CPB Netherlands Bureau for
Economic Policy Analysis

Saffier 3.0: Estimation results

This technical document supplements the general documentation of the macromodel Saffier 3.0. We report in more detail the estimation outcomes for the main equations in Saffier 3.0

We estimate an error correction specification for consumption, exports and imports. A polynomial adjustment cost specification, including expectations, is estimated for labour demand, investment, wages and prices.

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Contents

1 Introduction

We have described the latest version of the Saffier model in Bettendorf et al. (2021), including the estimation of the main equations (see Section 3). In this document we discuss in more detail the estimation outcomes of our preferred specification and alternative specifications.

An error correction specification is estimated for three equations (consumption, exports and imports). We follow the polynomial adjustment cost (PAC) approach of Tinsley (2002) in the estimation of 6 equations (labour demand, investment, three prices and wages). Expectations are captured by the PAC specification, except for the consumption equation (which includes a permanent income term). Expected values are generated as forecasts of a VAR model. All PAC equations share a core VAR model. Therefore, we start in the next section with a discussion of the set-up and results of this core VAR model. In estimating the PAC equations we use VAR-expectations. Since we assume static expectations in simulating the current version, we might instead estimate error correction models without forward looking terms. However, estimation results do not differ much between the PAC and ECM approach. In the following 7 sections we discuss successively the main behavioural equations (the last section covers the 3 price equations).

The estimation tasks were distributed as follows:

- Henk Kranendonk prepared the datasets for each estimation
- Stefan Boeters prepared Sections 2,3,4 and 9
- Loes Verstegen prepared Sections 5 and 8
- Leon Bettendorf prepared Sections 5,6 and 7

2 Core VAR

Following the approach of the ECB-BASE model (Angelini et al, 2019, Zimic and Marcelatti, 2017), we set up a core VAR model for forecasting the variables that determine the targets in the 6 PAC equations of Saffier 3.0 (three price equations, labour and investment demand, wage). The core VAR model contains three variables of the euro area (interest rate, inflation, output gap) and two variables for the Netherlands (inflation, output gap). This core VAR is used in the second (forecasting) step of all PAC estimations.

2.1 Core VAR set-up

Inspired by the set-up of the ECB model, the core VAR system contains 5 variables (y):

- output gap NL (GAP_NL)
- consumer price inflation NL (CPI_NL)
- short-term interest rate (RK_EA)
- output gap Euro Area (GAP_EA)
- consumer price inflation Euro Area (CPI_EA)

Each of these variables has a target ($\bar{y}$). Targets for GAP_NL and GAP_EA are zero (but kept in the notation for generality), targets for CPI_NL, RK_EA and CPI_EA are time-varying and taken from expert forecast series.

The general specification is:

$$\Delta y_t = R\Delta y_{t-1} + A(y_{t-1} - \bar{y}_{t-1})$$

with two 5×5 coefficient matrices (R and A) to be estimated. However, we adopt the assumption of an only partial linkage between the NL and the EA part of the VAR:

- EA variables do not depend on NL variables,
- NL variables depend on EA variables only through the common interest rate.

This leaves us with two times 15 parameters to be estimated:

	GAP_NL	CPI_NL	RK_EA	GAP_EA	CPI_EA
GAP_NL	$\times$	$\times$	$\times$	0	0
CPI_NL	$\times$	$\times$	$\times$	0	0
RK_EA	0	0	$\times$	$\times$	$\times$
GAP_EA	0	0	$\times$	$\times$	$\times$
CPI_EA	0	0	$\times$	$\times$	$\times$

The stability of the resulting VAR is most straightforwardly checked by formulating it as 10×10 system in levels and lagged levels. This gives the coefficient matrix]

$$\begin{bmatrix}
1+r_{11}+a_{11} & r_{12}+a_{12} & r_{13}+a_{13} & 0 & 0 & -r_{11} & -r_{12} & -r_{13} & 0 & 0 \\
r_{21}+a_{21} & 1+r_{22}+a_{22} & r_{23}+a_{23} & 0 & 0 & -r_{21} & -r_{22} & -r_{23} & 0 & 0 \\
0 & 0 & 1+r_{33}+a_{33} & r_{34}+a_{34} & r_{35}+a_{35} & 0 & 0 & -r_{33} & -r_{34} & -r_{35} \\
0 & 0 & r_{43}+a_{43} & 1+r_{44}+a_{44} & r_{45}+a_{45} & 0 & 0 & -r_{43} & -r_{44} & -r_{45} \\
0 & 0 & r_{53}+a_{53} & r_{54}+a_{54} & 1+r_{55}+a_{55} & 0 & 0 & -r_{53} & -r_{54} & -r_{55} \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}$$

whose eigenvalues can be checked. The largest eigenvalue with the sample 1996q3-2019q4 is 0.921, which gives a stable system.[1]

Coefficient matrices R and A, sample 1996-2016:

R	[, 1]	[, 2]	[, 3]	[, 4]	[, 5]
[1,]	−0.149	0.283	1.409	0.000	0.000
[2,]	−0.132	−0.041	0.183	0.000	0.000
[3,]	0.000	0.000	0.402	0.132	0.159
[4,]	0.000	0.000	0.451	0.123	0.293
[5,]	0.000	0.000	−0.094	0.040	−0.114

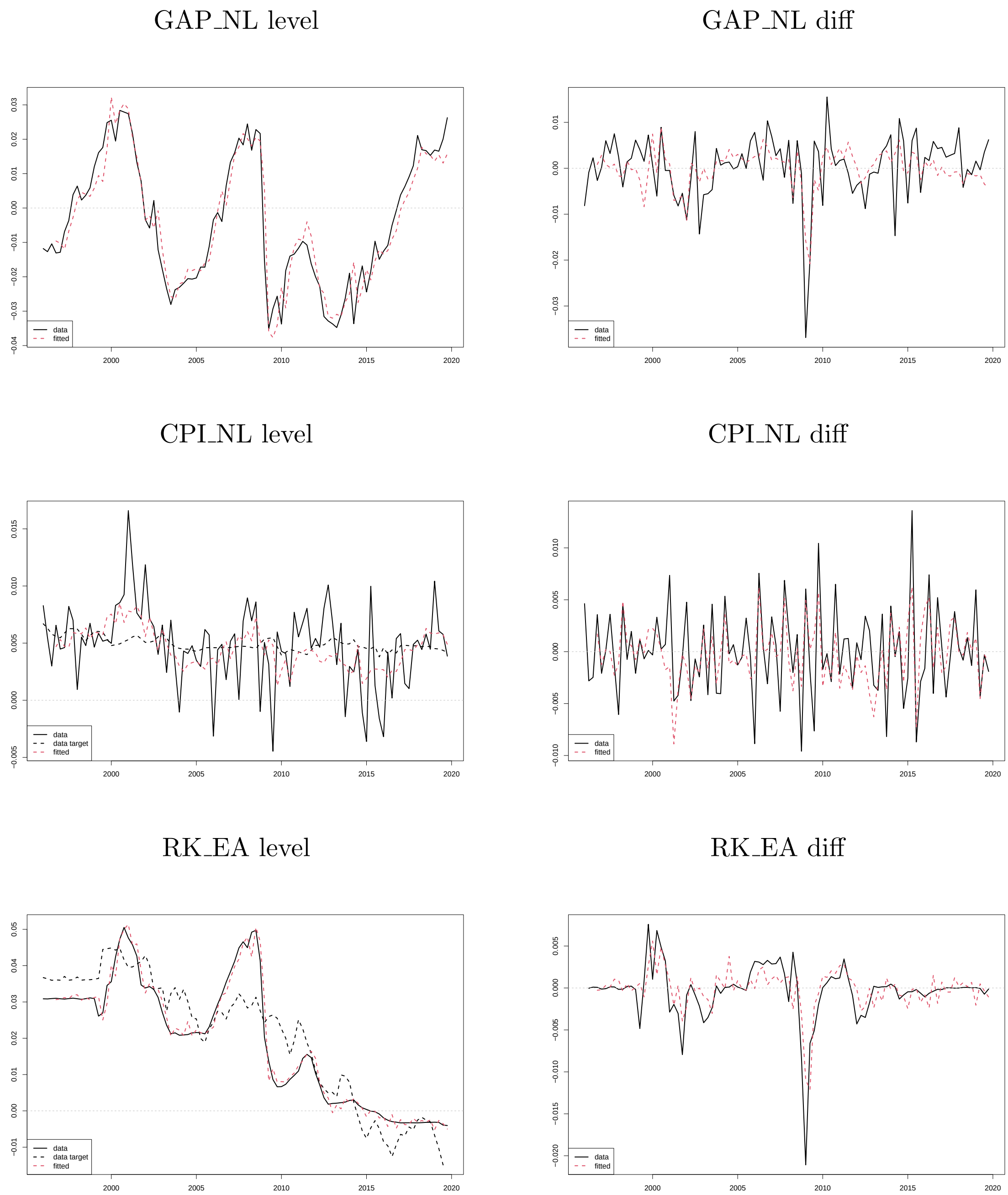
A	[, 1]	[, 2]	[, 3]	[, 4]	[, 5]
[1,]	−0.102	−0.182	−0.031	0.000	0.000
[2,]	0.059	−0.844	−0.026	0.000	0.000
[3,]	0.000	0.000	−0.085	0.007	0.110
[4,]	0.000	0.000	−0.151	−0.055	−0.046
[5,]	0.000	0.000	−0.079	0.060	−0.678

2.2 Fit core VAR

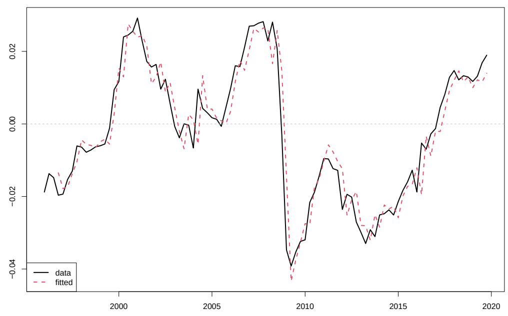
The following figures (5 core VAR variables in both levels and first differences) show the fit of the VAR equations.

[1] In an intermediate version we were struggling with instability due to data errors. So checking the eigenvalues is always a useful test.

Figure 1: Fit of the VAR equations

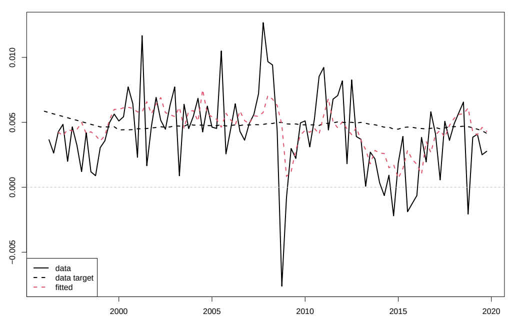


GAP_EA level

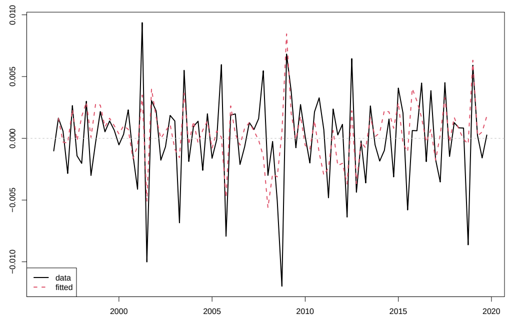


GAP_EA diff

CPI_EA level



CPI_EA diff

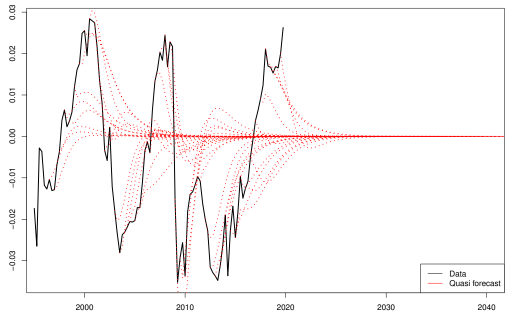


2.3 Forecast

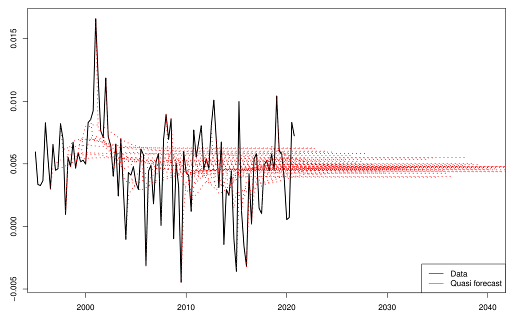
The following figures show the forecast properties of the core VAR. All 5 variables stabilise within a few years. The two gaps converge to zero, the other three variables have a variable target.

Figure 2: Forecasts of the VAR variables (1996-2019)

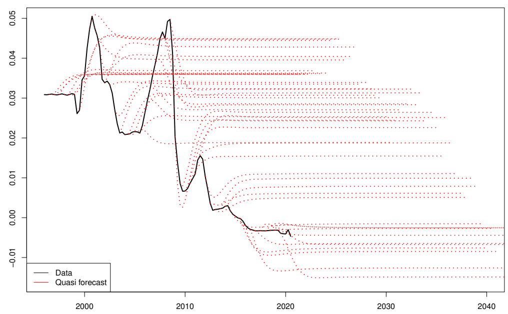
GAP_NL



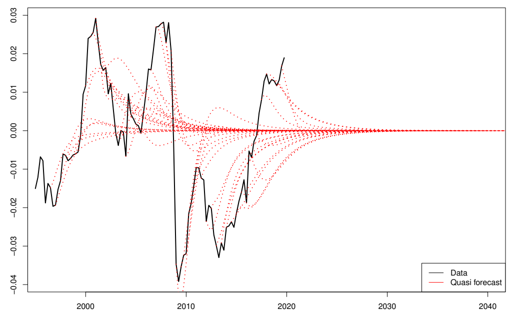
CPI_NL



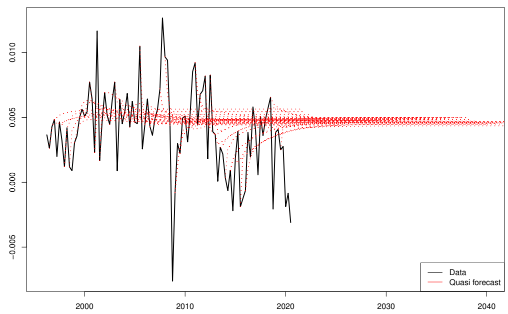
RK



GAP_EA



CPI_EA



3 Labour demand

We estimate labour demand of the market sector in total hours. In order to capture the effect of expectations, we set up our estimation in the polynomial adjustment cost (PAC) approach of Tinsley (2002), which is prominently featured in the FRB/US model (Brayton et al., 2000) and in ECB-BASE (Angelini et al, 2019).

The PAC approach results in an extended error-correction type of estimation equations. Estimation proceeds in three steps:

1. Long-term (co-integration) relationship estimated by OLS.
2. Forecasting relationships for the determinants of labour demand estimated in a VAR model with a limited number of core variables.
3. Short-term relationship estimated as an error-correction model with extensions accounting for expectation effects and auxiliary contemporaneous effects.

In the first step we estimate the long-term relationships, using the specification of the production function in the model, CES with $\sigma = 0.5$ (Section 3.2).

In the second step (Section 3.3), we estimate a VAR system based on interest rates, inflation rates and the output gap, which provides us with forecasts for the variables of interest (see Zimic and Marcelatti, 2017, for the general approach and Section 2, for the implementation in Saffier 3.0).

In the third step (Section 3.4), we estimate the core PAC equations, using short-term price and output changes and expected target changes as regressors.

The short-term coefficients used in Saffier 3.0 of Bettendorf et al. (2021) are documented in Table 1, first column. The error correction term is small and not significantly different from zero. Labour demand is the only PAC equation in the model (out of 6 that we have estimated) where the addition of a lagged dependent variable (PAC of degree $m = 2$) improves the fit considerably. The coefficients of the auxiliary variables are of the expected sign and highly significant. Still, due to the low error-correction coefficient, slow adjustment on the labour market remains a concern of the model results.

3.1 Data

- L_t: log labour demand in hours
- Y_t: log output
- PL_t: log hourly real wage
- C_t: log per unit structural real production cost
- HL_t: log structural labour productivity

HL_t is generated as the filtered residual of combining the production function of Saffier 3.0 (elasticity of substitution = 0.5, labour-saving technological progress only) with empirical quantities (output, labour and capital inputs). C_t is calculated consistently with the production function assumptions from the average factor shares, the factor prices and the structural labour productivity. All variables are in logs.

Estimation period is 1996q1-2019q4. We lose some observations at the start of the period when lags are involved.

3.2 Long run

The core parameters of the long-run equation for labour demand are not estimated, but imposed based on the production function assumptions ($\sigma = 0.5$). The only parameters to be estimated is the constant, which collects the average log labour share and different normalisation constants for the other variables. As a single constant for the whole period results in systematically positive residuals towards the end of the sample (which prove to be without explanatory value in the short run), we allow for one additive structural break in 2014q2.[2]

$$L_t = \alpha_0 + \alpha_1 \text{dum}_{14-19} + Y_t - \sigma \left(PL_t - C_t\right) + (\sigma - 1)HL_t$$

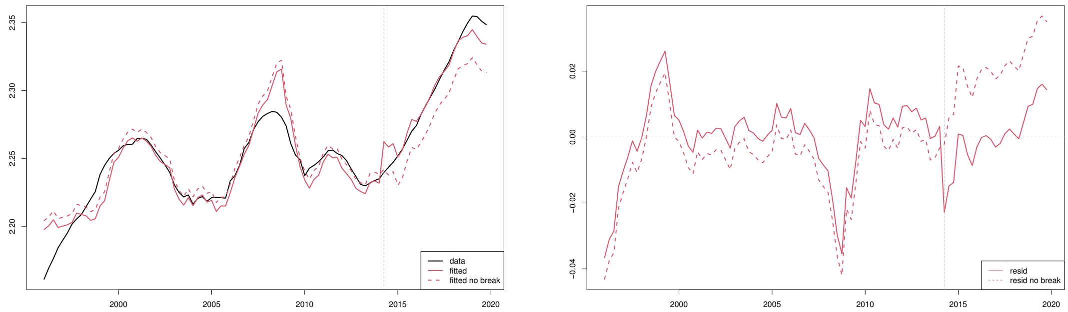
Fit (left) and residuals of the long-term equation are shown in Figure 3.

3.3 VAR

The VAR explaining the price expectations is built up in three steps. First, the core VAR in the five variables y_t = GAP_NL, CPI_NL, RK_EA, GAP_EA and CPI_EA is set up. This is documented in Section 2.

[2]The breakpoint has been determined by running a loop over candidate breakpoints between 2010 and 2017 and selecting the point that results in the best fit of the short-run equation.

Figure 3: Long-term: fit (left) and residuals (right)



Second, four explaining variables ($x_t = Y_t,\ PL_t,\ C_t,\ HL_t$) are forecast on basis of the "Dutch" variables in the core VAR and an autoregressive term:

$$\Delta x_t = \beta_0 + \beta_1 \Delta \text{GAP\_NL}_{t-1} + \beta_2 \Delta \text{CPI\_NL}_{t-1} + \beta_3 \Delta \text{RK\_EA}_{t-1} + \beta_4 \Delta x_{t-1}$$

The constants in these four equations are restricted so that the long-term growth rate of employment converges to the exogenous rate.[3]

Third, the forecast of the target for L_t is calculated using the parameters from the long-term equation.

[3] We have

$$\begin{aligned} g_Y &= c_Y/(1-r_Y) \\ g_W &= c_W/(1-r_W) \\ g_C &= c_C/(1-r_C) \\ g_H &= c_H/(1-r_H) \end{aligned}$$

where the c_i and r_i are the constants and the autoregressive coefficients in the VAR equations for the log changes in the respective variables. For $g_{L^*} = 0$, we need

$$g_Y - \sigma(g_W - g_C) + (\sigma - 1) g_H = 0$$

that is

$$g_H = \frac{g_Y - \sigma(g_W - g_C)}{1 - \sigma}$$

for $\sigma = 0.5$

$$g_H = 2g_Y - g_W + g_C$$

$$c_H/(1-r_H) = 2c_Y/(1-r_Y) - c_W/(1-r_W) + c_C/(1-r_C)$$

It turns out that r_H is estimated to be (slightly) above 1 (as it is in a single-equation estimation of H), resulting in an instability and diverging (instead of converging) growth rates. In order to impose stability, we further restrict $r_H = 0.9$.

As individual VAR coefficients are not particularly informative, we illustrate the performance of the VAR forecast with forecast figures for the four determinants of labour demand and the labour demand target itself.[4]

3.4 Short-term estimation: PAC

The PAC model is estimated as an ECM equation that is extended with one complex expectations term ("z_t"). This term is calculated from the forecast of the target variable and the other estimated parameters. Estimation is therefore iterative: z_t is calculated with given parameters and added as a time-varying offset for the estimation of an updated set of parameters.[5] This proceeds until convergence.

The base specification of the PAC equation is

$$\Delta L_t = \gamma_1 \left(L_t - L_t^{\star}\right) + \gamma_2 \Delta L_{t-1} + \gamma_3 \Delta Y_t + \gamma_4 \Delta W_t + \gamma_5 \Delta C_t + \gamma_6 \Delta H_t + z_t$$

Our specification search (documented in separate notes) resulted in a PAC of degree $m = 2$, i.e. with one autoregressive term.

Table 1 shows the estimation results. To put the results in perspective, we add the pure ECM results (without the z_t term) and the PAC results with $m = 1$.

The following figures show the fit and the residuals in the short run.

[4]These are "quasi forecasts" because the parameters have been estimated using the whole sample, not only the part that was known at the moment the forecast starts.

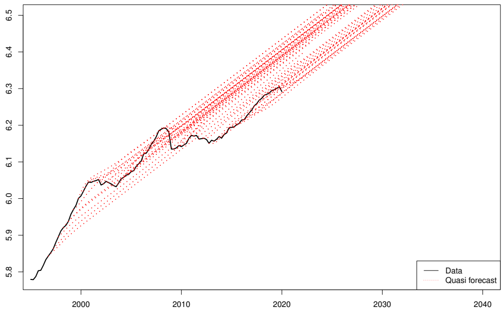
[5]The expectations term, z_t can be expressed as

$$z_t = \sum_{s=0}^{\infty} f_s \Delta p_{t+s}^{i\star}$$

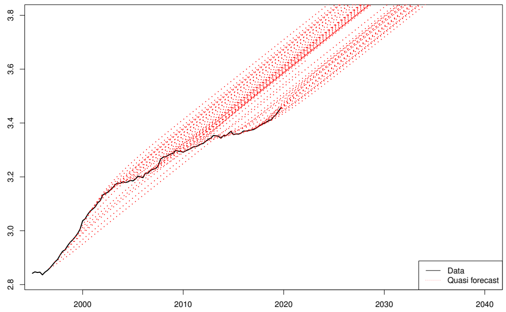
The expected changes in the target, $\Delta p_{t+s}^{i\star}$, are calculated by the VAR, the associated weights are functions of the estimated γ's. E.g. for $m = 1$ we have $f_s = \gamma_1 \left[\left(1-\gamma_1\right)\beta\right]^s$,where β is an exogenous discount factor.

Figure 4: Forecasts of the VAR variables Labour demand

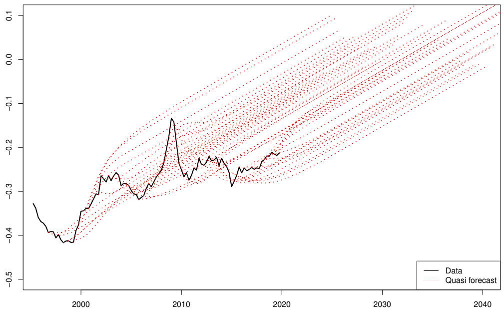
forecast logY, VAR labdem



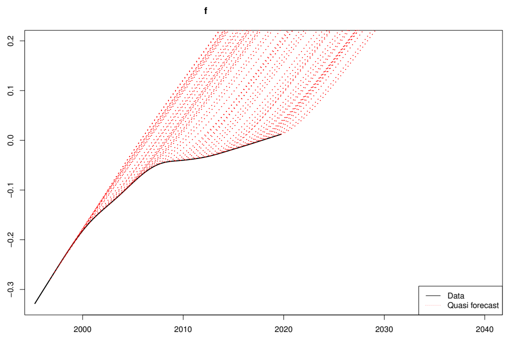
forecast logW, VAR labdem



forecast logC, VAR labdem



forecast logH, VAR labdem



forecast L*, VAR labdem

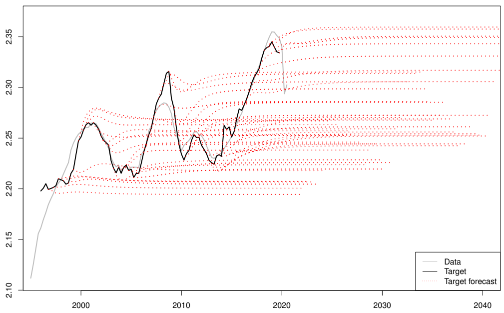


Figure 5: Short-term: fit (left) and residuals (right)

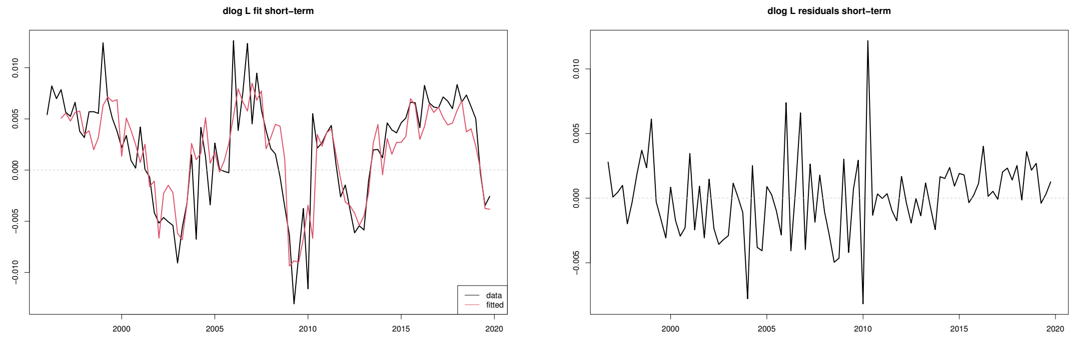


Table 1: Labour demand short-term

	PAC m=2	ECM	PAC m=1
γ_1	-0.047	-0.043	-0.080^{**}
	(0.035)	(0.031)	(0.037)
ΔL_{t-1} (γ_2)	0.385^{***}	0.441^{***}	
	(0.083)	(0.084)	
ΔY_t (γ_3)	0.309^{***}	0.332^{***}	0.467^{***}
	(0.066)	(0.066)	(0.056)
ΔW_t (γ_4)	-0.317^{***}	-0.317^{***}	-0.348^{***}
	(0.060)	(0.060)	(0.065)
ΔC_t (γ_5)	0.131^{***}	0.141^{***}	0.195^{***}
	(0.032)	(0.032)	(0.030)
ΔH_t (γ_6)	0.316^{**}	0.289^{**}	0.298^{**}
	(0.134)	(0.134)	(0.146)
R^2	0.708	0.708	0.641
Adj. R^2	0.688	0.688	0.621
Num. obs.	93	95	93
RMSE*100	0.300	0.303	0.329
ADF p	< 0.010	< 0.010	< 0.010
KPSS p	0.060	0.030	0.051
LB(1) p	0.066	0.023	0.016
LB(4) p	0.047	0.010	0.000

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

4 Investment

We estimate investment demand of the market sector, which is notoriously difficult to fit. In order to capture the effect of expectations, we set up our estimation in the polynomial adjustment cost (PAC) approach of Tinsley (2002), which is prominently featured in the FRB/US model (Brayton et al., 2000) and in ECB-BASE (Angelini et al, 2019).

The PAC approach results in an extended error-correction type of estimation equations. Estimation proceeds in three steps:

1. Long-term (co-integration) relationship estimated by OLS.
2. Forecasting relationships for the determinants of investment estimated in a VAR model with a limited number of core variables.
3. Short-term relationship estimated as an error-correction model with extensions accounting for expectation effects and auxiliary contemporaneous effects.

In the first step we estimate the long-term relationships, using a pure accelerator model without price effects (Section 4.2).

In the second step (Section 4.3), we estimate a VAR system based on interest rates, inflation rates and the output gap, which provides us with forecasts for the variables of interest (see Zimic and Marcelatti, 2017, for the general approach and Section 2, for the implementation in Saffier 3.0).

In the third step (Section 4.4), we estimate the core PAC equations, using short-term output changes and expected target changes as regressors.

The short-term coefficients used in Saffier 3.0 of Bettendorf et al. (2021) are documented in Table 2, first column. Both the error correction term and the short-term coefficient of output changes are large and significantly different from zero. Still, the fit of the equation is considerably lower than that of other PAC equations in the model.

4.1 Data

- I_t: log investment market sector
- Y_t: log output market sector
- PK_t: log user cost of capital (composed of rental rate and price of investment goods)
- C_t: log per unit structural real production cost

Estimation period is 1996q1-2019q4. We lose some observations at the start of the period when lags are involved.

4.2 Long run

We assume that the captial stock target follows from a CES production function with $\sigma = 0.5$ (for consistency with the rest of the model)

$$K_t^* = \alpha_0' + Y_t - 0.5\,(PK_t - C_t)$$

and that the target investment level is a fixed fraction (long-run growth + depreciation) of the target capital stock (so that the variables differ only by a constant η in logs).

$$I_t^* = K_t^* + \eta$$

We then estimate

$$I_t^* = \alpha_0 + Y_t - 0.5\,(PK_t - C_t) \tag{1}$$

where $\alpha_0 = \alpha_0' + \eta$.

Fit (left) and residuals of the long-run equation are shown in Figure 6.

4.3 VAR

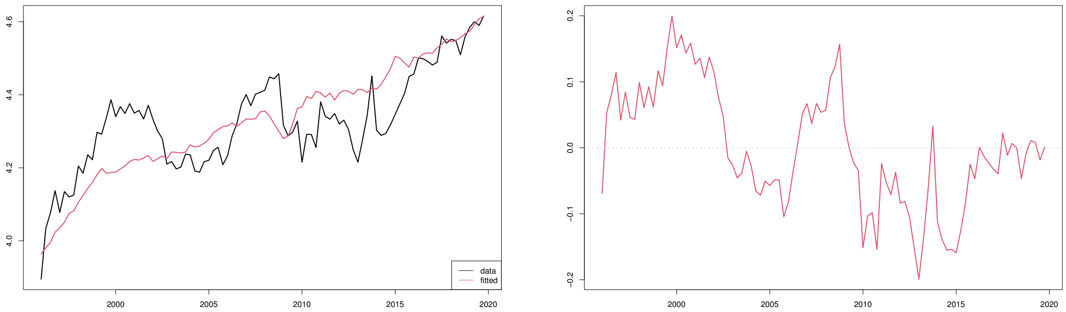
The VAR explaining the price expectations is built up in three steps. First, the core VAR in the five variables y_t = GAP_NL, CPI_NL, RK_EA, GAP_EA and CPI_EA is set up. This is documented in a separate note (Section 2).

Second, three explaining variables ($x_t = Y_t$, PK_t, C_t) are forecast on basis of the "Dutch" variables in the core VAR and an autoregressive term:

$$\Delta x_t = \beta_0 + \beta_1 \Delta \text{GAP\_NL}_{t-1} + \beta_2 \Delta \text{CPI\_NL}_{t-1} + \beta_3 \Delta \text{RK\_EA}_{t-1} + \beta_4 \Delta x_{t-1}$$

The constants in the equations for PK_t, C_t are restricted so that the long-term growth rate of these two prices converges to the same value.

Figure 6: Long-run: fit (left) and residuals (right)



Third, the forecast of the target for I_t is calculated using the parameters from the long-term equation.

As individual VAR coefficients are not particularly informative, we illustrate the performance of the VAR forecast with forecast figures for the three determinants of investment demand and the investment demand target itself.[6]

4.4 Short-term estimation: PAC

The PAC model is estimated as an ECM equation that is extended with one complex expectations term ("z_t"). This term is calculated from the forecast of the target variable and the other estimated parameters. Estimation is therefore iterative: z_t is calculated with given parameters and added as a time-varying offset for the estimation of an updated set of parameters.[7] This proceeds until convergence.

The base specification of the PAC equation is

$$\Delta I_t = \gamma_1 \left(I_t - I_t^{\star}\right) + \gamma_2 \Delta Y_t + z_t$$

Our specification search (documented in separate notes) resulted in a PAC of degree $m = 1$, i.e. without autoregressive terms.

[6] These are "quasi forecasts" because the parameters have been estimated using the whole sample, not only the part that was known at the moment the forecast starts.

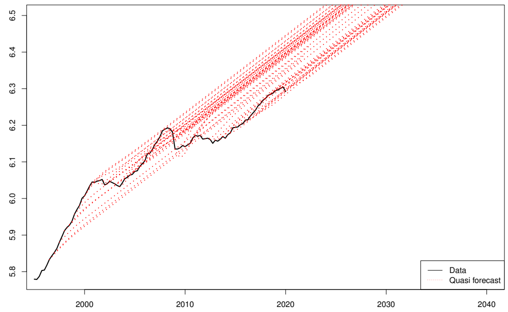
[7] The expectations term, z_t can be expressed as

$$z_t = \sum_{s=0}^{\infty} f_s \Delta p_{t+s}^{i\star}$$

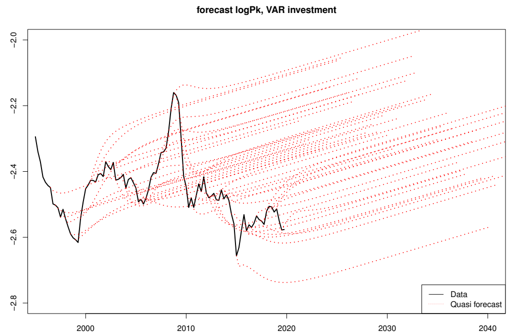
The expected changes in the target, $\Delta p_{t+s}^{i\star}$, are calculated by the VAR, the associated weights are functions of the estimated γ's. E.g. for $m = 1$ we have $f_s = \gamma_1 \left[\left(1-\gamma_1\right)\beta\right]^s$,where β is an exogenous discount factor.

Figure 7: Forecasts of the VAR variables Investment demand

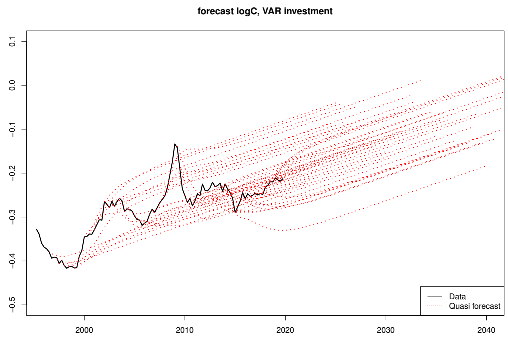
forecast logY, VAR investment



forecast logPk, VAR investment



forecast logC, VAR investment



forecast I*, VAR investment

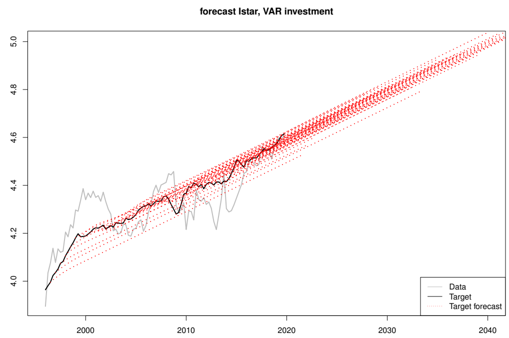


Table 2 shows the estimation results. To put the results in perspective, we also add the pure ECM estimation (without the z_t term).

The following figures show the fit and the residuals in the short run.

Figure 8: Short-run: fit (left) and residuals (right)

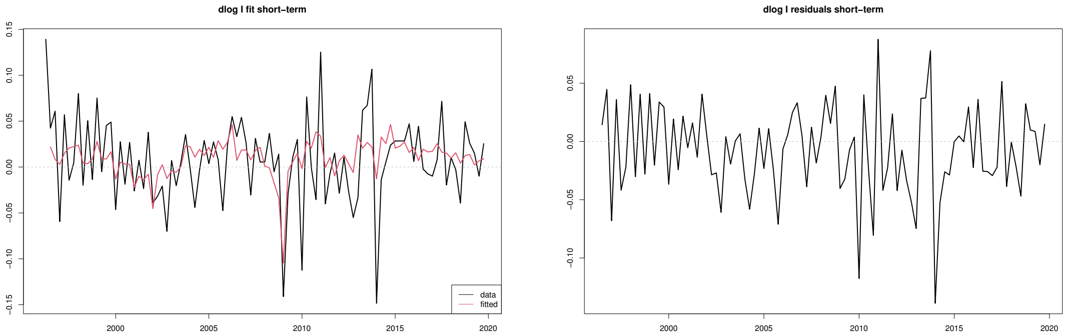


Table 2: Investment demand short-term

	PAC 5/21	ECM 5/21
γ_1	-0.126^{***}	-0.141^{***}
	(0.045)	(0.045)
ΔY_t (γ_2)	1.847^{***}	2.241^{***}
	(0.407)	(0.405)
R^2	0.234	0.302
Adj. R^2	0.218	0.287
Num. obs.	94	95
RMSE*100	3.910	3.936
ADF p	< 0.010	< 0.010
KPSS p	0.359	0.132
LB(1) p	0.059	0.090
LB(4) p	0.051	0.083

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

5 Consumption

An error correction specification is estimated for consumption with quarterly data of the period 1996q1-2019q4. We estimate the ECM in two steps; results for the long-run and short-run equation are reported in Section 5.1 and 5.2, respectively.

5.1 Long-run equation

5.1.1 Derivation

We estimate a Muellbauer-type consumption function. This equation contains elements of a life-cycle model where consumption depends on income growth expectations. It differs from traditional Euler equations in particular due to deviations from the strong assumptions about agents' rationality and expectations formation (Aron et al., 2012).

The derivation of the long-run target consumption equation is described in Aron et al. (2012). Real aggregate consumption c_t^* (including durables and imputed rents) is first specified as linear in net wealth (W_{t-1}) and so-called permanent non-property income (y_t^p):[8]

$$c_t^* = \phi_t W_{t-1} + \omega_t y_t^p \tag{2}$$

Parameters are not constant if the propensities to consume out of wealth and the permanent income growth are age-specific and the distribution of income and wealth across age groups is changing. Non-constant parameters also result when the real interest rate is not constant. We simplify by assuming that the parameters are constant. Next, we divide by real disposable non-property income y^{dnp}, defined as the sum of labour earnings, transfers, pensions, minus income taxes and social premiums paid by households, deflated by consumer prices (real disposable property income y^{dp} is defined as after-tax income from wealth). Log-approximating gives:

$$\ln c_t^* = \alpha_0 + \ln y_t^{dnp} + \gamma \frac{W_{t-1}}{y_t^{dnp}} + \alpha_1 \ln \left(\frac{y_t^p}{y_t^{dnp}} \right) \tag{3}$$

where $\gamma = \phi/\omega$ and $\alpha_0 = \ln \omega$.[9]

Our work differs from the studies by Muellbauer and co-authors (listed in Table 3) in two main respects.[10] First, they disaggregate wealth into net liquid, illiquid and housing

[8] Wealth is lagged because it is measured at the end of the period. We exclude property income from the income measure to avoid double counting of financial wealth.

[9] Taking the log of $\frac{c_t^*}{y_t^{dnp}} = \omega \left[\frac{\phi}{\omega} \frac{W_{t-1}}{y_t^{dnp}} + 1 + \frac{y_t^P - y_t^{dnp}}{y_t^{dnp}} \right]$ gives equation (3), using that $\ln(1+x) \approx x$ and $(y^P - y)/y \approx \ln(y^P/y)$.

[10] Detailed results are given in Ascione et al. (2019).

assets, allowing for different marginal propensities to consume out of the respective asset types. In an early stage of the project, we did not find evidence of different marginal propensities and decided to continue with aggregate net wealth. We plan to redo this analysis with recent data. Second, Muellbauer et al. allow for time-varying coefficients, by including interacting effects with an index measuring credit market liberalization. However, we did not find evidence that coefficients vary with conditions on credit markets.

The described consumption equation is estimated for several countries. Table 3 reports the long-run coefficients for different studies. We observe that there are quite some differences between countries. For example, credit conditions have had quite an impact on the consumption equation in the UK and the US, but this is not the case in Germany and Japan.

Table 3: Long-run estimation results in the literature

Author (year)	Version	Country	$\ln y^p/y^{dnp}$	HA/y^{dnp}	$IFA//y^{dnp}$	NLA/y^{dnp}	CCI
Aron et al. (2012)	3	UK	0.485***	0.047***	0.026***	0.126***	
	5		0.201***	0.043***	0.022***	0.114***	0.050***
	3	US	0.710***	0.044**	0.049	0.086**	
	5		0.588***	0.084***	0.011***	0.153***	0.146***
	3	Japan	0.471***	0.0034	0.039	0.064***	
	4		0.460***		0.063***		
Geiger et al. (2016)	1	Germany	0.346 (t=8.6)	-0.070 (t=-3.4)	0.016	0.095 (t=3.8)	0.025 (t=1.2)
	2		0.364 (t=8.2)	-0.069 (t=-3.4)	0.016	0.088 (t=3.2)	0.025
Muellbauer and Williams (2011)	1	Australia	0.20	0.0606***	0.0219**	0.1588***	0.1902***
	2		0.20	0.0646***	0.0194*	0.1683***	0.1875***
Muellbauer (2010)	1	UK	0.546 (t=4.7)	0.055 (t=11.5)	0.024 (t=0.024)	0.110 (t=6.5)	0.044 (t=4.4)
	2		0.727 (t=5.8)	0.046 (t=0.046)	0.026 (t=7.8)	0.095 (t=5.7)	0.036 (t=3.3)
Muellbauer et al. (2015)	2	Canada	1.187 (t=3.6)	-0.026 (t=-1.0)	0.039 (t=2.4)	-0.038 (t=-0.5)	
	4		0.695 (t=0.695)	-0.147 (t=-1.8)	0.024 (t=2.9)	0.07	0.194 (t=3.6)
Williams (2010)	6	Australia	0.1419***		0.0011*		
	9		0.0624**	0.0055***	0.0043	0.0172***	
Chauvin and Muellbauer (2018)	1	France	0.38 (t=2.3)	-0.108 (t=-4.2	0.020 (t=3.7)	0.096 (t=5.7)	0.036 (t=6.7)
	2		0.75 (t= 5.6)	0.070 (t=3.6)	0.020 (t=3.0)	0.100 (t=3.5)	

Notes: Statistical significance at the 10%, 5%, and 1% levels is denoted by $*$,$**$, and $***$.
NLA equals liquid assets minus debt (both private and housing debt); IFA is illiquid financial assets; HA is housing wealth and CCI is credit conditions index

5.1.2 Permanent income

Before estimating the consumption equation, calculation of permanent income is required (y^p). The deviation between permanent income and current income is calculated by discounting future income over the time horizon k at a quarterly discount factor β:

$$\mathrm{E}_t \ln\left(\frac{y_t^p}{y_t^{dnp}}\right) \approx \frac{\mathrm{E}_t \sum_{s=1}^{k} \beta^{s-1} \ln\left(y_{t+s}^{dnp}/y_t^{dnp}\right)}{\sum_{s=1}^{k} \beta^{s-1}} \tag{4}$$

Under the assumption of perfect foresight, we use actual realizations for future values of y_{t+s}^{dnp}. We use $k = 12$ (quarters) and $\beta = 0.95$. We choose a discount rate of $\eta = 0.05$ per quarter as in Williams (2010), Muellbauer and Williams (2011) and Aron et al. (2012). Figure 9 shows the resulting series of permanent income.

Instead of using actual values in the regressions (i.e. perfect foresight), we prefer to use predicted values of the deviation of permanent to current income (using backward-looking expectations). Notice that goodness of fit is not the ultimate aim of the forecasting equation. As pointed out by Chauvin and Muellbauer (2018) "households are bound to make serious forecast errors: (...) the aim is to capture what their views might have been given the kind of information to which households would have ready access". Based on the most promising income forecasting equations in Muellbauer-type consumption functions (see e.g. Muellbauer et al. (2015); Aron et al. (2012); Muellbauer and Williams (2011);Geiger et al. (2016)), we decided upon explaining the log ratio of permanent income to current income by a constant, contemporaneous log non-property income, one lag of income growth, consumer confidence, and the log of the ratio of the oil price and the consumer price. Results of the income forecasting equation are presented in Table 4 and Figure 9.

Figure 9: Ratio of permanent income and fitted values $\ln(y^p/y^{dnp})$

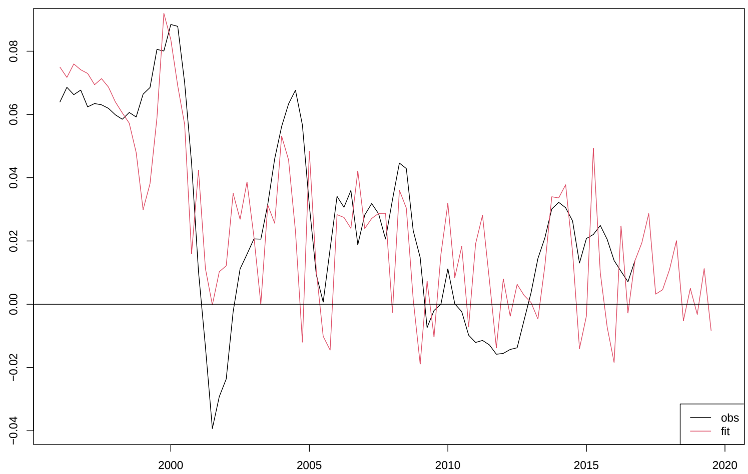


Table 4: Predicting ratio permanent income $\ln y^p/y^{dnp}$

Constant	1.064^{***}
	(0.135)
$\ln y^{dnp}$	-0.191^{***}
	(0.027)
$\Delta \ln y^{dnp}(-1)$	-0.472^{**}
	(0.207)
Consumer confidence	0.000^{***}
	(0.000)
$\ln(Po/Pc)$	0.010^{*}
	(0.006)
R^2	0.640
Adj. R^2	0.622
Num. obs.	86
RMSE*100	1.805
ADF p	< 0.010
KPSS p	0.696
LB(1) p	0.000
LB(4) p	0.000

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

5.1.3 Estimation results long-run equation

Estimation results of equation (3) are given in the first column of Table 5 (using the predicted values of permanent income from the income forecasting equation). We find an implausibly large marginal propensity to consume out of net wealth. Looking at the data, we need to account for two developments. First, the ratio c/y^{dnp} initially falls before getting rather stable (Figure 11a). A break at 2004q3 is supported by a breakpoint analysis of the residuals of (3). This development corresponds to an increasing share of non-property income in total income during the first years (Figure 10a). We account for this by extending the long-run equation with the ratio $y^{dnp}/(y^{dnp} + y^{dp})$.[11]

Second, we find in several housing-related series a turning point around 2014q1 (relative housing price; housing wealth, loan-to-value ratio). In particular, we observe in Figure 10b a strong recovery of the (housing) wealth ratio, while the consumption ratio remained stable during this period.[12] A break in the residuals of (3) around 2014 is not supported by a breakpoint analysis. The best option to deal with this break seems to be including a dummy for the period 2014q1-2019q4.[13] We estimate the extended long-run specification:

$$\ln \frac{c_t^*}{y_t^{dnp}} = \beta_0 + \beta_1 \ln \frac{y_t^p}{y_t^{dnp}} + \beta_2 \frac{W_{t-1}}{y_t^{dnp}} + \beta_3 \frac{y_t^{dnp}}{y_t^{dnp} + y_t^{dp}} + \beta_4 d\_per2_t \quad (5)$$

The second column of Table 5 shows that estimation results improve:

- The coefficient of permanent income is $\beta_1 = 0.82$. Table 3 reports estimates of 0.96 for the US, 0.75 for France and 0.11 for Australia.

- The coefficient of net wealth $\beta_2 = 0.05$ equals the marginal long-run propensity to consume out of net wealth when $c/y^{dnp} = 1$.[14] Table 3 shows estimates ranging from 0.03 in the UK to 0.08 in Canada.[15]

[11] Following the theoretical derivation, non-property income is the appropriate concept in the consumption function. In view of the poor empirical performance, total disposable income is used instead in some studies. We choose to add the share of non-property income as control variable.

[12] CBS reports that the net income from housing became positive in 2015; see `https://www.cbs.nl/nl-nl/nieuws/2020/52/vermogens-van-huishoudens-leveren-steeds-meer-inkomen`.

[13] Inspired by CPB research on the relationship between housing wealth and consumption (see Ji et al. 2019), we included interaction terms with housing variables. From CBS-statistics, we calculated the fraction of households for which the value of the mortgage exceeded the value of their house for the period 2006-2015 (`https://www.cbs.nl/nl-nl/cijfers/detail/81702NED`). This statistic is strongly correlated with the macro loan-to-value ratio, i.e. total mortgages/gross housing value. As we were not able to find significant interaction terms with this ratio, we excluded these from the specification.

[14] $dc_t/dW_t = c_t/y_t^{dnp}\beta_2$.

[15] See also the overview for the 4 large euro area countries in de Bondt et al. (2020).

- The initial rise in the non-property income share has a depressing effect on consumption ($\beta_3 = -0.77$).

Fitted values and residuals are given in Figure 11.

Figure 10: The share of non-property income $y^{dnp}/(y^{dnp} + y^{dp})$ and the wealth ratio W_{-1}/y^{dnp}

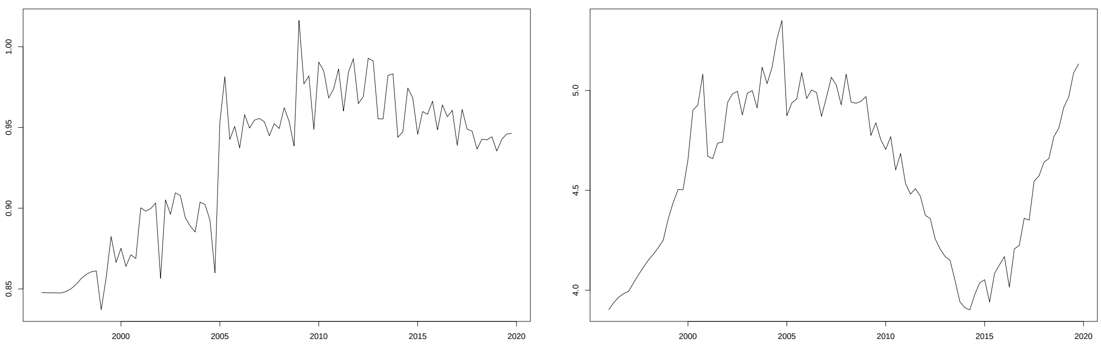


Figure 11: Fitted values and residuals of LR equation $\ln(c/y^{dnp})$

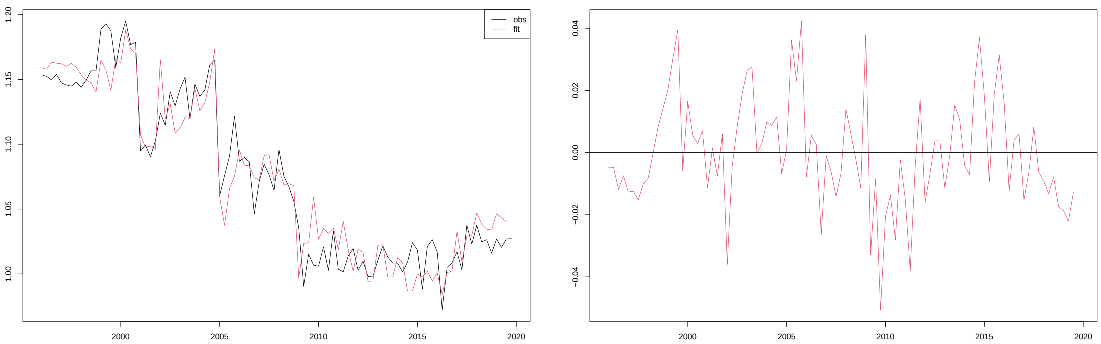


Table 5: Estimation results long-run consumption (1996q1-2019q4)

	Model 1	Model 2
Constant	-0.303^{***}	0.559^{***}
	(0.033)	(0.084)
$\ln y^p/y^{dnp}$	2.374^{***}	0.816^{***}
	(0.126)	(0.170)
W_{-1}/y^{dnp}	0.069^{***}	0.045^{***}
	(0.007)	(0.006)
$y^{dnp}/(y^{dnp}+y^{dp})$		-0.767^{***}
		(0.073)
Dummy 2014q1-2019q4		-0.020^{***}
		(0.005)
R^2	0.871	0.943
Adj. R^2	0.866	0.941
Num. obs.	95	95
RMSE*100	2.621	1.744
ADF p	< 0.010	< 0.010
KPSS p	0.035	0.336
LB(1) p	0.000	0.000
LB(4) p	0.000	0.000

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

5.2 Short-run equation

Dynamics are modeled within an ECM-framework:

$$
\begin{aligned}
\Delta \ln c_t =& \rho \ln \frac{c_{t-1}}{c^*_{t-1}} + \gamma_1 \sum_{j=0}^{2} \gamma_{1,j} \Delta \ln y^{dnp}_{t-j} + \gamma_2 \Delta \ln y^{dp}_t + \gamma_3 d\_per1_t \Delta \ln r^h_t \frac{W^{hd}_{t-1}}{y^{dnp}_{t-1}} + \\
& \gamma_4 \Delta \frac{p^h_t}{p^c_t} + \gamma_5 \frac{\ln l^{ms}_t - \ln l^{ms}_{t-4}}{4} + \gamma_6 d\_crisis_t + \gamma_7 d\_2006q1 + \epsilon_t
\end{aligned} \tag{6}
$$

Explanation of the variables:

- The error correction term is given by the (lagged) residual of the long-run equation.
- We include the weighted average growth rate of non-property real income. The weights are estimated, under the restriction that the sum of the three weights equals 1. These variables capture consumption responses by credit-constrained (or hand-to-mouth) households.
- We only include the current growth of property income, since lagged growth rates were insignificant.
- The interest rate on new mortgages r^h, weighted with the ratio of the mortgages to non-property income; d_per1 denotes the quarters before 2014q1.
- The change in the relative housing price.
- We include the average change (over the last 4 quarters) in the employment (in hours) of the market sector as confidence indicator.[16]
- We include the crisis-dummy to capture the quarters 2009q1/q2 and the 2006q1-dummy to capture a change in the measurement of the consumption of health care.

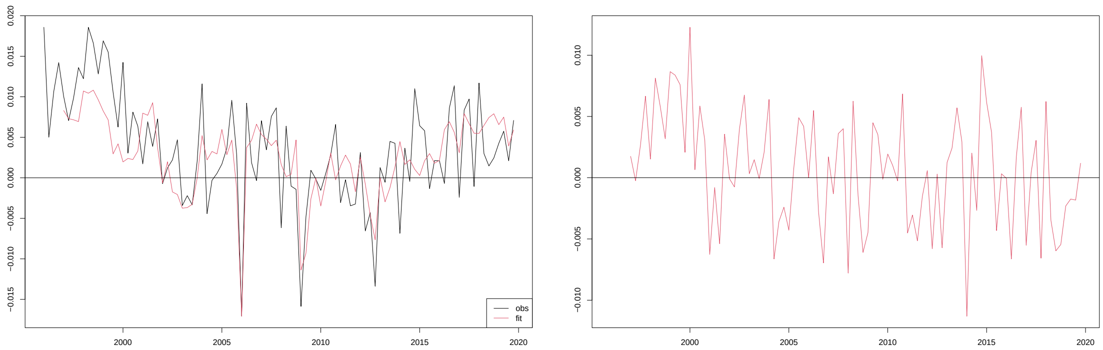
The first column of Table 6 shows results of an unrestricted estimation of equation (6). Besides insignificant effects of non-property income, it gives an implausibly large effect of changes in the relative housing prices ($\gamma_4 = 0.34$). Therefore, we decided to fix this coefficient at 0.15 (inspired by Berben et al. 2018). As a result, the error correction coefficient (ρ) dropped to an insignificant, small value. Hence, we imposed $\rho = -0.1$. The preferred specification is presented in the second column:

[16] We experimented to include instead the change in the unemployment rate as an indicator of uncertainty. However, the large estimated coefficient (-1.1) resulted in implausibly large changes of consumption growth in model simulations.

- The effect of the average growth of non-property income (γ_1) is significant and small. The current growth rate gets the largest weight (γ_{10}).
- Growth of non-property income has a larger effect on consumption growth than growth of property income. An average increase of non-property income of 1 euro increases real consumption by 0.12 euro in the same quarter, compared to 0.03 euro for an 1 euro increase in property income.[17]
- An increase in the (weighted) interest rate on mortgages has a negative effect on consumption growth before 2014q1 (γ_3). The effect is not significant after 2014q1.
- We find that an increase of the average employment growth with 1% point increases the growth of consumption with 0.5% in the same quarter.

Fitted values and residuals are given in Figure 12.

Figure 12: Fitted values and residuals of SR equation $\Delta \ln c$



[17]Based on $\Delta c = 0.129 c/y^{dnp} \Delta y^{dnp}$ and $\Delta c = 0.002 c/y^{dp} \Delta y^{dp}$; evaluated at 2019q4-values and neglecting the error correction adjustment.

Table 6: Estimation results short-run consumption

	Model 1	Model 2
$\ln(c/c^{*})_{-1}$	-0.091^{***}	-0.100
	(0.033)	
$\sum_j \gamma_{1j} \Delta \ln y^{dnp}_{-j}$	0.068	0.129^{**}
	(0.053)	(0.054)
$\Delta \ln y^{dnp}$	0.408	0.401^{**}
	(0.292)	(0.160)
$\Delta \ln y^{dnp}_{-1}$	0.334	0.292^{**}
	(0.251)	(0.141)
$\Delta \ln y^{dp}$	0.002^{***}	0.002^{**}
	(0.001)	(0.001)
$d\_per1 \Delta \ln r^{h} (W^{hd}/y^{dnp})_{-1}$	-0.072^{***}	-0.073^{***}
	(0.023)	(0.025)
$\Delta(p^{h}/p^{c})$	0.337^{***}	0.150
	(0.051)	
$(\ln l^{ms}_{t} - \ln l^{ms}_{t-4})/4$	0.231^{*}	0.482^{***}
	(0.120)	(0.109)
Dummy crisis	-0.016^{***}	-0.017^{***}
	(0.005)	(0.005)
Dummy 2006q1	-0.010^{***}	-0.010^{***}
	(0.003)	(0.004)
R^2	0.580	0.495
Adj. R^2	0.565	0.478
Num. obs.	92	92
RMSE*100	0.428	0.468
ADF p	< 0.010	< 0.010
KPSS p	0.142	0.014
LB(1) p	0.805	0.249
LB(4) p	0.659	0.192

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

6 Exports

We discuss the estimation of equations of three types of exports: exports of domestically produced goods and services, re-exports and exports of energy. We distinguish re-exports from other exports in view of its large share in total exports and its low share of value added compared to exported goods and services that are domestically produced. Therefore, increasing re-exports has a much smaller impact on gdp and a larger impact on imports than increasing domestically produced exports. We treat energy exports separately to account for the strongly fluctuating energy prices. The remaining exports, i.e. of domestically produced non-energy goods and services, make up the largest fraction of total exports.

6.1 Domestically produced exports of goods and services

6.1.1 Long-run

Specification We consider three determinants of domestically produced non-energy exports (b^d): world trade (m^w), output of the market sector (y^{ms}) and the relative price:(p^{bd}/p^w):

$$\ln b_t^{d*} = \beta_0 + \beta_1 \ln m_t^w + (1 - \beta_1) \ln y_t^{ms} + \beta_2 \ln(p_t^{bd}/p_t^w) \tag{7}$$

First, target exports depend on the exogenous relevant world trade. An increase in the foreign demand for domestically produced goods and services will have a positive effect on exports. Second, the expansion of exports is subject to capacity restrictions. Capacity is proxied by the current output of the market sector. Effects of a positive demand shock are limited by supply factors as labour supply and structural productivity growth. In addition, supply shocks that increase (decrease) potential output will permanently increase (decrease) the export volume. In view of long-run homogeneity, exports, world trade and output need to have a common growth rate on the balanced growth path. Therefore, we impose that the coefficients of y^{ms} and m^w add up to one. This specifications nests two extremes:

- $\beta_1 = 0$: no permanent effects of a world trade shock, since output converges to its potential level.
- $\beta_1 = 1$: maximal permanent effects of a world trade shock due to changes in the terms of trade.

Third, the relative price, or the terms of trade, equals the ratio between the export price and the exogenous world market price of goods and services. An increase in the relative price reflects a deterioration of external competitiveness, which depresses exports.

Estimation results Estimation results of equation (7) are given in column LR1 in Table 7.[18] We could not find valid instruments and therefore we prefer the OLS-results. We find a dominating effect of world trade (0.66) compared to output of the market sector (0.34).[19] The elasticity of the relative price (rp) is significant but is considered too small for the Netherlands (-0.54). Imbs and Mejean (2017) show that estimation on aggregate data, as we do, results in lower elasticities than estimation on bilateral sectoral trade data, due to a heterogeneity bias. Imbs and Mejean (2010) report an overview of trade elasticity estimations of a broad range of countries (but without the Netherlands).[20] The estimated price elasticities of exports of European countries range from -1.5 in Germany to -4 in Spain. We fix in column LR2 the long-run price elasticity at the lower bound of -1.5. As a result, the long-run effect of world trade increases, while the error correction coefficient is insignificant and small (-0.03).

We now have to deal with another problem. An analysis of the residuals of LR2 shows a structural break at 2007q1. This is clearly illustrated by plotting the ratio of the export volume and world trade (b^d/m^w) in Figure 13. After a sharp decline, this ratio develops more stable in the last years. A break in the trend of this series is identified in 2005q3. We estimate the export equation on the subsample 2006q1-2019q4 to account for this break.[21] We end up with the coefficients reported in the column LR3; fitted values and residuals are given in Figure 14.[22]

[18] After we have smoothed peaks in the export volume in 2000q4 and 2015q1.

[19] When freely estimated, the restriction that the coefficients of m^w and y^{ms} add up to one is rejected.

[20] Large trade elasticities are also reported in the Appendix of Freeman et al. (2022). The target elasticity in the Delfi-model of DNB equals -1.77, estimated on the larger sample 1980q1-2016q4 (Berben et al., 2018).

[21] Estimating on the sample starting in 2007q1 hardly affects the estimated coefficients.

[22] The restriction that the coefficients of m^w and y^{ms} add up to one is not rejected.

Figure 13: Ratio of exports of goods & services to relevant world trade (b^d/m^w)

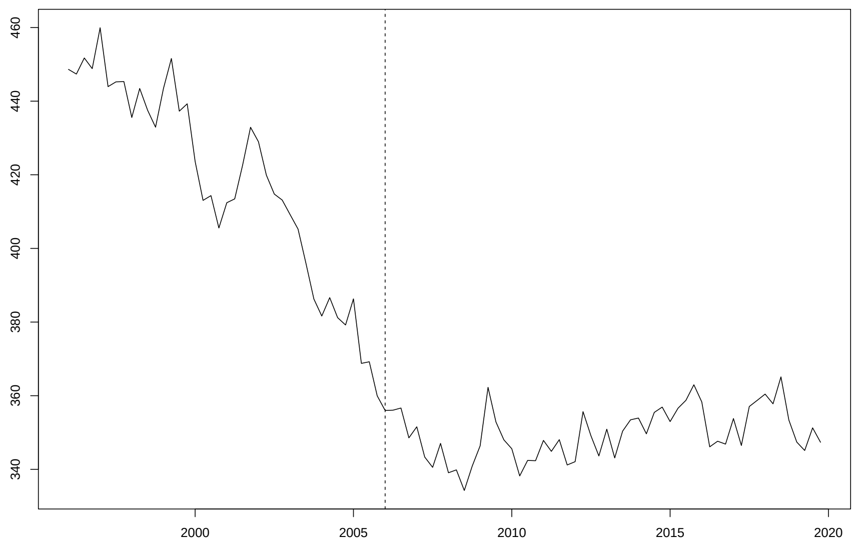


Figure 14: Fitted values and residuals of long-run equation $\ln b^d$

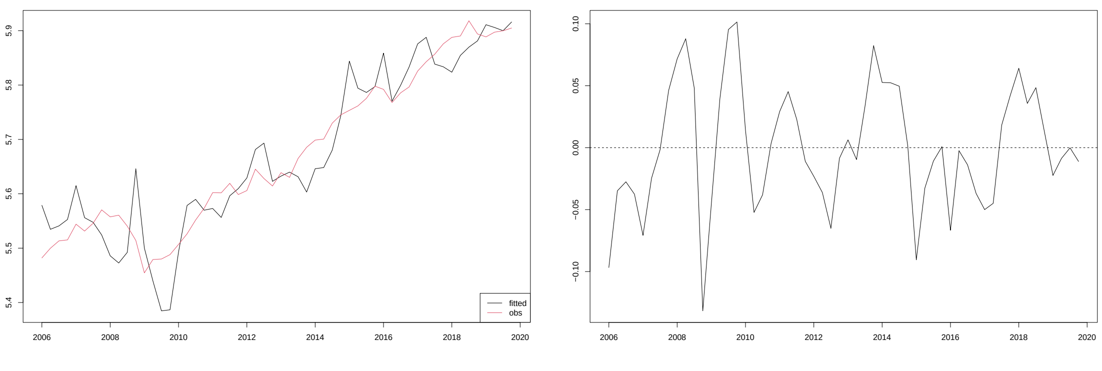


Table 7: Estimation results exports of goods & services

	LR 1[a]	LR 2[a]	LR 3[b]	SR 3[b]
constant	3.691^{***}	5.324^{***}	4.256^{***}	
	(0.168)	(0.235)	(0.483)	
$\ln m^w$	0.658^{***}	0.914^{***}	0.745^{***}	
	(0.026)	(0.036)	(0.076)	
$\ln rp^d$	-0.540^{***}	-1.500	-1.500	
	(0.064)			
$\ln(b^d_{-1}/b^{d*}_{-1})$				-0.068
				(0.051)
$\Delta \ln m^w$				0.663^{***}
				(0.117)
$\Delta \ln rp^d$				-0.132
				(0.079)
R^2	0.975	0.912	0.881	0.284
Adj. R^2	0.974	0.910	0.874	0.241
Num. obs.	96	96	56	55
RMSE*100	3.395	6.291	4.942	1.567
ADF p	< 0.010	< 0.010	< 0.010	< 0.010
KPSS p	0.080	0.563	0.796	0.678
LB(1) p	0.000	0.000	0.000	0.074
LB(4) p	0.000	0.000	0.000	0.476

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

[a] Sample 1997q1-2019q4; [b] 2006q1-2019q4.

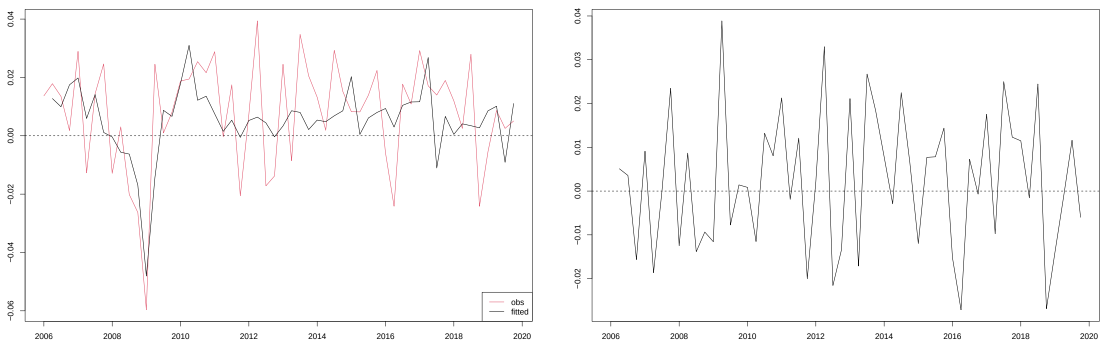
6.1.2 Short-run

The specification of the ECM is:

$$\Delta \ln b_t^d = \rho \ln(b_{t-1}^d / b_{t-1}^{d*}) + \gamma_1 \Delta \ln m_t^w + \gamma_2 \Delta \ln(p_t^{bd}/p_t^w) + \epsilon_t \tag{8}$$

The error correction term equals the lagged residual of the long-run equation (LR3).[23] Results are given in the last column of Table 7. We find a significant world trade effect but a insignificant error correction coefficient and price effect in the short run. The corresponding fit is presented in Figure 15.

Figure 15: Fitted values and residuals of short-run $\Delta \ln b^d$



[23]Estimation might suffer from an endogeneity problem of the relative price. We experimented on the full sample by instrumenting the growth rate of the domestic export price by the growth rate of effective labour costs, and the growth rate of the energy price. Following the diagnostic tests, the hypothesis of weak instruments is rejected; OLS is not consistent and the hypothesis of valid instruments is not rejected. IV-estimation results in a small, insignificant price elasticity, without affecting much the value of the other coefficients. We decided to use the OLS-coefficients.

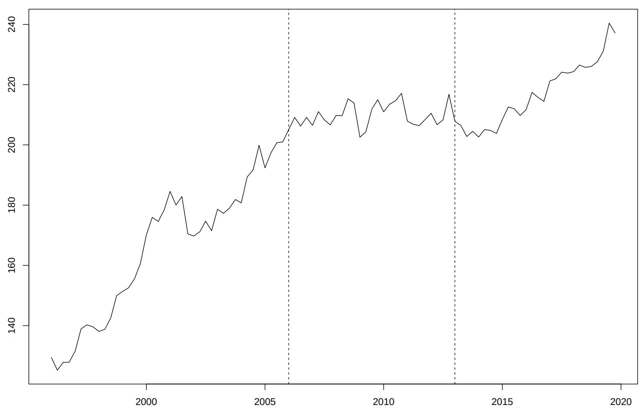
6.2 Re-exports

We estimate the same specifications (7) and (8), where the volume and price are replaced by b^r and p^r, respectively.[24]

Estimation results are given in Table 8. We find for long-run equation LR1 a world trade elasticity that is significantly large than one (meaning that the output elasticity is negative) and a significant price elasticity. However, inspection of the residuals shows breaks at 2005q3 and 2013q4. This is supported by the ratio of the volume of re-exports to world trade in Figure 16. We observe a strong increase of this ratio during the first years; then a stabilisation in a second sub-period, followed by a continuation of a rising trend during the last years. A breakpoint analysis results in trend breaks in 2006q1 and 2013q2. In this case, we account in column LR2 for the two (latter) breaks by extending the equation with two period dummies and three period-specific time trends. As a result, the world trade coefficient becomes not significantly different from one, but this is going at the expense of a smaller price elasticity. We impose the restriction $\beta_1 = 1$ since it seems plausible that capacity restrictions are less binding for re-exports. As expected, this restriction hardly affects the other coefficients in the final LR3. The fit is presented in Figure 17.

The results of the corresponding short-run equation are given in the last column. We find a significant, large error correction coefficient, a strong response to changes in world trade and an inelastic response to price changes ($p = 9.6\%$). Fitted values and residuals are presented in Figure 18.

Figure 16: Ratio of re-exports to world trade (b^r/m^w)



[24]We do not use an IV estimator, since endogeneity is less a problem for this type of exports.

Table 8: Estimation results re-exports (1996q1-2019q4)

	LR 1	LR 2	LR 3	SR 3
constant	8.063^{***}	5.696^{***}	4.981^{***}	
	(0.307)	(0.809)	(0.020)	
$\ln m^w$	1.427^{***}	1.104^{***}	1.000	
	(0.048)	(0.118)		
$\ln rp^r$	-0.915^{***}	-0.474^{***}	-0.465^{***}	
	(0.091)	(0.070)	(0.069)	
dummy_period_2		0.363^{***}	0.381^{***}	
		(0.042)	(0.037)	
dummy_period_3		-0.063	-0.039	
		(0.065)	(0.059)	
trend_1		0.007^{***}	0.008^{***}	
		(0.001)	(0.001)	
trend_2		-0.001	-0.000	
		(0.001)	(0.001)	
trend_3		0.005^{***}	0.005^{***}	
		(0.001)	(0.001)	
$\ln(b^r_{-1}/b^{r*}_{-1})$				-0.330^{***}
				(0.084)
$\Delta \ln m^w$				1.435^{***}
				(0.112)
$\Delta \ln rp^r$				-0.160^{*}
				(0.095)
R^2	0.989	0.997	0.997	0.592
Adj. R^2	0.989	0.997	0.997	0.579
Num. obs.	96	96	96	95
RMSE*100	4.755	2.535	2.546	1.969
ADF p	0.056	< 0.010	< 0.010	< 0.010
KPSS p	0.078	0.901	0.917	0.402
LB(1) p	0.000	0.000	0.000	0.794
LB(4) p	0.000	0.000	0.000	0.812

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$; the 3 sub-periods are determined by the breaks 2006q1 and 2013q2.

Figure 17: Fitted values and residuals of long-run equation $\ln b^r$

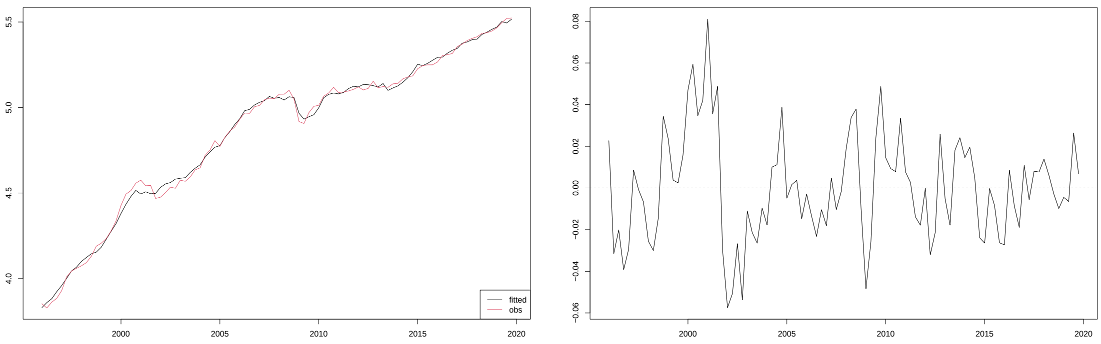
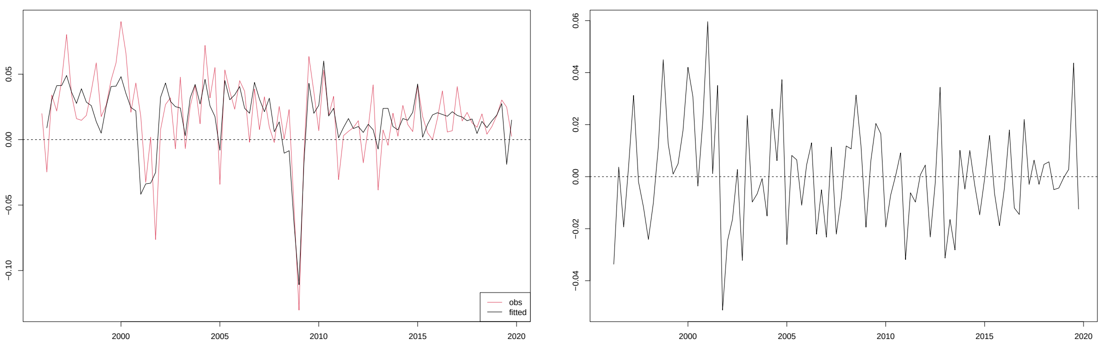


Figure 18: Fitted values and residuals of short-run equation $\Delta \ln b^r$



6.3 Exports of energy

Since the export price of energy hardly deviates from the world market price of energy, the energy price is expressed relative to the world price of goods and services to keep the equation homogenous in prices ($\ln rp^e = \ln(p^{be}/p^w)$). The relative price is not significant in long-run equation LR1 in Table 9 and is therefore dropped in LR2. The price elasticity is small and significant in the accompanying short-run equation SR2. The effect of world trade is large both in the long run and short run. The corresponding fitted values and residuals are given in Figures 19-20.

Table 9: Estimation results energy exports (1996q1-2019q4)

	LR 1	LR 2	SR 2
constant	2.561^{***}	2.165^{***}	
	(0.598)	(0.392)	
$\ln m^w$	0.768^{***}	0.706^{***}	
	(0.092)	(0.060)	
$\ln rp^e$	-0.037		
	(0.042)		
$\ln(b^e_{-1}/b^{e*}_{-1})$			-0.128^{***}
			(0.039)
$\Delta \ln m^w$			0.849^{***}
			(0.234)
$\Delta \ln rp^e$			-0.115^{**}
			(0.056)
R^2	0.830	0.829	0.177
Adj. R^2	0.825	0.823	0.150
Num. obs.	96	96	95
RMSE*100	10.400	10.443	3.888
ADF p	0.021	0.017	< 0.010
KPSS p	0.180	0.162	0.311
LB(1) p	0.000	0.000	0.182
LB(4) p	0.000	0.000	0.175

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Figure 19: Fitted values and residuals of long-run equation $\ln b^e$

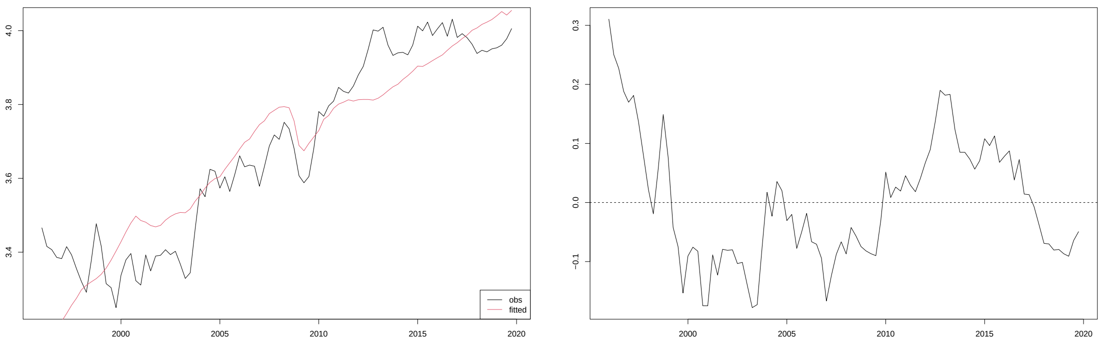
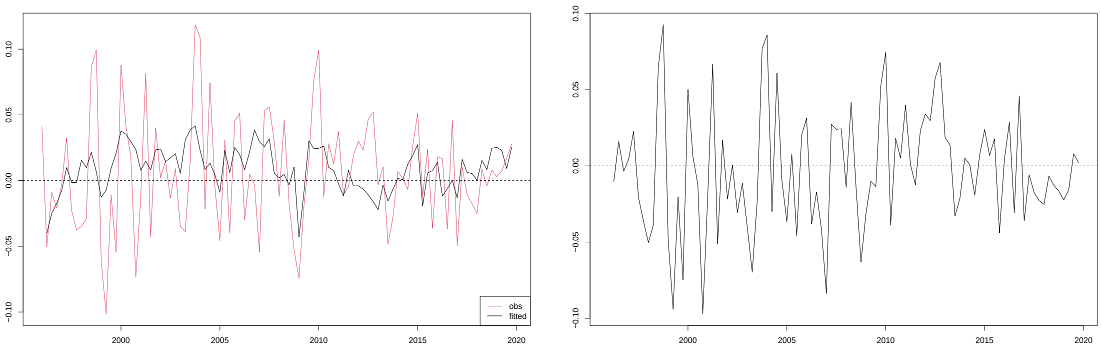


Figure 20: Fitted values and residuals of short-run equation $\Delta \ln b^e$



7 Imports

We discuss the estimation of equations of three types of imports: import of (non-energy) goods and services, imports for re-exports and import of energy.

7.1 Imports of goods and services

Imports depend on a measure of effective import demand (mv^d) and the relative import price.[25] Effective import demand is defined as a weighted sum of consumption, investment (of market and non-market sectors), government spending (on goods & services and transfers in kind) and exports of domestically produced goods and services, where the weights are average import intensities of the demand categories:

$$mv_t^d = 0.43c_t + 0.58i_t^{ms} + 0.18(i_t^{pl} + i_t^{kw} + i_t^{wo}) + 0.19(g_t^{sn} + g_t^m) + 0.41b_t^d \tag{9}$$

The relative price is a weighted average of the relative import price of the demand categories:

$$rp_t^{md} = \frac{p_t^{md}}{mv_t^d}\left(\frac{0.43c_t}{p_t^c} + \frac{0.58i_t^{ms}}{p_t^{ims}} + \frac{0.18i_t^{pl}}{p_t^{ipl}} + \frac{0.18i_t^{kw}}{p_t^{ikw}} + \frac{0.18i_t^{wo}}{p_t^{iwo}} + \frac{0.19(g_t^{sn} + g_t^m)}{p_t^g} + \frac{0.41b_t^d}{p_t^{bd}}\right) \tag{10}$$

We impose the homogeneity restriction that the coefficient of mv^d equals one in the target equation.[26] The restricted long-run equation is:

$$\ln m_t^{d*} = \beta_0 + \ln mv_t^d + \beta_2 \ln rp_t^{md} \tag{11}$$

Estimation results in column LR1 in Table 10 show a significant price elasticity. However, the error correction coefficient in the accompanying short-run equation SR1 is small and insignificant. When we perform a breakpoint analysis of the residuals of LR1, we find a break in 2010q4. Figure 21a shows a rising trend in the observed ratio of imports. Figure 21b suggests that the break is related to a fall in the relative import price during the first years, followed by a more stable development after the break.

Therefore, we allow that both the constant term and price elasticity in the target equation differ in quarters before and after 2010q4. The import equations are now specified as:

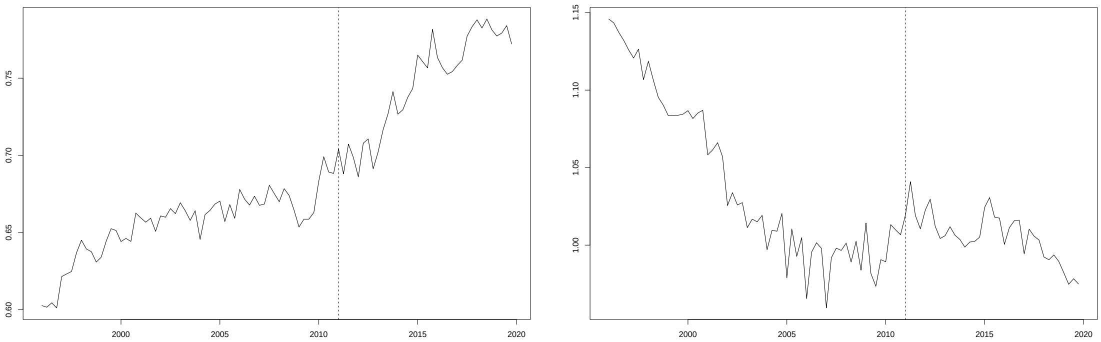
$$\ln m_t^{d*} = \beta_0 + \ln mv_t^d + (\beta_2 + \beta_3 per_{2t}) \ln rp_t^{md} + \beta_4 per_{2t} \tag{12}$$

$$\Delta \ln m_t^d = \rho \ln(m_{t-1}^d / m_{t-1}^{d*}) + \gamma_1 \Delta \ln mv_t^d + \gamma_2 \Delta \ln rp_t^{md} + \epsilon_t \tag{13}$$

[25] We have smoothed peaks in the import volume in 1996q4, 2015q1 and 2015q2.

[26] When we estimate the equation freely, the coefficient of mv^d is significantly larger than one ($\beta_1 = 1.67(0.03)$), while the price elasticity is significantly positive ($\beta_2 = 0.57(0.09)$).

Figure 21: Ratio of imports of goods & services to effective demand (m^d/mv^d) and the relative price (rp^{md})



with $per_2 = 1$ starting in 2010q4. We find in column LR2 that the price elasticity is significantly larger in the second period ($\beta_2 + \beta_3 = -1.6$). The resulting error coefficient in SR2 is now larger and significant. The short-run response to effective demand is elastic and the price elasticity is insignificant. Long-run and short-run fitted values and residuals are given in Figures 22-23, respectively.

Table 10: Import equation Goods and Services (1996q1-2019q4)

	LR 1	SR 1	LR 2	SR 2
constant	-0.347^{***}		-0.402^{***}	
	(0.007)		(0.005)	
$\ln mv$	1.000		1.000	
$\ln rp^{md}$	-1.056^{***}		-0.550^{***}	
	(0.135)		(0.073)	
$\ln rp^{md} * per_2$			-1.079^{***}	
			(0.315)	
per_2			0.115^{***}	
			(0.007)	
$\ln(m^d_{-1}/m^{d*}_{-1})$		-0.034		-0.157^{***}
		(0.025)		(0.049)
$\Delta \ln mv$		1.436^{***}		1.426^{***}
		(0.106)		(0.101)
$\Delta \ln rp^{md}$		-0.042		-0.089
		(0.097)		(0.095)
R^2	0.920	0.619	0.981	0.650
Adj. R^2	0.918	0.607	0.981	0.639
Num. obs.	96	95	96	95
RMSE*100	5.632	1.322	2.731	1.267
ADF p	0.244	< 0.010	< 0.010	< 0.010
KPSS p	< 0.001	0.106	0.212	0.329
LB(1) p	0.000	0.021	0.000	0.057
LB(4) p	0.000	0.015	0.000	0.026

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. $per_2 = 1$ in 2010q4-2019q4

Figure 22: Fitted values and residuals of long-run equation $\ln m^d$

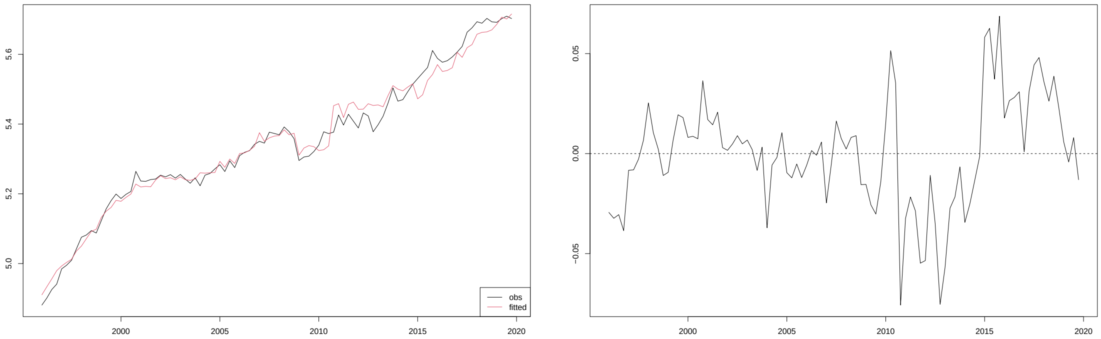
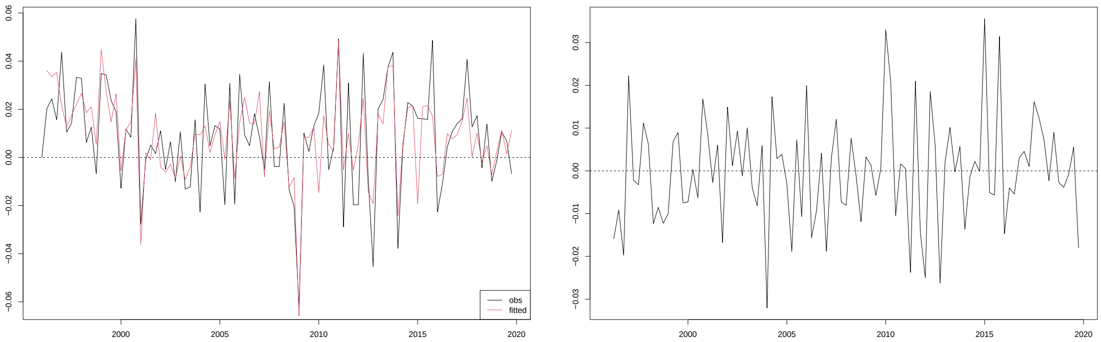


Figure 23: Fitted values and residuals of short-run equation $\Delta \ln m^d$



7.2 Imports for re-exports

We cannot estimate equations for these imports since quarterly data are not available. Target imports (excluding energy) are linked to re-exports using the average import intensity: $m_t^{r*} = 0.9b_t^r$. We fix the error coefficient ad-hoc at 0.3 and the short-run elasticity of b^r at its long-run value:

$$\Delta \ln m_t^r = -0.3 \ln(m_{t-1}^r / m_{t-1}^{r*}) + 0.9 \Delta \ln b_t^r + \epsilon_t \tag{14}$$

7.3 Imports of energy

We do not estimate the target equation of energy imports. Target energy import is defined as the sum of the energy use in the production of six categories (mainly energy export b^e), fixing the intensities at average values:[27]

$$m_t^{e*} = 0.027c_t + 0.012i_t^{ms} + 0.004(g_t^{sn} + g_t^m) + 0.038b_t^d + 0.725b_t^e \tag{15}$$

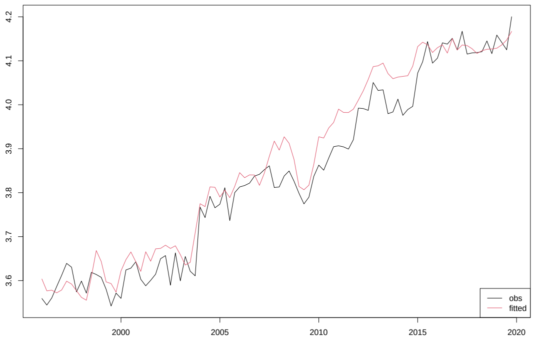
The implied fitted values and residuals are presented in Figure 24.

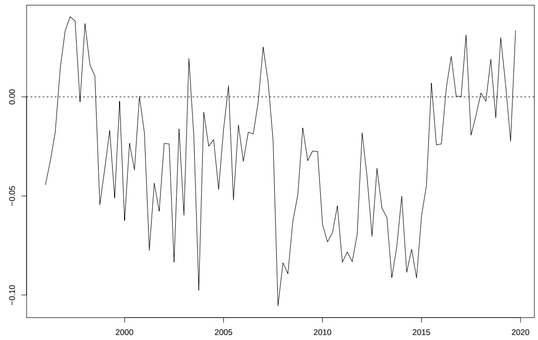
The short-run equation is specified as:

$$\Delta \ln m_t^e = \rho \ln(m_{t-1}^e / m_{t-1}^{e*}) + \gamma_1 \Delta \ln b_t^e \tag{16}$$

The estimation results in Table 11 show a large adjustment speed and a positive response to the growth in energy exports. The fitted values and residuals are given in Figure 25.

Figure 24: Fitted values and residuals of long-run equation $\ln m^e$





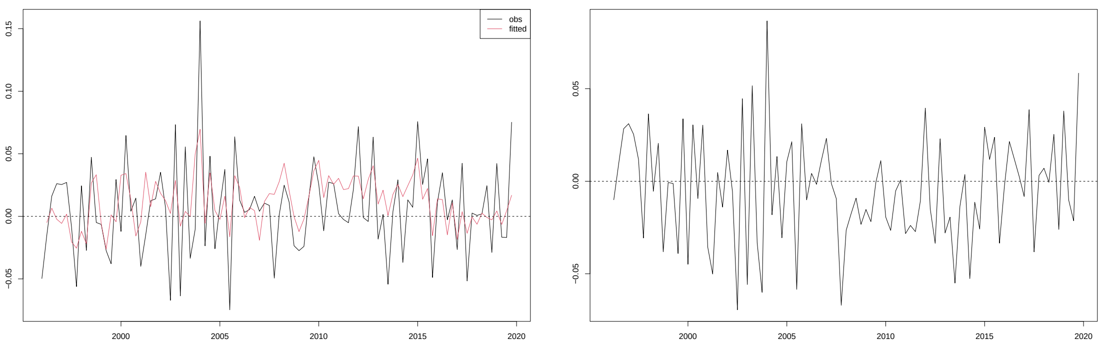
[27] We have smoothed a peak in the import volume in 1996Q4.

Table 11: Short-run import equation energy (1996q1-2019q4)

$\ln(m^e_{-1}/m^{e*}_{-1})$	-0.304^{***}
	(0.066)
$\Delta \ln b^e$	0.366^{***}
	(0.072)
R^2	0.352
Adj. R^2	0.338
Num. obs.	95
RMSE*100	2.985
ADF p	< 0.010
KPSS p	0.287
LB(1) p	0.004
LB(4) p	0.027

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Figure 25: Fitted values and residuals of short-run equation $\Delta \ln m^e$



8 Wages

We estimate a wage equation for the market sector, using the polynomical adjustment cost (PAC) approach of Tinsley (2002). This approach is prominently featured in the FRB/US model (Brayton et al 2000) and in ECB-BASE (Angelini et al. 2019).

The PAC approach results in an extension of the error correction specification. Estimation of the wage equation proceeds in three steps:

1. Long-run (co-integration) relationship estimated by OLS.
2. Forecasting relationships for the determinants of wages estimated in a VAR model with a limited number of core variables.
3. Short-run relationship estimated as an error-correction model with extensions for expectation effects and auxiliary contemporaneous effects. In this step, we estimate a separate short-run relationship for the wages of employees, for which we do allow for expectation effects, and for the incomes of self-employed, for which we use the simple error-correction model instead of a PAC.

The wage equation is estimated with quarterly data for the period 1996q1-2019q4. Results for the long-run relationship, the VAR and the short-run wage equations are reported in Section 8.1, 8.2 and 8.3, respectively.

8.1 Long-run equation

The target labour income share depends linearly on unemployment, the replacement rate and the tax wedge.[28] Wages grow one-to-one with labour productivity (h^l) and the producer price level (p^y), since the model needs to converge to a constant labour income share in the long run. We have experimented with non-linear versions of the wage equation, including non-linearity at the zero lower bound of the unemployment rate and an interaction term between the replacement rate and unemployment. The resulting estimates either prove almost linear or implausible. Besides, we have also experimented with a Phillips-curve wage equation, which did not lead to an improvement of the results. We estimate the long-run specification:

$$\ln p_t^{l*,ms} = \beta_0 + \ln h_t^l + \ln p_t^y + \beta_1 u_t + \beta_2 \ln t_t^w + \beta_3 \ln rr_t + \beta_4 D_{09q2} + \beta_5 S_{05q4-11q3} \quad (17)$$

The dependent variable in the long-run wage equation is the (log) nominal wage cost per hour ($p^{l*,ms}$). This wage cost includes the income of both employees and self-employed,

[28] The tax wedge is defined as the ratio between the nominal labour cost and the nominal net wage. The replacement rate equals the ratio between the net unemployment benefit and the net wage.

and no distinction is made between contract wages and incidental wages. For the calculation of wage costs per hour and labour productivity per hour, a filtered series for the ratio of hours per person is used.[29]

Looking at the data, we need to account for two developments. First, a dummy for the second quarter of 2009 (D_{09q2}) is included in the specification, to account for the large drop in productivity due to the credit crisis. Second, we observe in Figure 26 that the labour income share has not been constant over time. Since the other variables in this model cannot explain the development of the labour income share, a step dummy is included for the middle of the sample period ($S_{05q4-11q3}$). The step dummy gives a temporary decrease in the constant between 2005q4 and 2011q3.

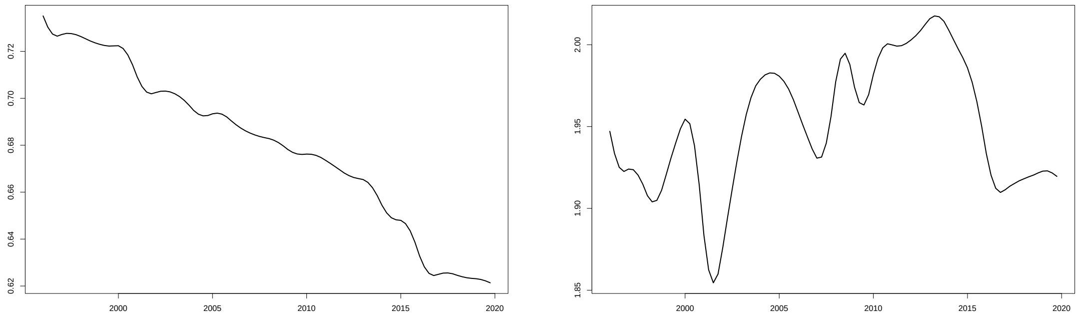
Figure 26: Labour income share (1996q1-2019q4)

The coefficients of the replacement rate (rr) and the tax wedge (t^w) cannot be robustly estimated. The replacement rate falls linearly during the sample period, as shown in Figure 27, such that free estimation would result in this coefficient picking up all other possible explanations for the decline in the labour income share. For that reason, the elasticity with respect to the replacement rate and tax wedge are fixed according to the empirical literature that exploits the variation over countries (see Folmer, 2009).

The coefficient of the unemployment rate (u) is significantly estimated at -1.075, which

[29]The main reason for doing this is to avoid spurious correlation between wage costs per hour and labour productivity per hour.

Figure 27: Replacement rate and tax wedge (1996q1-2019q4)



is smaller than in Saffier 2.1. This is supported by recent findings on a decreasing impact of unemployment on wages and on wage growth falling behind with economic growth (see for example Bonam et al., 2018).

Table 12 shows the estimation results for the long-run wage equation. The coefficients for the producer price, labour productivity, replacement rate and tax wedge are given for completeness, but are calibrated rather than estimated. Fitted values (left) and residuals of the long-run equation are given in Figure 28.

Figure 28: Fitted values and residuals of LR equation

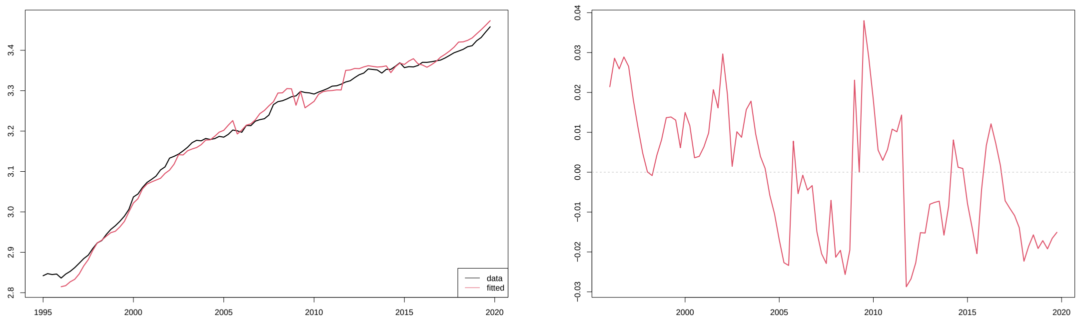


Table 12: Estimation results long-run wage equation (1996q1-2019q4)

	OLS
constant (β_0)	-0.569^{***}
	(0.007)
$\ln h_t^l$	1
$\ln p_t^y$	1
u (β_1)	-1.075^{***}
	(0.137)
$\ln t_t^w$ (β_2)	0.25
$\ln rr_t$ (β_3)	0.2
D_{09q2} (β_4)	0.051^{***}
	(0.016)
$S_{05q4-11q3}$ (β_5)	-0.051^{***}
	(0.004)
R^2	0.992
Adj. R^2	0.992
Num. obs.	96
RMSE*100	1.561
ADF p	< 0.010
KPSS p	0.002
LB(1) p	0.000
LB(4) p	0.000

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

8.2 VAR

The VAR explaining the wage expectations is built up in three steps. First, the core VAR in the five variables y_t = GAP_NL, CPI_NL, RK_EA, GAP_EA and CPI_EA is set up. This is documented in Section 2.

Second, three explanatory variables ($x_t = h_t^l, p_t^y, u_t$) are forecast on the basis of the "Dutch" variables in the core VAR and an autoregressive term:[30]

$$\Delta x_t = \gamma_0 + \gamma_1 \Delta \text{GAP\_NL}_{t-1} + \gamma_2 \Delta \text{CPI\_NL}_{t-1} + \gamma_3 \Delta \text{RK\_EA}_{t-1} + \beta_4 \Delta x_{t-1} \tag{18}$$

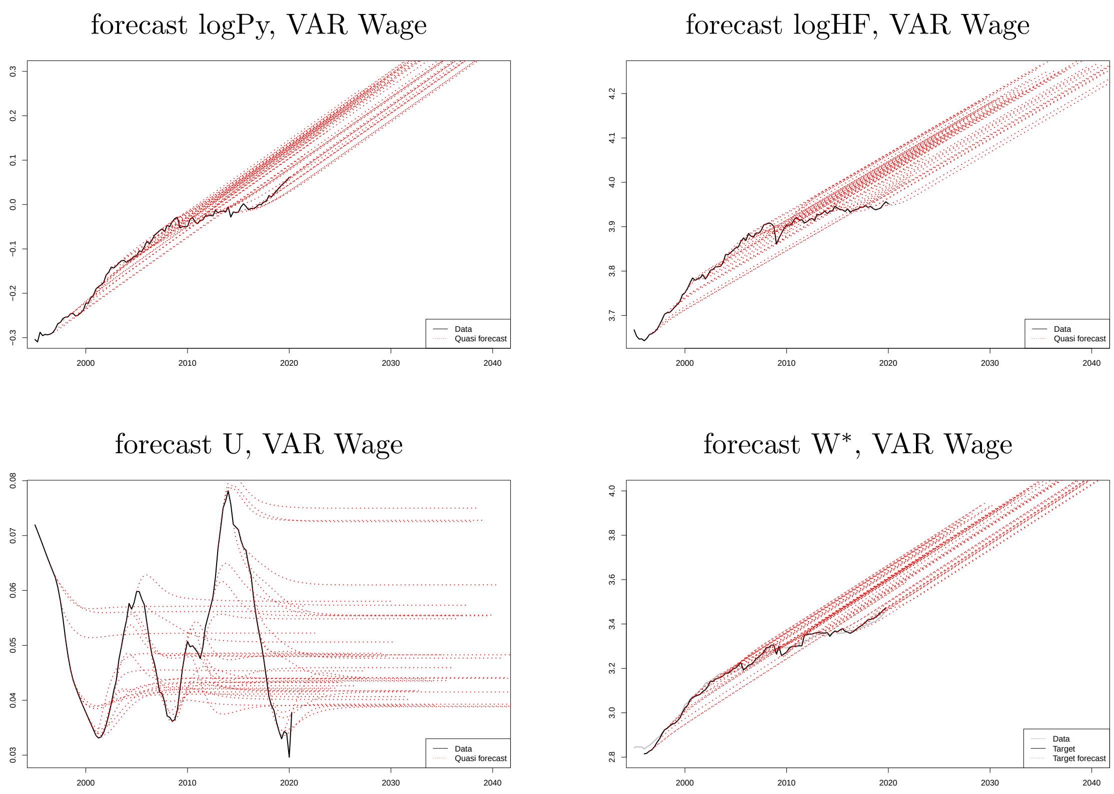
Third, the forecast of the target for $p_t^{l,ms}$ is calculated using the parameters from the long-run equation.

As individual VAR coefficients are not particularly informative, we illustrate the performance of the VAR forecast with forecast figures for the three determinants of the wage cost and the wage cost itself.[31]

[30]Note that the VAR is estimated with data until 2016q4.

[31]These are "quasi forecasts" because the parameters have been estimated using the whole sample, not only the part that was known at the moment the forecast starts.

Figure 29: VAR forecasts, Wage equation



8.3 Short-run equation

The dynamics of wages of employees and self-employed are modeled and estimated separately. The wage cost of employees responds very differently to unemployment, productivity growth and consumer price inflation. To estimate the separate dynamic equations, we first calculate the long-run wage for employees and self-employed from the uniform long-run wage. In the sample, wages per hour of employees are on average 9% higher than the uniform target wage. The long-run wage of employees is hence given by:

$$p_t^{le*,ms} = 1.09 p_t^{l*,ms} \tag{19}$$

Similarly, the long-run wage of self-employed is on average 68% of the uniform wage:

$$p_t^{ls*,ms} = 0.68 p_t^{l*,ms} \tag{20}$$

8.3.1 Short-run equation for employees (PAC)

For the dynamics of employee wages, the PAC model is estimated as an ECM equation that is extended with an expectations term z_t. This term is calculated from the forecast of the target variable and the other estimated parameters. Estimation is therefore iterative; z_t is calculated with given parameters and added as a time-varying offset for the estimation of an updated set of parameters.[32] This proceeds until convergence. Our PAC specification has degree $m = 1$, that is, without autoregressive terms.

The basic PAC specification is extended with auxiliary variables to improve the data fit. Next to the error correction term and the expectations term, the growth rates of labour productivity, consumer prices and the employee and employer tax wedge are included. The estimated PAC specification is:

$$\Delta \ln p_t^{le,ms} = \alpha_0 \ln \frac{p_{t-1}^{le,ms}}{1.09 p_{t-1}^{l*,ms}} + \alpha_1 \Delta \ln p_t^c + \alpha_2 \Delta \ln h_t^l + \alpha_3 \Delta t_t^{ww} + \alpha_4 \Delta t_t^{wl} + z_t + \epsilon_t \tag{21}$$

Employee wage costs respond significantly to current changes in the tax wedge of employers (α_3). We could not find a plausible estimate of the effect of changes in the tax wedge of employees. The coefficient is fixed at the same value as in the long run, such that the incidence of tax rates in the short run is the same as in the long run.

[32] The expectations term, z_t, can be expressed as

$$z_t = \sum_{s=0}^{\infty} f_s \Delta p_{t+s}^{le*,ms}$$

The expected changes in the target, $\Delta p_{t+s}^{le*,ms}$, are calculated by the VAR, the associated weights are functions of the estimated α's in the dynamic equation.

Table 13 shows the estimation results. The coefficient for employee tax wedge is given for completeness, but is calibrated rather than estimated.

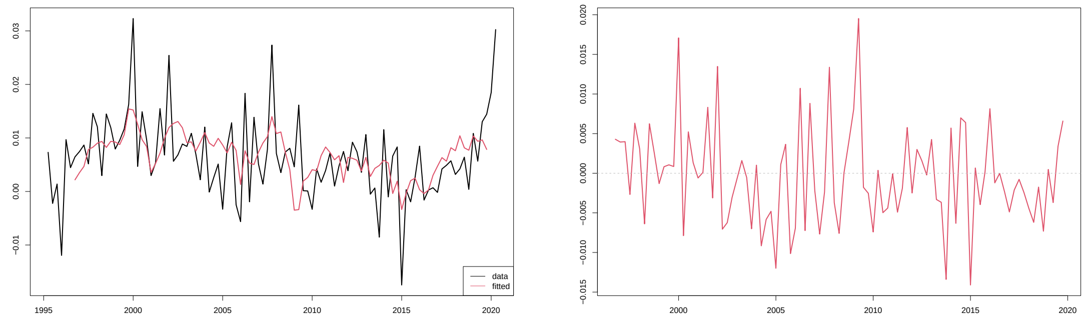
Table 13: Estimation results dynamic wage equation employees (1996q1-2019q4)

	PAC
$\ln(p_{-1}^{le,ms}/p_{01}^{le*,ms})$ (α_0)	-0.109^{***}
	(0.038)
$\Delta \ln p^c$ (α_1)	0.207^{*}
	(0.121)
$\Delta \ln h^l$ (α_2)	$0.153*$
	(0.086)
$\Delta \ln t^{ww}$ (α_3)	0.611^{**}
	(0.270)
$\Delta \ln t^{wl}$ (α_4)	0.25
R^2	0.613
Adj. R^2	0.595
Num. obs.	93
RMSE*100	0.618
ADF p	< 0.010
KPSS p	0.198
LB(1) p	0.401
LB(4) p	0.587

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Fitted values (left) and residuals of the dynamic equation for employee wages are given in Figure 30.

Figure 30: Fitted values and residuals of dynamic equation for employees



8.3.2 Short-run equation for self-employed (ECM)

The growth rate of labour income of self-employed is modeled as a ECM specification with an autoregressive term. We did not find strong evidence in favour of effects of expectations and tax rate changes. The estimated error correction coefficient (α_0) is small and insignificant. The growth rate of the income of self-employed is strongly correlated with wage growth in the previous quarter.

$$\Delta \ln p_t^{ls,ms} = \alpha_0 \ln \frac{p_{t-1}^{ls,ms}}{0.68 p_{t-1}^{l*,ms}} + \alpha_1 \Delta \ln p_{t-1}^{ls,ms} \tag{22}$$

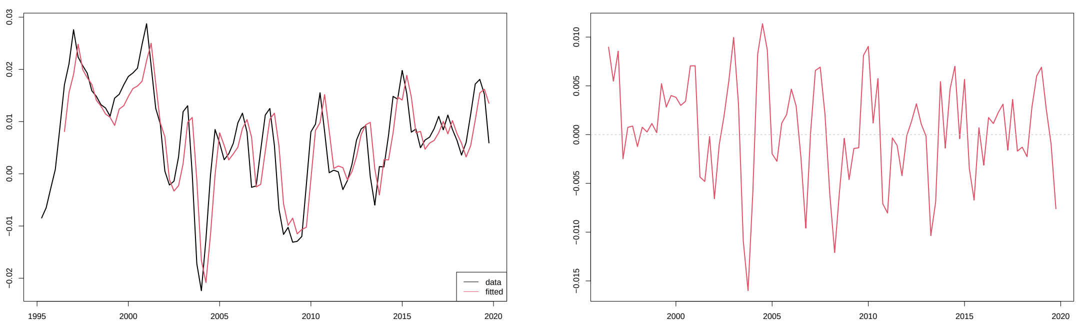
Table 14 shows the estimation results. Fitted values (left) and residuals of the dynamic equation for wages of self-employed are given in Figure 31.

Table 14: Estimation results dynamic wage equation self-employed (1996q1-2019q4)

	PAC
$\ln(p_{-1}^{ls,ms}/p_{01}^{ls*,ms})$ (α_0)	-0.014
	(0.010)
$\Delta \ln p_{-1}^{ls,ms}$ (α_1)	0.918^{***}
	(0.047)
R^2	0.813
Adj. R^2	0.808
Num. obs.	94
RMSE*100	0.532
ADF p	< 0.010
KPSS p	0.350
LB(1) p	0.000
LB(4) p	0.000

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Figure 31: Fitted values and residuals of dynamic equation for self-employed



9 Prices

We estimate three core equations for prices of use categories: consumption of private households, investment and exports (excluding energy and re-exports). In order to capture the effect of expectations, we set up our estimation in the polynomial adjustment cost (PAC) approach of Tinsley (2002), which is prominently featured in the FRB/US model (Brayton et al., 2000) and in ECB-BASE (Angelini et al, 2019).

The PAC approach results in an extended error-correction type of estimation equations. Estimation proceeds in three steps:

1. Long-term (co-integration) relationship estimated by OLS.

2. Forecasting relationships for the determinants of the prices of interest estimated in a VAR model with a limited number of core variables.

3. Short-term relationship estimated as an error-correction model with extensions accounting for expectation effects and auxiliary contemporaneous effects.

In the first step we estimate the long-term relationships of the three prices as a system, using input prices, structural labour productivity and a linear trend for the macro mark-up as explanatory variables (Section 9.2).

In the second step (Section 9.3), we estimate a VAR system based on interest rates, inflation rates and the output gap, which provides us with forecasts for the prices of interest (see Zimic and Marcelatti, 2017, for the general approach and Section 2, for the implementation in Saffier 3.0).

In the third step (Section 9.4), we estimate the core PAC equations, using short-term price and productivity changes and expected target changes as regressors.

The short-term coefficients used in Saffier 3.0 of Bettendorf et al. (2021) are documented in Table 19. Error correction terms for the consumption and export prices are moderate and much lower than for investment. Short-term coefficients of the input prices are in most cases in a reasonable range, but must occasionally be restricted to be non-negative. The effect of productivity is always negative, as expected. Many short-term coefficients are not significantly different from zero. This suggests scope for the improvement of the estimation set-up. However, in our extensive specification search (see the bullet items in Section 9.4) we were not able to find estimation equations with a better performance.

9.1 Data

- p_t^i: log price index by use category ($i = C, I, B$), excluding indirect taxes
- p_t^{Le}: log productivity-corrected wage
- p_t^K: log user cost of capital
- p_t^M: log import price index
- p_t^E: log energy price index
- h_t: log index of structural labour productivity

Estimation period is 1996q1-2019q4. We lose some observations at the start of the period when lags are involved.

9.2 Long-term equations

Each price is modelled as a weighted sum of the input prices:

$$p_t^i = \alpha_i^0 + s_i^L p_t^{Le} + s_i^K p_t^K + s_i^M p_t^M + s_i^E p_t^E + \alpha_i^1 h_t + \alpha_i^2 t$$

- α_i^0 is a constant that accounts for price and trend normalisations.
- s_i^L, s_i^K, s_i^M, s_i^E are empirical value shares calibrated from the consolidated production matrix. We have tried to estimate these coefficients as well, but failed to get estimates in a plausible range.[33]
- α_i^1 captures an effect of productivity increase ("Baumol" effect, different productivity developments by sector).
- α_i^2 is supposed to capture an effect of the economy-wide mark-up rate. This has increased over time, but is highly endogenous. Therefore we "instrument" it with a time trend.

[33] We also tried to estimate equations in which p_t^M has a double role as both input price (via α_i^3) and as competitors' price (via $1 - \alpha_i^3$):

$$p_t^i = \alpha_i^0 + \alpha_i^3 \left(s_i^L p_t^{Le} + s_i^K p_t^K + s_i^M p_t^M + s_i^E p_t^E \right) + (1 - \alpha_i^3) p_t^M + \alpha_i^1 h_t + \alpha_i^2 t$$

However, the estimated values of α_i^3 were not in a plausible range.

- The three long-term equations for p_t^C, p_t^B, p_t^I are estimated as a system with a restriction on the α_i^1 parameters:

$$w_h^C \alpha_C^1 + w_h^B \alpha_B^1 + w_h^I \alpha_I^1 = 0$$

  where the w_h^i weights are value shares in production.

Table 15 shows the long-term estimation results. Coefficients for the input prices are given for completeness, but are calibrated rather than estimated.

The following graphs show the fit and the residuals of the long-term equations.

Table 15: Prices long-term

	PC lt	PB lt	PI lt
const (α^0)	-0.873^{***}	-0.746^{***}	-1.147^{***}
	(0.011)	(0.012)	(0.018)
prod (α^1)	0.392^{***}	-0.334^{***}	-0.221
	(0.046)	(0.048)	
mark-up (α^2)	-0.195	0.847^{***}	0.355
	(0.147)	(0.159)	(0.228)
PL	0.380	0.343	0.398
PK	0.158	0.194	0.097
PM	0.432	0.405	0.493
PE	0.030	0.058	0.012
R^2	0.969	0.914	0.885
Adj. R^2	0.969	0.912	0.883
Num. obs.	96	96	96
RMSE*100	1.720	2.116	2.232
ADF p	< 0.010	< 0.010	< 0.010
KPSS p	0.471	0.384	0.870
LB(1) p	0.000	0.000	0.003
LB(4) p	0.000	0.000	0.000

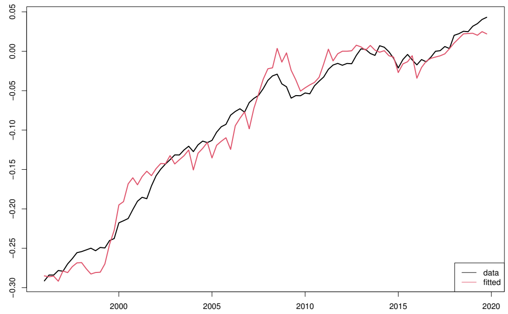
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

9.3 VAR

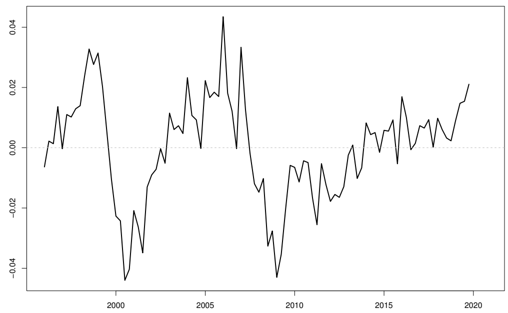
The VAR explaining the price expectations is built up in three steps. First, the core VAR in the five variables y_t = GAP_NL, CPI_NL, RK_EA, GAP_EA and CPI_EA is set up.

Figure 32: Fit and residuals of the long-term price equations

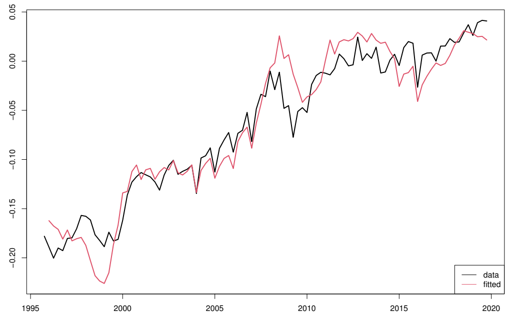
log PC fit long-term



log PC residuals long-term

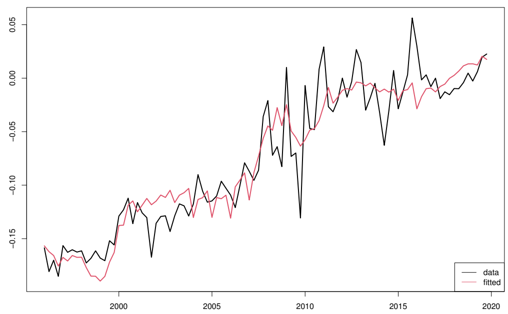


log PB fit long-term

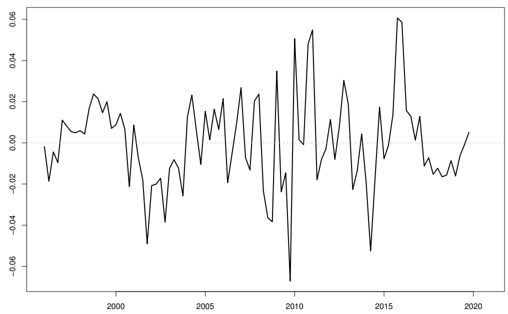


log PB residuals long-term

log PI fit long-term



log PI residuals long-term



This is documented in Section 2.

Second, five explaining variables ($x_t = p_t^{Le}$, p_t^K, p_t^M, p_t^E, h_t) are forecast on basis of the "Dutch" variables in the core VAR and an autoregressive term:

$$\Delta x_t = \beta_0 + \beta_1 \Delta \text{GAP\_NL}_{t-1} + \beta_2 \Delta \text{CPI\_NL}_{t-1} + \beta_3 \Delta \text{RK\_EA}_{t-1} + \beta_4 \Delta x_{t-1}$$

The constants in the four price equations are restricted so that the long-term growth rate of all prices is the same. The constant in the labour productivity equation is restricted so that the long-term growth rate is equal to the average growth in the sample.[34]

Third, the forecast of the targets for p_t^C, p_t^B, p_t^I is calculated using the parameters from the long-term equations.

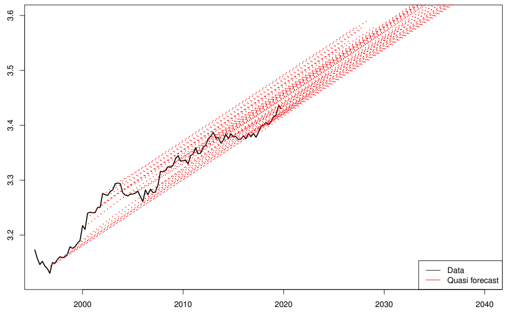
As individual VAR coefficients are not particularly informative, we illustrate the performance of the VAR forecast with forecast figures for the five determinants and the three prices to be explained.[35]

[34] Fixing the growth rate is not equivalent to fixing the parameter because of the autoregressive terms: $g = \beta_0 / (1 - \beta_4)$.

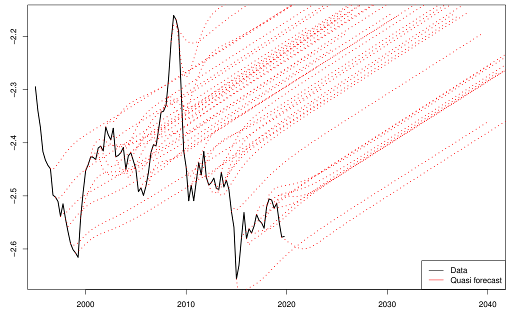
[35] These are "quasi forecasts" because the parameters have been estimated using the whole sample, not only the part that was known at the moment the forecast starts.

Figure 33: Forecasts of the VAR variables Prices

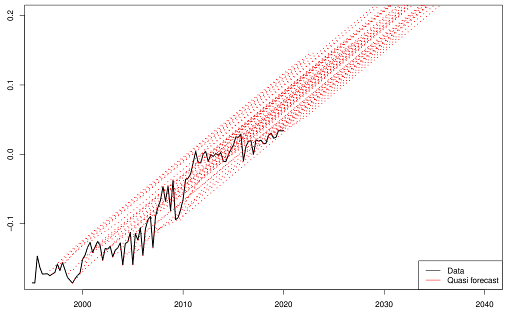
forecast ple, VAR prices



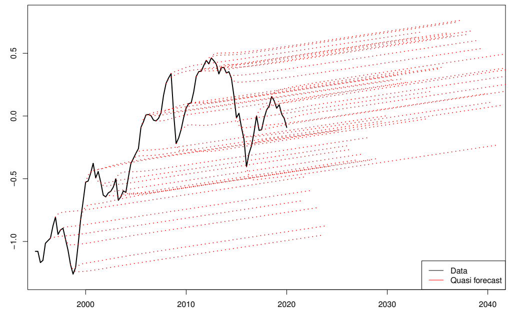
forecast pk, VAR prices



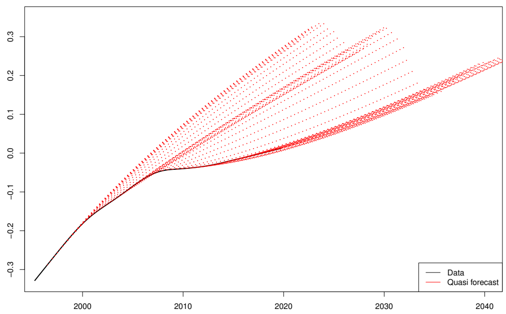
forecast pm, VAR prices



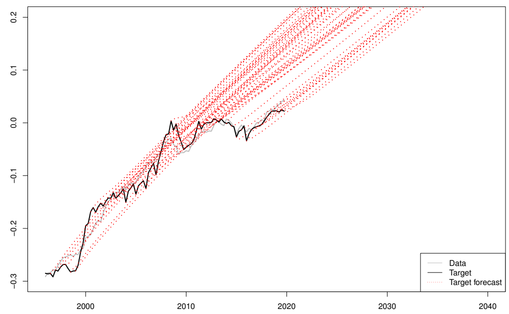
forecast pe, VAR prices



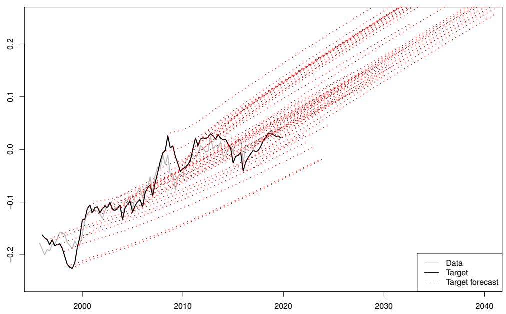
forecast h, VAR prices



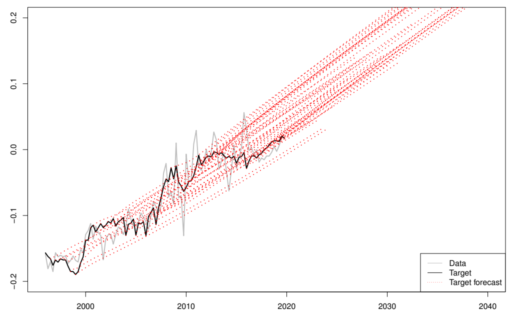
forecast pc*, VAR prices



forecast pb*, VAR prices



forecast pi*, VAR prices



9.4 Short-term estimation: PAC

The PAC model is estimated as an ECM equation that is extended with one complex expectations term ("z_t"). This term is calculated from the forecast of the target variable and the other estimated parameters. Estimation is therefore iterative: z_t is calculated with given parameters and added as a time-varying offset for the estimation of an updated set of parameters.[36] This proceeds until convergence.

The basic specification of the PAC equation is

$$\Delta p_t^i = \gamma_0 + \gamma_1 \left(p_t^i - p_t^{i\star}\right) + \gamma_2 \Delta p_t^L + \gamma_3 \Delta p_t^K + \gamma_4 \Delta p_t^M + \gamma_5 \Delta p_t^E + \gamma_6 \Delta h_t^r + z_t$$

Our specification search (documented in separate notes) resulted in the following choices:

- We estimates PACs of degree $m = 1$, i.e. without autoregressive terms.
- We use the raw wage p_t^L rather than the productivity-corrected wage.
- We use raw labour productivity h_t^r rather than structural (HP-filtered) productivity.
- We include a constant to capture the increasing trend in the mark-up.
- The equation for p_t^C is extended with a lagged term in the wage change: Δp_{t-1}^L
- The equations for p_t^C and p_t^B are extended with dummy variables for the four quarters of the crisis year 2009.

Table 16 shows the estimation results. To put the results in perspective, we also add tables with pure ECM results (without the z_t term) in Table 17 and PACs of degree $m = 2$ in Table 18 (lagged difference of the dependent variable added as a regressor). Extending the PAC to $m = 2$ does not improve the fit largely. The AR-coefficients themselves remain insignificant and the other coefficients are robust. We therefore choose for the simpler $m = 1$.

[36] The expectations term, z_t can be expressed as

$$z_t = \sum_{s=0}^{\infty} f_s \Delta p_{t+s}^{i\star}$$

The expected changes in the target, $\Delta p_{t+i}^{i\star}$, are calculated by the VAR, the associated weights are functions of the estimated γ's. E.g. for $m = 1$ we have $f_s = \gamma_1 \left[(1-\gamma_1)\,\beta\right]^s$,where β is an exogenous discount factor.

Figure 34: Fit and residuals of the short-term price equations

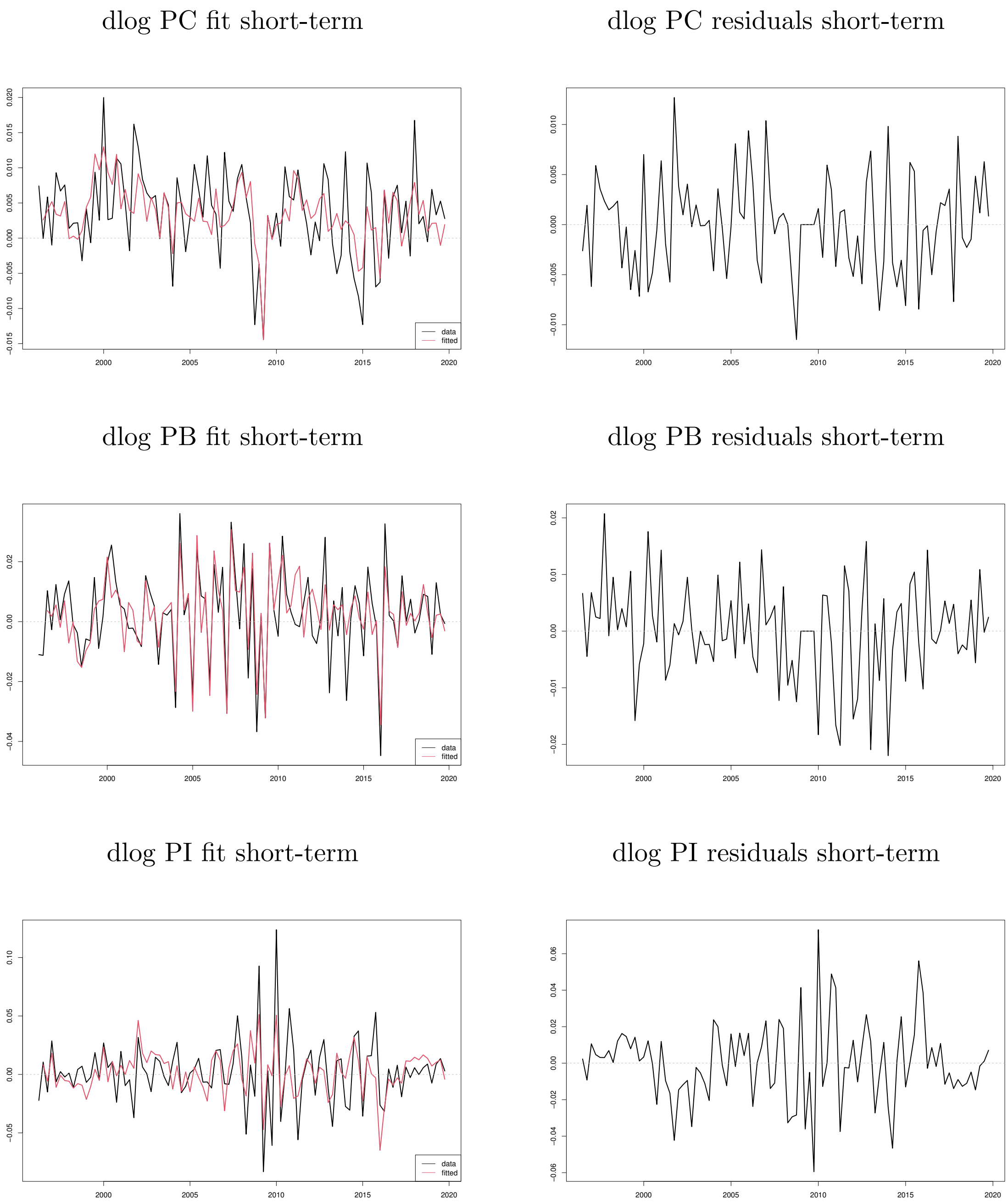


Table 16: Prices short-term PAC unrestricted

	PC st	PB st	PI st
γ_0	0.001	0.000	-0.001
	(0.001)	(0.001)	(0.003)
γ_1	-0.063^{*}	-0.117^{**}	-0.693^{***}
	(0.036)	(0.053)	(0.106)
Δp_t^L (γ_2)	0.040	-0.100	0.265
	(0.061)	(0.108)	(0.258)
Δp_{t-1}^L	0.141^{**}		
	(0.061)		
Δp_t^K (γ_3)	0.028	-0.002	0.020
	(0.019)	(0.035)	(0.073)
Δp_t^M (γ_4)	-0.023	0.611^{***}	0.133
	(0.034)	(0.059)	(0.133)
Δp_t^E (γ_5)	0.023^{***}	0.020^{*}	0.005
	(0.007)	(0.012)	(0.028)
Δh_t^r (γ_6)	-0.112	-0.105	-0.196
	(0.079)	(0.136)	(0.269)
d_2009q1	-0.006	-0.030^{**}	
d_2009q2	-0.020^{***}	-0.002	
d_2009q3	0.000	0.016	
d_2009q4	-0.001	-0.009	
R^2	0.550	0.702	0.425
Adj. R^2	0.484	0.662	0.378
Num. obs.	94	94	94
RMSE*100	0.475	0.848	2.135
ADF p	< 0.010	< 0.010	< 0.010
KPSS p	0.690	0.035	0.845
LB(1) p	0.696	0.160	0.864
LB(4) p	0.143	0.046	0.001

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 17: Prices short-term ECM

	PC st	PB st	PI st
γ_0	0.002^{***}	0.002	-0.002
	(0.001)	(0.001)	(0.003)
γ_1	-0.052	-0.103^{*}	-0.686^{***}
	(0.037)	(0.052)	(0.105)
Δp_t^L (γ_2)	0.069	-0.073	0.504^{*}
	(0.062)	(0.107)	(0.256)
Δp_{t-1}^L	0.156^{**}		
	(0.061)		
Δp_t^K (γ_3)	0.039^{**}	0.027	0.094
	(0.020)	(0.035)	(0.073)
Δp_t^M (γ_4)	-0.008	0.653^{***}	0.435^{***}
	(0.034)	(0.059)	(0.132)
Δp_t^E (γ_5)	0.027^{***}	0.031^{***}	0.016
	(0.007)	(0.012)	(0.028)
Δh_t^r (γ_6)	-0.095	-0.133	-0.212
	(0.080)	(0.135)	(0.268)
d_2009q1	-0.006	-0.033^{**}	
d_2009q2	-0.020^{***}	-0.000	
d_2009q3	0.000	0.019^{*}	
d_2009q4	-0.001	-0.007	
R^2	0.545	0.698	0.423
Adj. R^2	0.479	0.659	0.377
Num. obs.	95	95	95
RMSE*100	0.481	0.847	2.129
ADF p	< 0.010	< 0.010	< 0.010
KPSS p	0.284	0.193	0.623
LB(1) p	0.674	0.075	0.837
LB(4) p	0.131	0.050	0.001

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 18: Prices short-term PAC unrestricted, m = 2

	PC st	PB st	PI st
γ_0	0.001	0.000	-0.001
	(0.001)	(0.001)	(0.003)
γ_1	-0.066^{*}	-0.112^{**}	-0.687^{***}
	(0.037)	(0.052)	(0.132)
Δp^i_{t-1}	-0.074	-0.116	-0.008
	(0.099)	(0.072)	(0.104)
Δp^L_t (γ_2)	0.043	-0.093	0.268
	(0.062)	(0.107)	(0.260)
Δp^L_{t-1}	0.145^{**}		
	(0.061)		
Δp^K_t (γ_3)	0.030	0.006	0.020
	(0.020)	(0.035)	(0.074)
Δp^M_t (γ_4)	-0.021	0.579^{***}	0.135
	(0.034)	(0.062)	(0.134)
Δp^E_t (γ_5)	0.023^{***}	0.020^{*}	0.004
	(0.007)	(0.012)	(0.029)
Δh^r_t (γ_6)	-0.102	-0.055	-0.196
	(0.080)	(0.139)	(0.271)
d_2009q1	-0.007	-0.030^{**}	
d_2009q2	-0.020^{***}	-0.004	
d_2009q3	-0.001	0.013	
d_2009q4	-0.001	-0.006	
R^2	0.554	0.710	0.425
Adj. R^2	0.482	0.668	0.371
Num. obs.	94	94	94
RMSE*100	0.474	0.836	2.134
ADF p	< 0.010	< 0.010	< 0.010
KPSS p	0.651	0.056	0.848
LB(1) p	0.868	0.493	0.851
LB(4) p	0.108	0.080	0.001

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

9.5 Restrictions on short-term price coefficients

Negative effects of input prices on output prices do not make sense economically. Therefore we restrict the short-term price coefficients to be positive. This applies to p_M in the consumption-price equation and to p_L and p_K in the export-price equation. As these coefficients were only slightly and insignificantly negative in Table 16, the effect of the restriction on the other parameters is small (see our preferred Table 19).

Table 19: Prices short-term PAC restricted

	PC st	PB st	PI st
γ_0	0.001	−0.000	−0.001
	(0.001)	(0.001)	(0.003)
γ_1	-0.070^{*}	-0.124^{**}	-0.693^{***}
	(0.035)	(0.052)	(0.106)
Δp_t^L (γ_2)	0.032		0.265
	(0.061)		(0.258)
Δp_{t-1}^L	0.137^{**}		
	(0.060)		
Δp_t^K (γ_3)	0.027		0.020
	(0.019)		(0.073)
Δp_t^M (γ_4)		0.603^{***}	0.133
		(0.058)	(0.133)
Δp_t^E (γ_5)	0.022^{***}	0.018	0.005
	(0.007)	(0.011)	(0.028)
Δh_t^r (γ_6)	−0.107	−0.117	−0.196
	(0.078)	(0.125)	(0.269)
d_2009q1	−0.008	-0.031^{**}	
d_2009q2	-0.018^{***}	−0.003	
d_2009q3	0.000	0.017^{*}	
d_2009q4	−0.001	−0.007	
R^2	0.550	0.699	0.425
Adj. R^2	0.490	0.667	0.378
Num. obs.	94	94	94
RMSE*100	0.477	0.853	2.135
ADF p	< 0.010	< 0.010	< 0.010
KPSS p	0.650	0.061	0.845
LB(1) p	0.700	0.132	0.864
LB(4) p	0.120	0.028	0.001

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

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