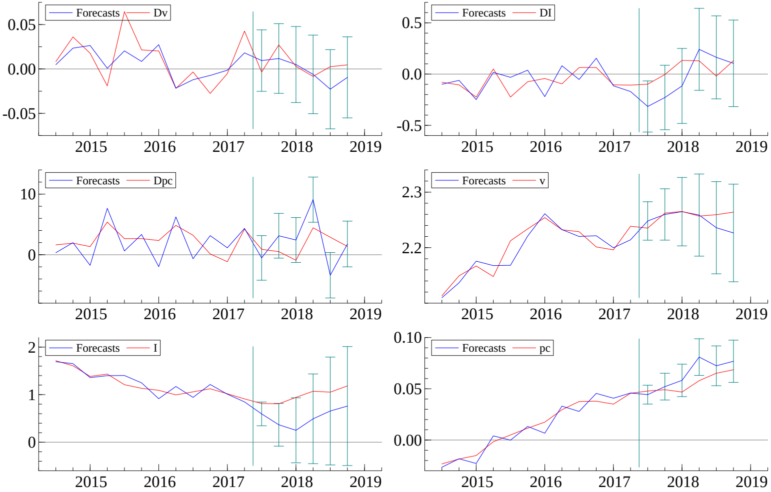
Vector SEM-AR 1-1 test:F(9,126) = 1.4132[0.1892]

Vector Normality test: $\chi^2(6) = 7.9898$ [0.2389]

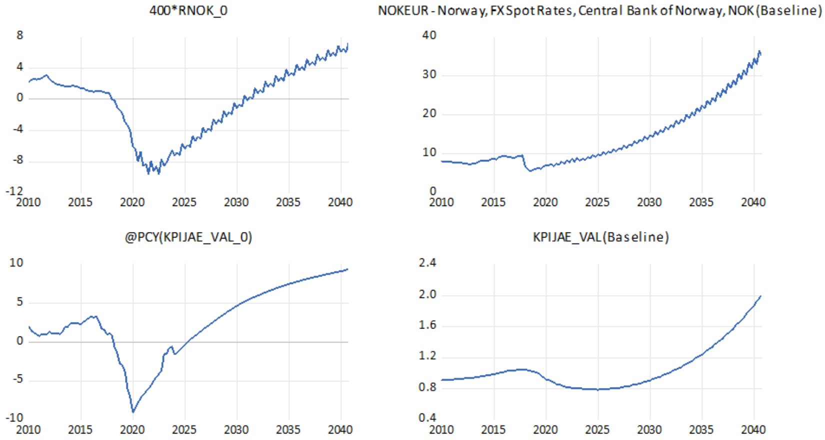
Dynamic Simulations



Dynamic Forecasts



Out of sample Simulations using a Gauss-Seidel (Fair-Taylor) iterative scheme



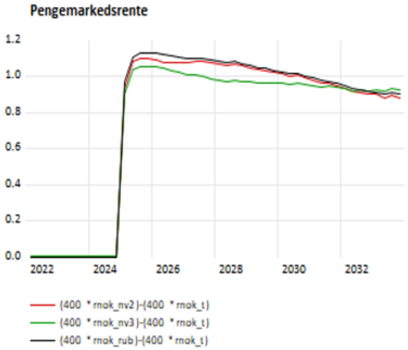
Adaptive expectation formation (VARS)

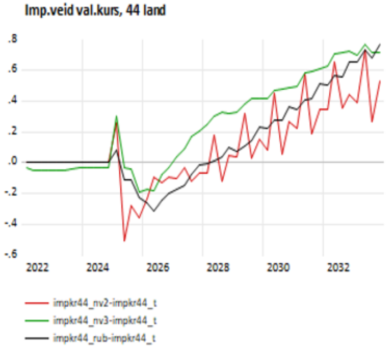
$$\Delta p_t - \Delta p_t^* = \delta(s_t + p_t^* - p_t) + \beta E_t(\Delta_2 p_{t+2} - \Delta_2 p_{t+2}^*)$$

$$\Delta p_t - \Delta p_t^* = \delta(s_t + p_t^* - p_t) + \beta(INFORVH_t - \Delta_2 p_{t+2}^*)$$

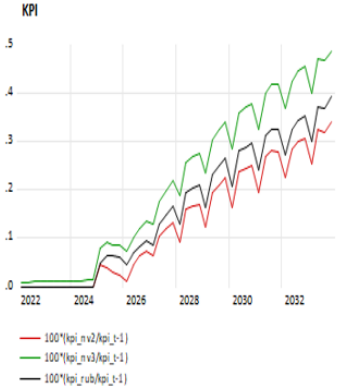
$$INFORVH_t = c + \sum_{j=0}^{k} \gamma_j \Delta p_{t-j} + \varphi D_t$$

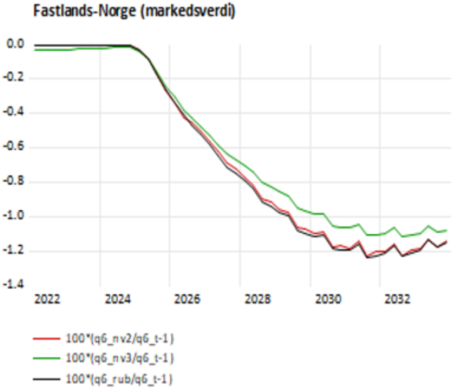
Foreign interest rate shift



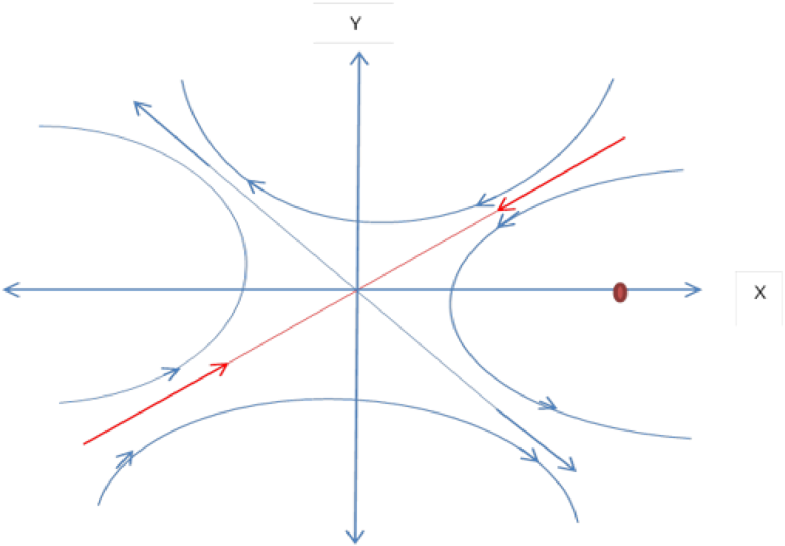


Foreign interest rate shift





Incorporate the saddle path of a stylized DSGE model



DSGE model with a strict inflation targeting CB

$$q_t = s_t + p_t^* - p_t$$

$$\pi_{t+1} - \pi_{t+1}^* = \frac{1}{\beta}\Delta(\pi_t - \pi_t^*) + \frac{(-\delta)}{\beta}q_t$$

$$q_{t+1=(\frac{\beta\sigma-1}{\beta})\Delta(p_t - p_t^*)+(\frac{\beta+\delta}{\beta})q_t+\alpha(i_{t-1}-i_{t-1}^*)+\epsilon_t}$$

$$(i - i^*)_t = \alpha(i - i^*)_{t-1} + \sigma(\pi_t - \pi_t^*) + \epsilon_t$$

$$\epsilon_t = \rho\epsilon_{t-1} + \sigma_\epsilon v_t$$

$$\delta = \frac{(1-\Theta)(1-\Theta\beta)}{\Theta}$$

DSGE: Calibration Schemes

Parameter	Description	Sim 1	Sim 2	Sim 3	Sim 4
β	Discount factor	0.53	0.99	0.53	0.990
θ	Calvo parameter	0.0873	0.0873	0.75	0.75
σ	Taylor rule inflation response $\sigma = (1/\beta - \alpha)$	0.967	0.090	0.967	0.210
α	Taylor rule degree of interest rate smoothing	0.92	0.92	0.92	0.800
ρ_ϵ	Persistence of monetary policy innovations	0.000	0.000	0.000	0.000
σ_ϵ	Standard Deviation of monetary policy innovations	0.0025	0.0025	0.0025	0.0025

Simulation 1: Empirical parameter values

	pi	i	policy_shock	q
ri_gap(-1)	-90.560436	17.787417	0	-8.868306
eta_eps	-0.246088	0.048335	1.000000	-0.024099

Simulation 2: Empirical parameters, but higher discount factor

	pi	i	policy_shock	q
ri_gap(-1)	-932.190928	32.034623	0	-89.861301
eta_eps	-2.533128	0.087051	1.000000	-0.244188

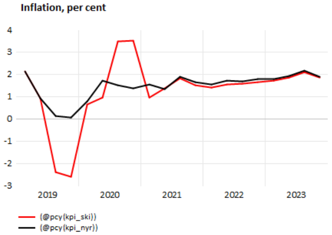
Simulation 3: Empirical parameters, but higher price stickiness

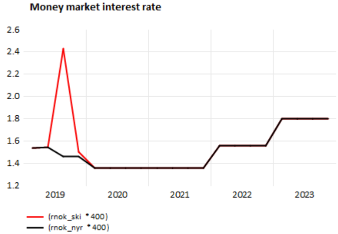
	pi	i	policy_shock	q
ri_gap(-1)	-41.787037	206.402430	0	-151.165065
eta_eps	-0.113552	0.560876	1.000000	-0.410775

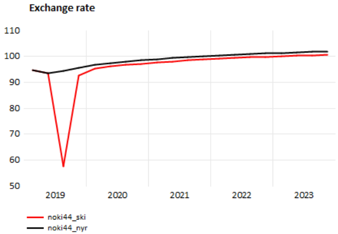
Simulation 4: "Textbook" discount factor and price stickiness, empirical value for interest smoothing

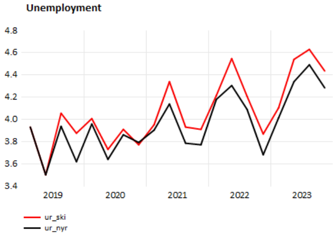
	pi	i	policy_shock	q
ri_gap(-1)	-74.487518	257.400389	0	-314.959870
eta_eps	-0.232773	0.804376	1.000000	-0.984250

DSGE in KVARTS Impuls responses of a monetary policy shock: SIM1

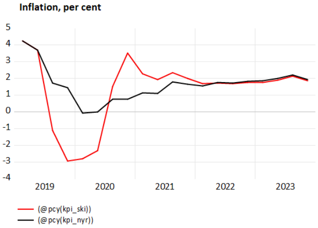


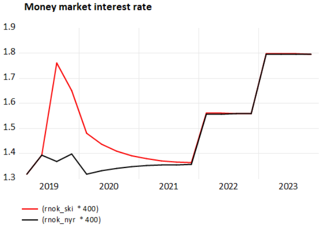


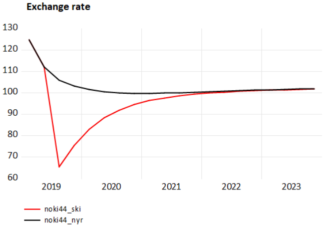


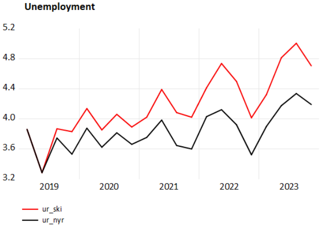


DSGE in KVARTS Impuls responses of a monetary policy shock: SIM4









Conclusions

- In specific cases may be possible to freely estimate a structural model that comes close to being consistent with some features in DSGE framework
- In the framework of a general equilibrium model of a two-country two-markets economy we do find support for the existence of a New-Keynesian Phillips curve.
- As far as the operationalization of forward looking expectations in macroeconomic models is concerned, our analysis indicates that this may be facilitatet by
    1. utilising an adaptive expectation formation scheme
    2. Incorporating the saddle path solution of a rational expectation general equilibrium model directly as a sub model in within a wider macro econometric environment.

Thank You

Operationalizations of IA

$$\Delta s_{t-1} = \underset{(0.04)}{0.09} + \underset{(0.089)}{0.229} \Delta s_{t-2} + \underset{(0.003)}{0.007} \Delta(p_t - p_t^*) - \underset{(0.001)}{0.003} \Delta(p_{t-}$$

$$- \underset{(0.001)}{0.004} \Delta(p_{t-2} - p_{t-2}^*) - \underset{(0.013)}{0.067} \Delta poil_t - \underset{(0.001)}{0.004} \Delta(i_t - i_t^*)$$

$$- \underset{(0.056)}{0.174} (s_{t-1} + p_{t-1}^* - p_t) - \underset{(0.0007)}{0.0019} ((i_{t-1} - \Delta p_{t-1}) - (i_{t-1}^* - \Delta p_{t-1}^*)$$

$$- \underset{(0.021)}{0.054} (vogava_{t-1}) + \underset{(0.056)}{0.174} \text{SDUM081084} + \epsilon_t^s \quad (1)$$

$$\Delta i_t = \underset{(0.11)}{0.168} + \underset{(0.05)}{0.97} \Delta i_t^* + \underset{(0.035)}{0.134} \Delta i_{t-1} + \underset{(0.038)}{0.147} \Delta \Delta_4(p_t)$$

$$- \underset{(0.023)}{0.083} (i_{t-1} - i_{t-1}^*) - \underset{(0.028)}{0.074} u_{t-1} + \underset{(0.033)}{0.203} \Delta_4 p_{t-1}$$

$$- \underset{(0.095)}{0.519} \text{SDUM031032}) - \underset{(0.12)}{1.09} (\text{DUM033}) - \underset{(0.12)}{0.39} (\text{DUM041})$$

R&D

1. The *lowest* level of R&D intensity refers to firms without R&D expenditures (i.e., R&D inactive firms)
2. The second level refer to firms with positive R&D in a broad sense – i.e. not restricted to scientific R&D
3. The third level refers to firms that apply for R&D-related IP (patents or industrial designs).

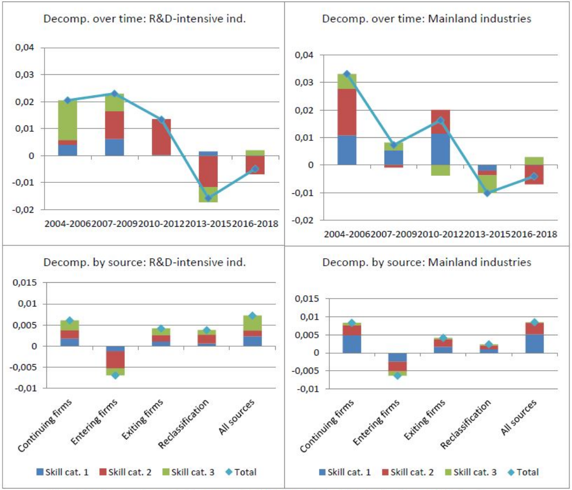


Figure 5: Aggregate productivty growth 2004-2018 in the R&D-intensive vs. Mainland industries. Decomposition by ordinal human capital (skill) category (B = 3 categories). See Section 3.1 for definition of the categories.