Output Gap Estimates for Finland with Multivariate Filters

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Evaluation of appropriateness of fiscal policy is partly based on information on cyclical situataion of the economy. While the distinction between cyclical fluctuations and structural changes in economy is based on estimates of potential output and its growth, these estimates are also affected by forecast developments. This discussion paper introduces a model that provides up-to-date information on cyclical output and unemployment in Finland based solely on quarterly data. In recent literature, the output gap is argued to be affected by channges in priveate sector credit and debt service burden. We extend our baseline model to test this hypothesis in Finnish economy.

1 Introduction

Potential output can be defined as the maximum level of output that can be produced without giving rise to inflation, that is, sustainable level of output.[1]

[1]See Okun (1962).

In turn, output gap is measured as the difference between actual and potential output.[2] When actual and potential output are equal, inflation should be stable. If actual output exceeds the potential, then inflation should increase, and fall if actual output is below its potential.

Estimating potential output is important since it can give essential information where the economy is now and where it is going in the future. However, a challenge related to estimating potential output and output gap are that they are unobservable variables and must be derived from observable variables, that are thought to be correlated with the potential output. In many macroeconomic models, output gap is the key variable that drives the nominal price and wage dynamics (Laxton and Tetlow 1992). Therefore, in the existing literature, the symptom of unsustainability is closely tied to inflation developments. In DSGE models define potential output as the output that corresponds to fully flexible prices and wages, makin a distinction between normal inflation development and one caused by nominal rigidities.

Giving an accurate estimate of potential output is highly important for monetary and fiscal policy. For example, central banks set a path for the nominal interest rate to accomplish the target level of inflation and other possible targets. If the estimate of potential output is inaccurate, e.g., giving negative measure of output gap when it is actually positive, then the stance of monetary policy could amplify the business cycle and lead to central bank failing to reach its goal (Laxton and Tetlow 1992). In the case of fiscal policy, the inaccurate estimate of potential output can, e.g., lead to fiscal authorities' setting tax base at the

[2] Kiley (2013) gives three alternative definitions of the output gap. These are:

i.) the deviation of output from its long-run stochastic trend (i.e., the Beveridge-Nelson cycle)

ii.) the deviation of output from the level consistent with current technologies and normal utilization of capital and labor input (i.e. the production function approach)

iii.) the deviation of output from a "flexible price" or natural rate level

level that is in line with overly optimistic views about potential output growth.

Economists often use univariate statistical filters, such as the Hodrick-Prescott (HP) filter[3] to derive empirical approximations for trend, or potential, GDP. Advantages of these type of methods include their simplicity, transparency and that they are easily applicaple to any country where GDP data is available. However, their limitation is that they lack economic structure and therefore the estimates can be better interpreted as trend growth rather than potential growth (Blagrave et al. 2015). Additionally, univariate filters suffer from end-of-sample problem, which means that when the sample is extended as more data becomes available, the estimates towards the end of a sample period are subject to significant revisions.

A trend or potential output can also be estimated by using various filtering techniques to the inputs of a production function. The estimates for output gap vary over time as newer data becomes available. In the case of univariate filtering techniques the revisions for the most recent quarters tend to be particularly large, creating a problem for current analysis and forecasting. This problem is especially large in a small open economies where the Quarterly National Accounts tend to be revised substantially between releases. The problem of large revisions can be lessened by enlarging the filter from an univariate setup to a bivariate or a multivariate one.[4] Introduction of less revised data, such as survey data, to the filter, makes the estimates for output gap more stable over data releases.

The idea of multivariate filters (MVF) is to include economic structure to the estimates of potential output by conditioning them on some theoretical relationships (e.g., the Phillips curve).[5] An advantage of using MVF is that

[3]See Hodrick and Prescott (1997).

[4]See, e.g, Blagrave et al. (2015) for summary of common estimation methods for potential output in macroeconomic literature.

[5]Previous literature that utilizes MVFs: Laxton and Tetlow (1992), Kuttner (1994), Benes et al. (2010).

estimates of the potential output and output gap correspond to the Okus's definition of potential output (Blagrave et al. 2015). On the other hand, the end-of-sample problem still remains.

Output gap for Finland is estimated by few domestic research organizations, namely Ministry of Finance, Bank of Finland and ETLA, who publish their output gap estimates biannually. However they do not make the time series for output gap, potential output and equilibrium unemployment rate publicly available, but release mainly forecasts with few years of history.

This paper utilizes a multivariate filtering (MVF) method for measuring potential output and the output gap for Finland. The used MVF method incorporates empirical relationships between actual and potential GDP, unemployment and inflation, within the framework of a small macroeconomic model.

There exist a growing literature on estimating potential output utilizing information about the financial cycle. E.g., Borio et al. (2017) point out that the standard non-inflationary approach of estimating potential output can be too restrictive in estimating potential output. This is because, even when inflation is low and stable, accumulating financial imbalances can lead to unsustainable level of potential output. Also omitting this information from the estimation of potential output can lead to less reliable estimates of potential output/output gap (Borio et al. 2017). Therefore, in a second step, we investigate whether adding information about the financial cycle to our model improves our estimation of potential output/output gap in Finland. Particularly, we expand our MVF by adding leverage and debt service gaps into our model (following the method by Juselius et al. 2016). Unusually strong financial booms are likely to coincide with positive supply-side shocks putting downward pressure on prices while at the same time providing fertile ground for asset price booms that weaken financial constraints. This combination can amplify the financial cycle, especially if supported by inappropriate monetary policy. Financial cycle may lead to an unsustainable sectoral misallocation of resourcest to sectors that are especially sensitive to credit, such as real estate. Financial and real developments can mask the underlying financial vulnerabilities that eventually bring the expansion to an end. Exceptionally tight financial conditions can hold back the economic recovery, as the overhand of debt makes the task of reshuffling capital and labor harder, hindering the correction of the resource misallocation built-up during the boom.

Positive finance-neutral output gaps imply that the economy is running beyond long-run sustainable levels which might warrant monetary tightening and vice versa. To the extent that finance-neutral output gaps signal unsustainability associated with financial cycles, the policy implications may be less straighforward than traditional output gaps. As financial cycles are usually of longer duration than typical business cycles, policy will need to take into account longer horizons and recognize that the impact of policy may be quite persistent. Reining in a finance-induced economic boom may involve alternative policy tools apart from common monetary policy, not least macropru measures. For example in a bust, balance sheet repair may be more effective than monetary policy in mitigating contractionary financial headwinds.

The rest of the paper is organized as follows. The section 2 explains the multivariate filter approach that we use for estimating potential output. Section 3 discussed the data and estimation details. The estimation results and accuracy test for our baseline model are presented in Section 4. In Section 5 we add financial factors to our MVF and compare the results to the baseline model. Section 6 concludes.

2 Baseline model

2.1 Multivariate filter model for the Finnish economy

Our baseline model for estimating potential output is based on the MVF method presented e.g. by Benes et. al (2010). The model relates developements of trends and actual values of real output, inflation and unemployment rate. The output gap y_t is defined as log difference between actual GDP Y_t and potential, or trend, GDP $\bar{Y}_t$:

$$y_t = 100 \left[\ln (Y_t) - \ln \left(\bar{Y}_t \right) \right]$$

and is affected by the current and expected inflation through relation:

$$y_t = \rho_1 y_{t-1} + \frac{\rho_2}{100} \left(\pi_t - \pi_t^E \right) + \epsilon_t^y, \tag{1}$$

where inflation expectations follow a random walk process

$$\pi_t^E = \pi_{t-1}^E + \epsilon_t^{\pi E}.$$

The resulting level and changes in output gap are used to explain the fluctuations in inflation:

$$\pi_t = \pi_{t-1} + \beta y_t + \Omega \left(y_t - y_{t-1} \right) + \epsilon_t^{\pi}, \tag{2}$$

and unemployment gap u_t. The unemployment gap is defined as the difference between the equilibrium unemployment rate $\bar{U}_t$ and the actual unemployment rate U_t

$$u_t = \bar{U}_t - U_t,$$

i.e. the unemployment gap is positive when unemployment is below its equilibrium level. The change in unemployment gap is affected by the level of output gap:

$$u_t = \phi_u u_{t-1} + \phi_y y_t + \epsilon_t^u. \tag{3}$$

This equation is closely related to the Okun's Law - a positive output gap increases unemployment gap i.e. decreases unemployment. A positive output gap also decreases the equilibrium unemployment rate, which fluctuates around its steady state rate. The change in equilibrium unemployment rate is modeled as

$$\bar{U}_t - \bar{U}_{t-1} = -\frac{1}{100}\left[\omega y_{t-1} + \lambda\left(\bar{U}_{t-1} - U^{SS}\right)\right] + S_t^U + \epsilon_t^{\bar{U}}, \tag{4}$$

where $U^{ss}$is the steady state rate of unemployment and S_t^U is persistent shock process following an AR(1) process:

$$S_t^U = (1-\alpha)\, S_{t-1}^U + \epsilon_t^{SU}.$$

The inclusion of the output gap in the equation (4) reflects hysteresis effects from economy-wide demand fluctuations.

The evolution of the potential output depends on its trend growth rate,S_t^Y, and on changes in equilibrium unemployment:

$$\bar{Y}_t = \bar{Y}_{t-1} - \theta\left(\bar{U}_t - \bar{U}_{t-1}\right) - (1-\theta)\frac{\left(\bar{U}_{t-1} - \bar{U}_{t-20}\right)}{19} + \frac{S_t^Y}{4} + \epsilon_t^{\bar{Y}}. \tag{5}$$

A permanent 1 percentage point increase in equilibrium unemployment rate decreases the output potentia by θ percent; a negative effect continues for a further 19 quarters, such that the long-run decline in the level of potential output is 1 percent. The trend growth rate follows a process around annualized steady state growth rate, G^{SS},:

$$S_t^Y = \tau G^{SS} + (1-\tau)\, S_{t-1}^Y + \epsilon_t^{SY} \tag{6}$$

To ensure that potential output growth does not deviate too far from steady state, the following equation is added to the model:

$$4\left(\bar{Y}_t - \bar{Y}_{t-1}\right) = G^{SS} + \epsilon_t. \tag{7}$$

where ϵ_t denotes a measurement error reflecting our prior beliefs about how potential output growth will fluctuate around the steady state rate G^{SS}

2.2 Data

The data available covers observations for Finland from 1997Q1 to 2020Q4 and includes real GDP, consumer price inflation (HICP), consumers inflation expectations and unemployment. The GDP is from the Quarterly National Accounts by Statistics Finland, the data on HICP inflation is acquired from the Eurostat. Data on unemployment rate is based on the Labour Force Survey data and is seasonally adjusted using Demetra. The inflation expectations are based on the Consumer Confidence survey data.

The data is depicted in Figure 1. In 2000's annual growth rate of real GDP was 3.5% and unemployment rate declined annually almost half percentage points. After 2008 the economic growth has remained slower than in previous decades and the unemployment rate has remained rather stable at 8%, on average. The data shows two occasions with large changes in unemployment rate. In 2009Q2 the unemployment rate increased by 1.5 percentage points in one quarter and in 2018Q2 unemployument rate declined by 1.4 percentage points in one quarter. The data shows three periods with consumer price inflation higher than the target rate of 2% and all of these period came as a surprise to consumers. The data on GDP for 2020 is still preliminary, thus the estimation period is restricted to 1997Q1:2019Q4.

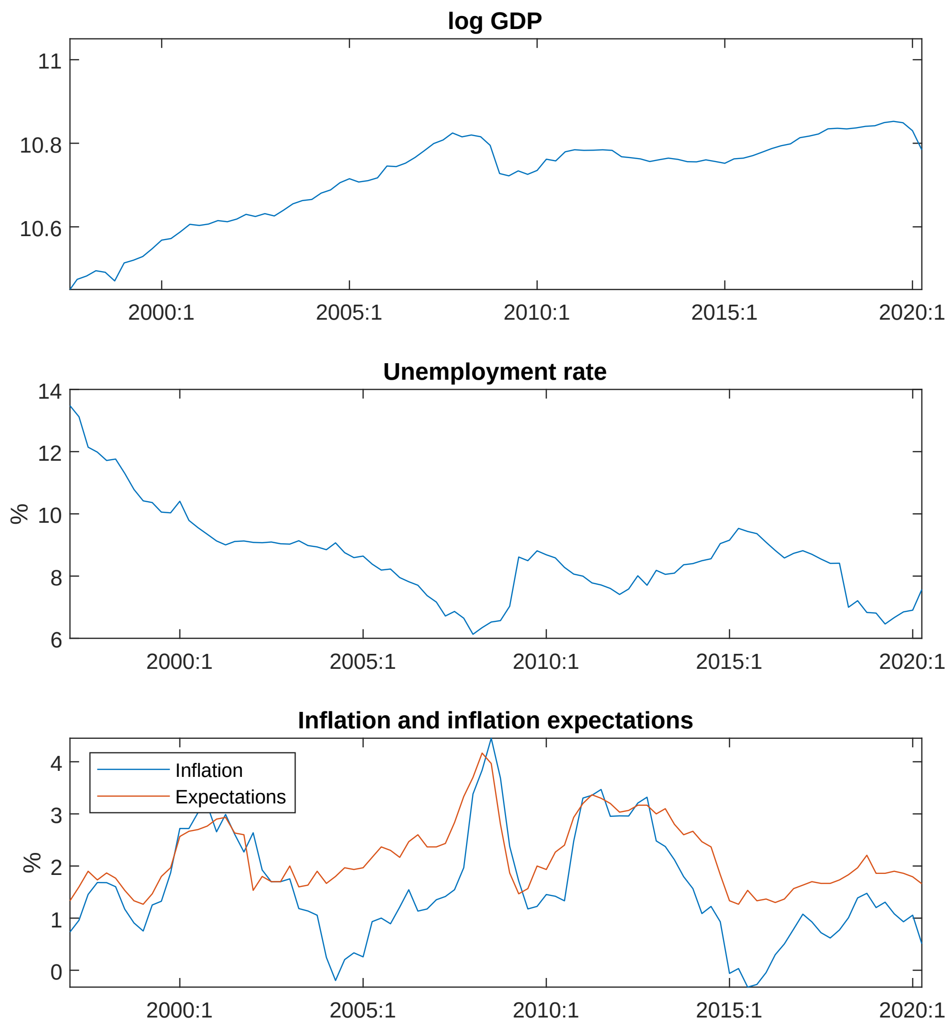

Figure 1: Data

2.3 Estimation results

To estimate the model we use bayesian methods provided by the IRIS-toolbox for Matlab. The prior distributions for steady state parameters, G^{SS}, $U^{SS}$are selected to contain the variation in data averages with different time windows. Other prior distributions are selected as uninformative. The parameter estimates are presented in Table 1.

Parameter		Prior		Posterior	
	Mode	Standard deviation	Distribution	Mode	Standard deviation
G^{SS}	0.96	0.2	Γ	1.22	0.19
U^{SS}	6.96	0.5	Γ	7.00	0.5
α	0.64	0.2	Γ	0.72	0.03
β	0.21	0.1	Γ	0.19	0.02
λ	0.17	0.2	Γ	0.25	0.03
ϕ_u	0.64	0.2	Γ	0.89	0.07
ϕ_y	0.17	0.2	Γ	0.10	0.02
ρ_1	0.64	0.2	Γ	0.71	0.18
ρ_2	0.64	0.2	Γ	0.82	0.03
τ	0.17	0.2	Γ	0.31	0.03
θ	0.69	0.1	Γ	0.72	0.02
ω	1.5	1	Γ	2.27	0.05
Ω	0.17	0.2	Γ	0.12	0.03
σ^{ϵ^y}	0.71	0.5	Γ	1.47	0.04
$\sigma^{\epsilon^{SY}}$	1.43	1	Γ	1.27	0.04
σ^{ϵ^u}	0.07	0.5	Γ^{-1}	0.42	0.08
$\sigma^{\epsilon^{\bar{U}}}$	0.03	0.5	Γ^{-1}	0.44	0.03
$\sigma^{\epsilon^{SU}}$	0.03	0.5	Γ^{-1}	0.04	0.02
σ^{ϵ^π}	0.12	0.5	Γ^{-1}	0.59	0.03
$\sigma^{\epsilon^{\pi E}}$	0.12	0.5	Γ^{-1}	0.44	0.02
$\sigma^{\epsilon^{\bar{Y}}}$	0.12	0.5	Γ^{-1}	0.10	0.04
σ^{ϵ}	3.88	0.5	Γ^{-1}	3.19	0.24

Table 1: Estimation results

2.4 Results for the baseline model

Figure 2 depicts the estimated output gap and unemployment gap together with inflation. The figure is based on latest data available in September 2021.

Following the equation (3), movements of the unemployment gap follow the ones of output gap. Compared to the output gap, the unemployment gap has much smaller variation and it reacts slowly to changes in the business cycle. The model recognizes the business cycle peaks in 2007, 2011 and 2017 and the slumps in 2008, 2015 and 2020. The unemployment cycle seems to follow the business cycle with a delay of one or two quarters. The model interprets the devolopments in 2004 -2007 as a big positive output gap or boom, leaving the recession after the financial crisis mild when compared to ones experienced in 2015 and 2020. According to the model, the output gap was negative in 2014-2016 and positive in 2017Q1-2020Q1. Based on the data on 2020 the model indicates that the output gap reached -5.7 percentage points in the second quarter of 2020. Also the unemployment gap has turned negative in the second quarter of 2020.

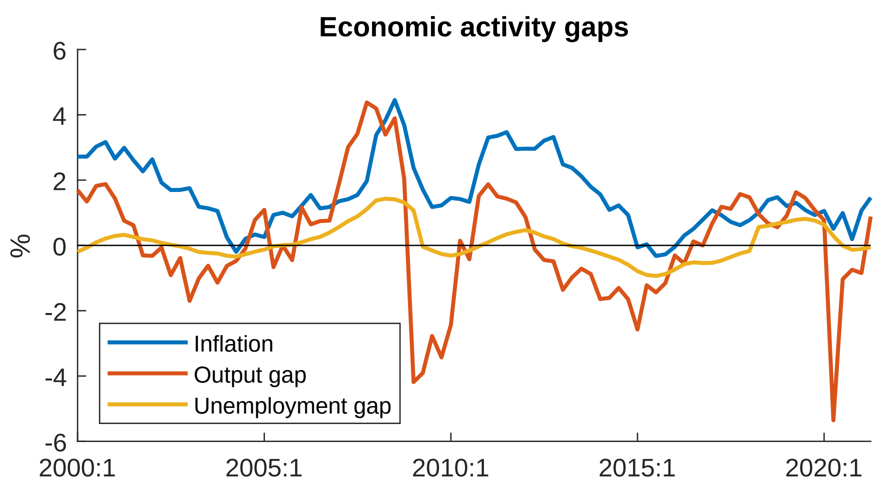

Figure 2: Inflation, unemployment gap and output gap.

Figure 3 compares the annual growth rates of potential output and actual output. According to the model the year-on-year growth rate of potential output has varied between 0.6%, in 2009, and 2.3%, in 2001. The latest data indicates that potential output growth has remained rather stable in 2010s and in the beginning of 2020s.

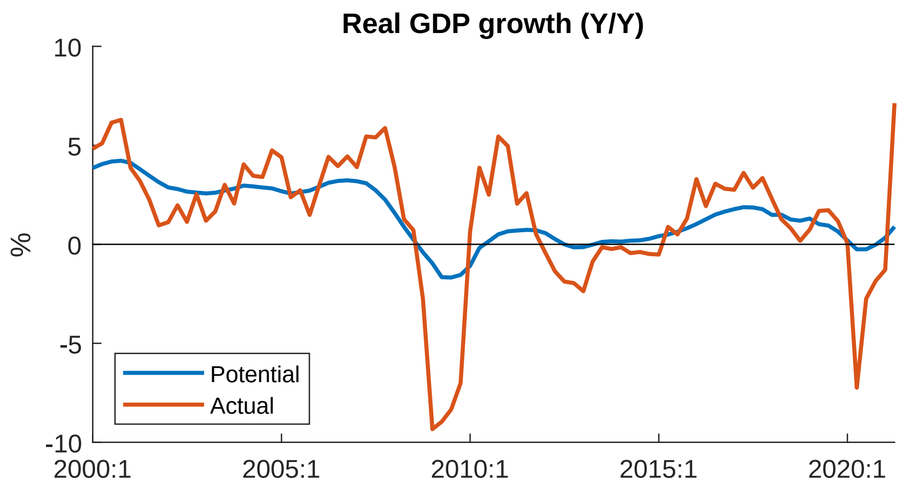

Figure 3: Annual growth rates of actual and potential GDP

Figure 4 depicts the evolution of unemployment around its estimated equilibrium levels. The equilibrium unemployment rate declined from 2000 till 2009, increased between 2010 and 2014, but started to fall again in 2015. However, the ongoing corona crisis has led the equilibrium unemployment rise again. The actual unemployment has been below its equilibrium level before the financial crisis, around 2006–2009, before the financial crisis, around 2012, and before the corona crisis in 2018-2019. During these periods also the output gap has been positive. The actual unemployment was declining strongly between 2016–2019 as a result of favorable economic cycle. In the last quarter of 2020 the actual unemployment rate is estimated to be 0.5 pp above its equilibrium level of 7.7%.

Because one purpose of our model is to acquire a reliable view of the current state of the business cycle in Finland, we continue our analysis by testing the performance of the model with a set of vintage data covering all releases of Quarterly National Accounts between March 2002 and August 2021. The

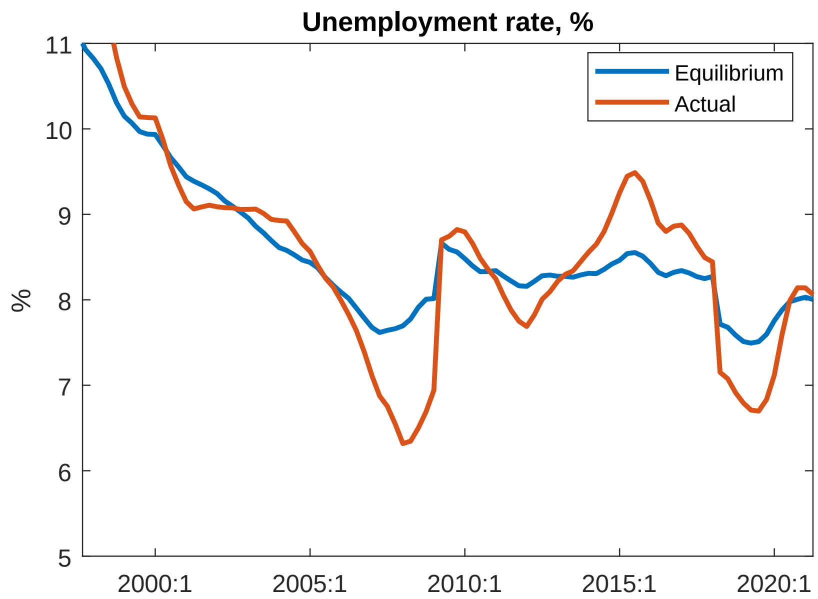

Figure 4: Variation of the unemployment rate around its equilibrium trend.

vintage data set is acquired from the OECD database[6] and from data releases by Statistics Finland. The vintages are only for the GDP as data on the other variables of the model are not revised after their first publication.

[6]This dataset is available from: `https://stats.oecd.org/Index.aspx?DataSetCode=MEI_ARCHIVE`.

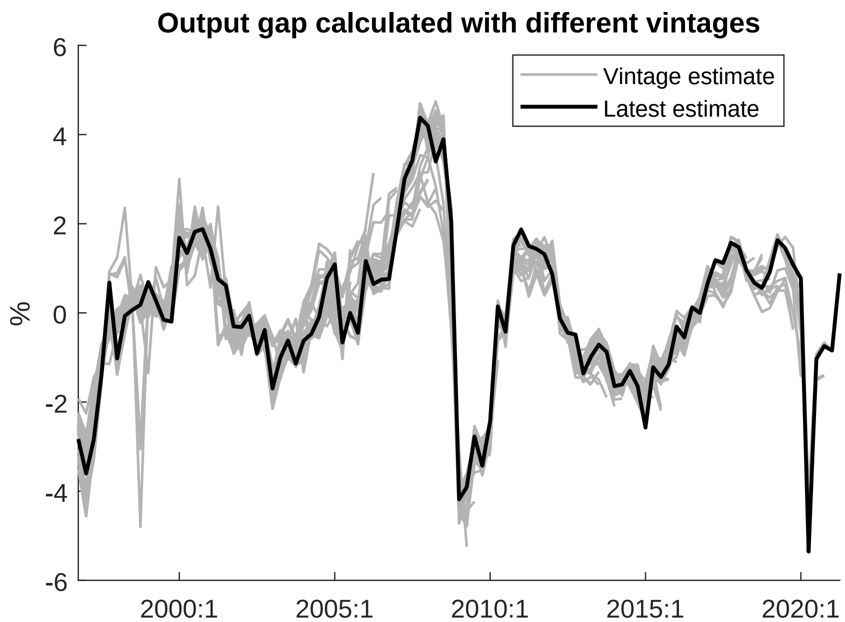

Figure 5: Output gap with Quarterly National Accounts vintage data covering all releases between January 2005 and August 2021.

Figure 5 shows that during exceptionally strong business cycle peak in 2007-2008 the difference between estimates winth vintage data and latest data was at its largest. The accuracy tests doesn't include the seasonal adjustment of unemployment rate as the seasonally adjusted unemployment rate is estimated from the Labour Force Survey data available in August 2021.

For comparison we run the univariate HP-filter, with smoothing parameter set to 1600, over the vintage data set. These results are depicted in Figure 6. Comparison of these results with the estimates in Figure 5 shows that the output gap estimates from the MVF get revised less when the data is revised.

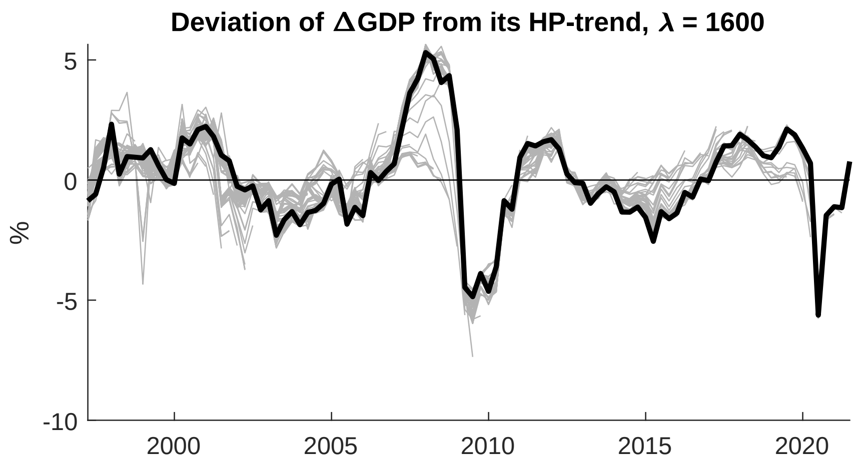

Figure 6: Deviation from HP-trend calculated with Quarterly National Accounts vintage data covering all releases between January 2005 and March 2021.

3 Financial cycles

3.1 Financial cycles in Finland

In this section we examine whether information about the financial cycle is useful in esimating potential output for Finland. Following Juselius et al. (2016), we next introduce financial cycles to our multivariate filter to investigate whether financial factors improve our estimation of potential output.

We consider two additional gaps that help describing the financial cycle and add them into our model specified in Section 2. The first indicator is the leverage gap which relates the private sector credit to GDP level and to real asset prices. The long term realtion is presented in the equation (8). The log level of private sector credit, cr, is assumed to evolve following the log level of nominal GDP, y^n, and asset prices, p_A. As an asset price indicator we use price index for old apartments from Statistics Finland.[7] This variable catches

[7] In Juselius et al. (2016) the constructed asset price index contains also information on commercial property and equities. In Finland, large proportion of households wealth is

the positive relationship between debt and asset (housing) prices stemming from using housing wealth as a collateral or as a source of revenue (see e.g. Juselius et al. 2016).[8] The leverage gap, $\tilde{lev}_t$, is the deviation from this long term relation:

$$cr_t = \bar{lev} + \beta_{cry} y_t^n + \beta_{crp} p_{A,t} + \tilde{lev}_t. \tag{8}$$

Our second equation captures the relationship between credit-to-GDP ratio and the average lending rate on debt outstanding. The relation is described in eaguation (9), where the average lending rate, i_L, is the effective interest rate on private sector credit. The debt service gap,$\tilde{dsr}_t$ is the deviation form this relation[9]:

$$(cr_t - y_t^n) = \bar{dsr} + \beta_{lev} i_{L,t} + \tilde{dsr}_t. \tag{9}$$

3.2 Multivariate filter with financial cycles

Following Juselius et al. (2016), we assume a negative relation between the debt service gap and the growth rate of potential output. This is motivated by the fat that high debt service burden decreases consumption and investment. We also assume a negative relation between the leverage gap and the output gap. That is, when the amount of credit in the economy is higher than it should be, given the GDP and asset prices, it will start to decrease and suppress private demand. The financial cycle variables are introduced into our baseline model through equations (1) and (6), i.e.

invested in the housing markets...

[8]Juselius et al. (2016) use a composite asset price index, that capturing both residential and commercial properties, to explain movements of credit-to-GDP ratio. This setup cannot be replicated with Finnish data, as property price index is not available and the available asset price indeces cannot explain the trend in the Finnish credit-to-GDP ratio. The specification in (8) yields a stationary leverage gap.

[9]For the long term interest rate we use the effective lending rate of the stock of private debt, which proxies the private sector's debt service burden.

$$y_t = \rho_1 y_{t-1} + \rho_2 \left(\pi_t - \pi_t^E\right) - \psi_{lev} \tilde{lev}_t + \epsilon_t^y, \tag{10}$$

and

$$S_t^Y = \tau G^{SS} + (1-\tau) S_{t-1}^Y - \psi_{dsS} \tilde{dsr}_{t-1} + \epsilon_t^{SY} \tag{11}$$

The timeseries of the debt service gap,$\tilde{dsr}$ shows strong autocorrelation. The debt service gap and leverage gap are added to the baseline as exogenous processess, i.e. they are not affected by the fluctuations in the other variables of the model. The debt service gap is assumed to follow an exogenous AR(1) process,

$$\tilde{dsr}_t = \beta_{dsr} \tilde{dsr}_{t-1} + \epsilon_t^{dsr}. \tag{12}$$

The leverage gap is assumed to follow a process

$$\tilde{lev}_t = \beta_L \tilde{lev}_{t-1} + \psi_{DS} \tilde{dsr}_t + \epsilon_t^{lev}. \tag{13}$$

3.3 Data and estimation

Figure (7) depicts the effective interest rate, credit to GDP ratio and real asset prices in Finland during 1999Q1-2020Q4. The quarterly data for private sector debt, loans and interest expenditure is based on sectoral accounts by Statistics Finland and is available only from 1999 onwards. The OMXH index is acquired from the database of the Bank of Finland.

The leverage gap and dept service gap and their dynamics, i.e equations (12)-(13) are estimated with ordinary least squares using data from period 1999Q1-2019Q4, as the statistics for 2020 are still preliminary. The estimation results are presented in the Figure8 shows the evolution of the Finnish leverage gap and debt service gap in 1999Q1-2020Q4. In literateure positive leverage gap is argued to reduce credit growth substantially and, through this, affects output

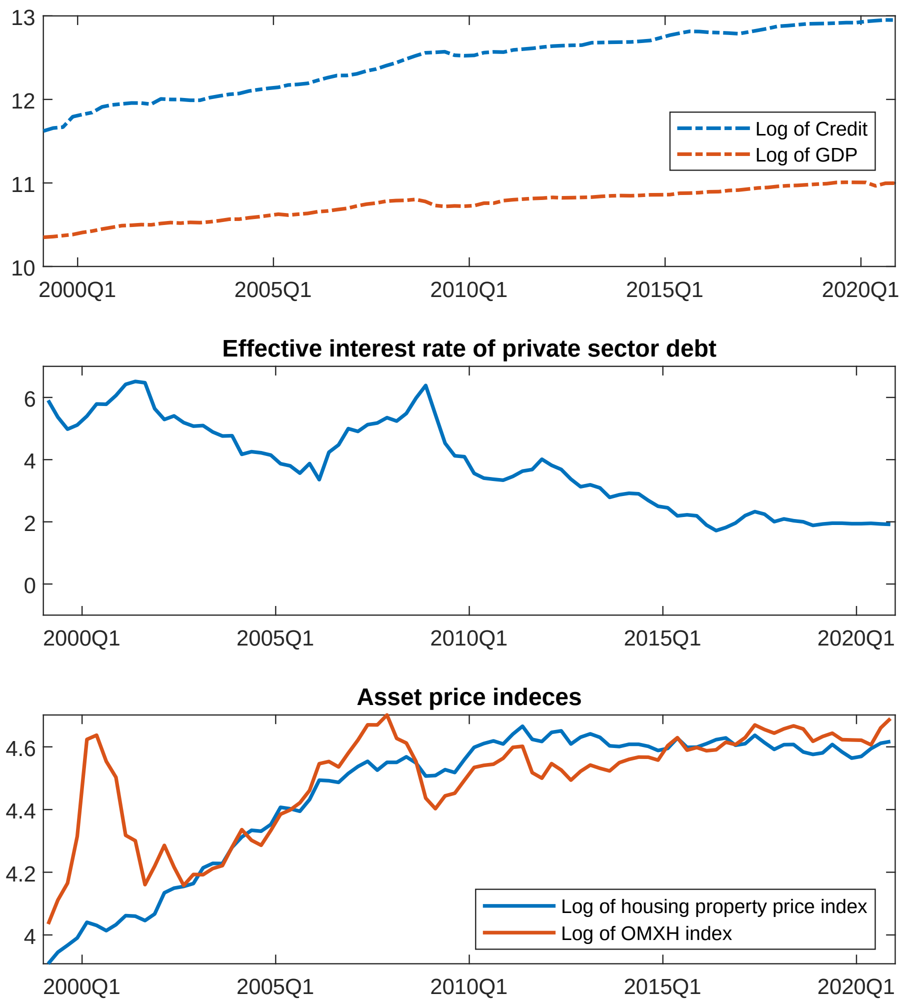

Figure 7: Financial data.

negatively (Juselius et al. 2016). This hyphothesis seems to hold also in the Finnish data, which shows slihtly negative leverage gap during the period of rapid growth in 2000's, widening remarkably just before the financial crisis. The leverage gap stayed positive in 2010's when GDP growth was slower than in previous decades. It seems that also the growth period in 2016-2018 was associated with a positive leverage gap. The debt service gap reached its highest positive value during the financial crisis. When the debt service gap is positive (above its long-run equilibrium), the output growth declines as greater share of gross domestic product is used to service debt. The burden may be easened by low level of interet rates, as has happened during the estiamtion period.

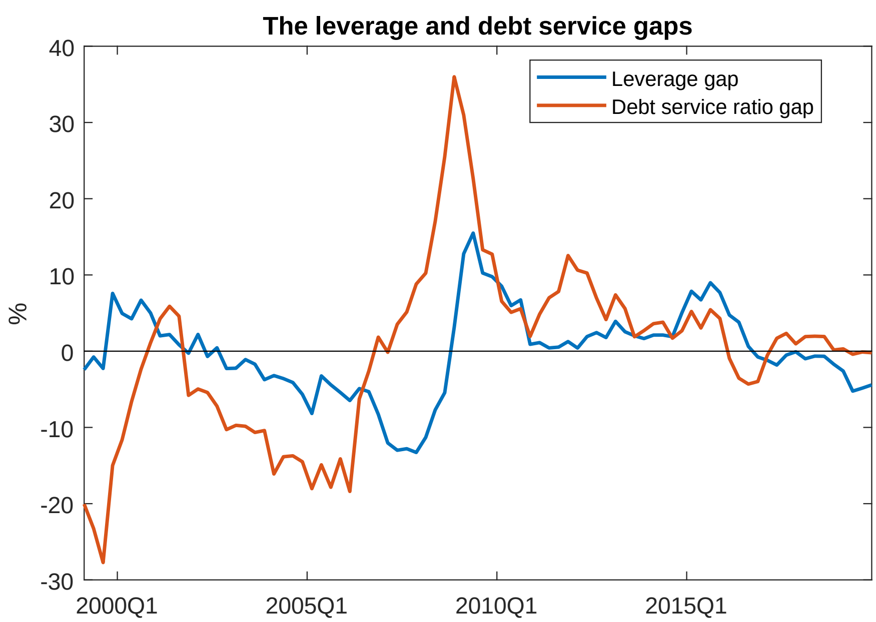

Figure 8: The leverage gap and the debt service gap.

The data used to estimate our baseline model is appended with these two indicators, which evolve independent form the rest of the model. In the estimation, we use uninformative priors and priors for the common variables of these two models are the same. The parameter estimates are presented in Table 2. In general, the estimates for common variables change slightly as new variables are added to the model. The effect of the debt service gap on trend growth rate is small, captured by parameter, ψ_{dsS}, and the effect of the leverage gap is only a bit larger, captured by parameter ψ_{lev}. These estimates are however slightly larger than ones reported in Juselius et al. (2016). Inclusion of financial variables to the model changes model dynamics only slightly. Compared to our baseline model, larger value of parameter λ in the extended model indicate for shorter deviation of equilibrium unemployment from its steadystate value. Adding leverage gap to the equation (10) reduces the effect of inflation on output gap dynamics, seen in smaller estimate for parameter ρ_2. The larger value of τ decreases the deviations of potential output growth rate from the stetady-state growth rate.

The resulting output gap with financial variables is presented in the Figure 9 alongside the one estimated with our baseline MVF above. Output gaps estimated with different models are presented in Figure 9. The resulting estimates for output gap do not differ from each other remarkably. Output gap estimated with financial indicate for slightly higher overheating before the financial crisis period (2005–2008) than the output gap estimated with our baseline model. While these two gaps move very similarly after the financial crisis, the model with financial cycle indicates for deeper downturn in 2015 and slower recovery in 2016. The model with financial variables indicates slightly lower values for the equilibrium unemployment rate over the years 2009-2014 and higher equilibrium unemployment rate in 2015-2017. The annualized trend growth rates are presented in Figure 10. The difference between the results is most notable during the period of financial crisis, when the financial cycle was strongest.

Parameter		Prior			Posterior
	Mode	Standard deviation	Distribution	Mode	Standard deviation
G^{SS}	0.96	0.2	Γ	1.012	0.192
U^{SS}	6.964	0.5	Γ	6.993	0.486
α	0.643	0.2	Γ	0.801	0.013
β	0.210	0.1	Γ	0.253	0.013
λ	0.167	0.2	Γ	0.678	0.016
ϕ_u	0.643	0.2	Γ	0.742	0.068
ϕ_y	0.167	0.2	Γ	0.093	0.011
ρ_1	0.643	0.2	Γ	0.844	0.011
ρ_2	0.643	0.2	Γ	0.383	0.011
τ	0.167	0.2	Γ	0.474	0.013
θ	0.686	0.1	Γ	0.748	0.009
ω	1.5	1	Γ	1.509	0.024
Ω	0.167	0.2	Γ	0.232	0.010
ψ_{lev}	0.167	0.2	Γ	0.133	0.009
ψ_{dsS}	0.167	0.2	Γ	0.025	0.007
σ^{ϵ^y}	0.714	0.5	Γ^{-1}	2.276	0.021
$\sigma^{\epsilon^{SY}}$	1.429	1	Γ^{-1}	3.081	0.048
σ^{ϵ^u}	0.073	0.5	Γ^{-1}	0.124	0.050
$\sigma^{\epsilon^{\bar{U}}}$	0.034	0.5	Γ^{-1}	0.247	0.012
$\sigma^{\epsilon^{SU}}$	0.034	0.5	Γ^{-1}	0.128	0.013
σ^{ϵ^π}	0.121	0.5	Γ^{-1}	0.786	0.010
$\sigma^{\epsilon^{\pi E}}$	0.121	0.5	Γ^{-1}	0.646	0.009
$\sigma^{\epsilon^{\bar{Y}}}$	0.121	0.5	Γ^{-1}	0.101	0.020
σ^{ϵ}	3.881	0.5	Γ^{-1}	2.994	0.241

Table 2: Estimation results

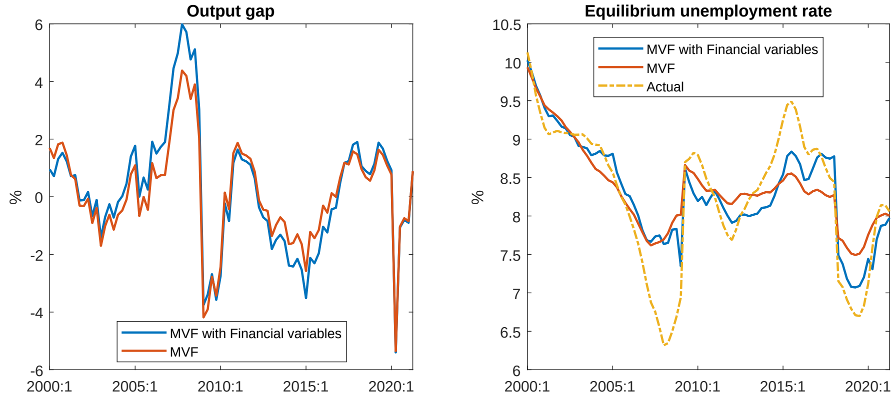

Figure 9: The output gap estimated with multivariate filter with information on financial cycle.

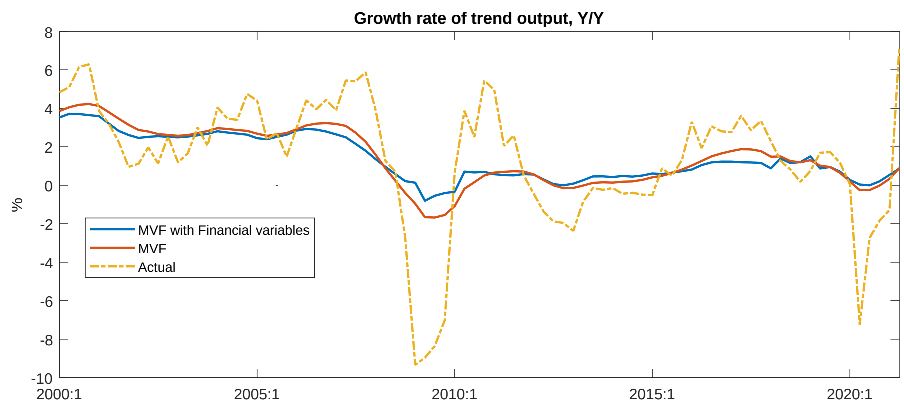

Figure 10: The output gap estimated with multivariate filter with information on financial cycle.

4 Conclusions

In this paper we estimated output gaps for Finland using multivariate filtering (MVF) techniques containing also information about the financial cycle. We find that the multivariate filter with GDP, unemployment rate, inflation and inflation expectations provides stable estimates for Finnish output gap. We estimate financial cycle indicators for Finland and show that while large financial cycles affect the trend growth rate of the economy these cycles have not played a role in the Finnish economy during the past business cycle. According to our estimates, the expceptionally low trend growth rate experienced in 2012-2014 was not caused by financial cycle.

Models presented in the paper were estimated with latest data available in March 2021. The data for the year 2020 was not used in the estimation as there is still large uncertainty on latest developments on Quarterly National Accounts level. However the latest data shows that the Covid-19 pandemy caused a output gap of almost same magnitude as in the fiancial crisis but didn't turn the trend GDP into a decline in a same extend as the financial crisis did.

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Appendix 1 Financial cycle indicators

We define the leverage gap as deviation of (log) private sector credit from its level predicted by (log) GDP and index for asset prices. The leverage gap is often described as deviation of debt-to-GDP ratio from its long run path. While the variation of this ratio is rather well explained by the variation of housing price index, see Table 3, the resulting error process, or the leverage gap, has an unit root. When the (log) level of credit is explained by the (log) level of nominal GDP, it turns out that changes in credit grows twice as rapid as GDP value. This relation can be somewhat improved by including also (log) housing price index to predictors, (AIC), but improvement in the result doesn't fully compensate the increase in complexity (BIC). The leverage gaps estimated with models presented in the table 3 are depicted in Figure 11. The specification (2) is selected to estimate the leverage gap.

	(1) $\ln(\text{credit})$	(2) $\ln(\text{credit})$	(3) $\ln(\text{credit})$	(4) $\ln\left(\frac{\text{credit}}{\text{GDP}}\right)$	(5) $\ln\left(\frac{\text{credit}}{\text{GDP}}\right)$
constant	-9.252***	-8.320***	-9.325***	-1.755***	-2.191***
	(0.382)	(0.665)	(0.428)	(0.189)	(0.401)
gdp	2.021***	1.884***	2.037***		
	(0.036)	(0.088)	(0.0566)		
hpi		0.121*		0.776***	
		(0.071)		(0.042)	
capi			-0.024		0.866***
			(0.063)		(0.089)
R^2	0.975	0.976	0.975	0.803	0.535
AIC	-237.49	-238.44	-235.64	-172.37	-100.05
BIC	-232.63	-231.15	-228.35	-167.51	-95.19
N	84	84	84	84	84

$^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$
$gdp = \ln(\text{GDP})$, $hpi = \ln(\text{Housing price index})$
$capi = \ln(\text{Composite asset price index})$

Table 3: Table

The debt service gap is defined in equation (12) and is assumed to follow an

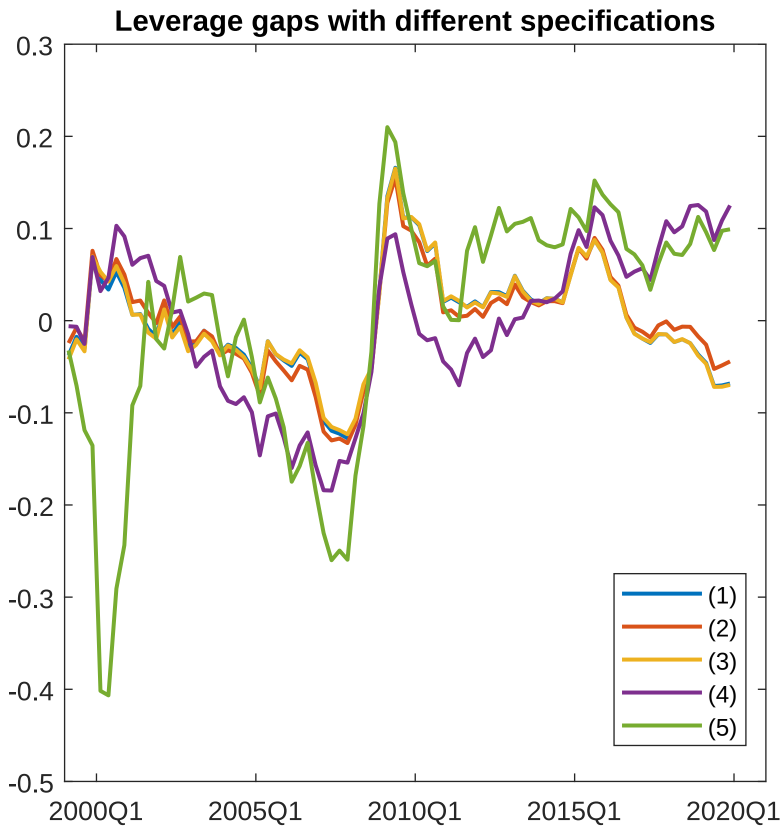

Figure 11: Leverage gaps with different specifications

exogenous AR(1) process

$$dsr_t = \underset{(0.039)}{0.916}\tilde{dsr}_{t-1} + \epsilon_t^{dsr}$$

and $\epsilon_t^{dsr} \sim N(0, 3.933)$.

We assume a positive relation between leverage gap and debt-service-gap, following the specification given in equation (13):

$$\tilde{lev}_t = \underset{(0.047)}{0.867}\tilde{lev}_{t-1} + \underset{(0.024)}{0.085}\tilde{dsr}_t + \epsilon_t^{lev}$$

and $\epsilon_t^{lev} \sim N(0, 2.379)$.