Synchronization and similarity of regional and sectoral output gaps in Poland: Impact and recovery from the COVID-19 pandemic

Mirosław Błażej[1] Mariusz Górajski[1,2] Magdalena Ulrichs[1,2]

[1] Statistics Poland, Department of Macroeconomic Studies and Finance
[2] University of Łódź, Department of Econometrics

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Outline

The views and opinions presented in this article are those of the authors and have not been endorsed by Statistics Poland

Introduction & Motivation

- potential output and the output gap play a central role in macroeconomic policy evaluations; it is the leading indicator of inflationary pressures in the Phillips curves and useful response variable of fiscal and monetary policy rules (Woodford, 2003; Galí, 2008; Walsh, 2010)
- output gap contains valuable information on the cyclical position of an economy
- potential growth constitutes a summary indicator of the economy's capacity to generate sustainable, non-inflationary growth (Havik et al., 2014)
- potential output and output gap are unobservable or latent variables
- no consensus regarding the methodology of estimating and assessing the level of unobservable potential production and the output gap, estimation of the output gap is more an art than a science (Orphanides and van Norden, 2002; Ódor and Jurasekova Kucserova, 2014; Edge and Rudd, 2016)

Definitions of Potential Output and Output Gap

potential output may differ according to the time perspective (Havik et al., 2014):

- over the short run, it may be the total demand level created without supply constraints and inflationary pressure,
- over the medium term, it is the productive output capacity that the expansion of the market may endogenously generate,
- in the long term, it is linked to the future evolution of technical progress (or total factor productivity) and the growth rate of potential labour

According to Woodford 2003, Gali 2008, and Walsh 2010 :

- potential output is the natural level of output defined as the equilibrium level of output under flexible prices in a DSGE model, completely independent of monetary policy, should vary in response to real disturbances (productivity shocks, taste shocks of various sorts, and variations in government purchases)
- output gap is the log difference of actual output and the natural level of output

Many Approaches to Potential Output Measurement

potential output estimation based on macro data (see Anderton et al., 2014; Blagrave et al., 2015; Álvarez and Gómez-Loscos, 2018; Chen and Gornicka, 2020):

- it is extracted from actual output by a univariate filter, and it rests on minimal economic theory (Beveridge and Nelson, 1981; Hamilton, 2018; Quast and Wolters, 2020)
- it is estimated within multivariate unobserved components or DSGE models, it rest on economic theory (Kuttner, 1994; Doménech and Gómez, 2006; Hirose and Naganuma, 2010; Tóth, 2021),
- it originates from the structural model of the supply side of the economy, potential output is determined as the specific value of an aggregate production function, e.g., OECD, EC models, (Lemoine et al., 2010; Havik et al., 2014; Chalaux and Guillemette, 2019; Blondeau et al., 2021),
- it is estimated using multivariate model that assumes that only supply shocks affect potential output, e.g., structural vector autoregression models (SVARs) in the spirit of Blanchard and Quah (1989) and Gali and Gertler (2000)

Our Contribution

- We propose a microeconometric model for output gap estimation based on microdata from the Business Tendency Surveys (BTS) and Annual Non-Financial Enterprises Survey (ANFES).
  - First stage: for each sector, three factor production function estimation by applying the Olley and Pakes (1996) model with the ACF correction (Ackerberg et al., 2015); include the capacity utilisation rate form the BTS in the estimation of the production function
  - Second stage: calculate entrepreneur's potential levels of capacity utilization, labour and capital: trends from the Hodrick-Prescott (HP), ESM and Hamilton filters; use them in production functions to construct aggregate indices of potential outputs and output gaps; main-, regional-, and sectoral output gap decompositions.
- Application for the Manufacturing, Construction and Services in Poland:
  - regional and sectoral output gap decompositions
  - micro- vs. macro-founded output gaps
  - synchronization and similarity of regional and sectoral output gaps

Production Function

- the Cobb-Douglas production function with capacity utilisation of enterprise i in period t:

$$Y_{it} = TFP_{it} U_{it}^{\beta_{u,d}} K_{it}^{\beta_{k,d}} L_{it}^{\beta_{l,d}} e^{\varepsilon_{it}}, \; i \in S_d, \tag{1}$$

where Y_{it} and K_{it} express gross value added (output) and capital firm-level values; TFP_{it} is the Solow residual; U_{it} is the capacity utilisation; L_{it} is the number of full-time equivalent employees; and $e^{\varepsilon_{it}}$ is the output shock, S_d is the sector of the economy (Greenwood et al., 1986; Wen, 1998; Basu et al., 2006; Fernald, 2012; Gradzewicz et al., 2018),

- the control function approach (Olley and Pakes, 1996) assumes that the unobservable TFP process assumes a Markov property:

$$TFP_{it} = e^{\xi_{it}} g\left(TFP_{it-1}, \lambda_r, \lambda_t\right), \;\; i \in S_d, \tag{2}$$

where λ_r and λ_t are regional and time dummy variables and $e^{\xi_{it}}$ is the independent white-noise idiosyncratic productivity shock.

Production Function Estimation

- The production function equation (1)-(2) is estimated using ANFES∩BTS panel data by employing the Olley and Pakes (1996) (OP) model with the Ackerberg et al. (2015) (ACF) correction to the control function approach,
  - company investment expenditure i_{it} control for unobserved TFP indices,
  - $\omega_{it} = \log TFP_{it}$ is a state variable in the company decision problem consisting in the selection of production factors,
  - for a given level of physical capital K_{it}, firms choose their capacity utilisation U_{it} and labour L_{it} before observing productivity shocks ξ_{it}
- two-stage procedure:
  1. approximate the unobservable productivity $\omega_{it} = \omega_{it}(k_{it}, l_{it}, u_{it}, i_{it})$ using a polynomial function of capital, labour, capacity utilisation, and investment outlays,
  2. calculate the production function to obtain a non-linear regression equation for the gross value-added for the enterprises that survived in the market.

Firm-level Potential Inputs and Outputs

- time series imputation based on linear interpolation,
- apply HP filter for every company i to extract the trends in firm-level time series of labour L_{it}^{POT}, capacity utilisation U_{it}^{POT}, and capital stock K_{it}^{POT},
- we also apply state-space versions of exponential smoothing models (ESM; Hyndman et al. (2002)) and the Hamilton filter (Hamilton, 2018)
- firm-level potential outputs for $i \in S_d$:

$$y_{it}^{POT\ UKL} = \hat{\beta}_{u,d} u_{it}^{POT} + \hat{\beta}_{k,d} k_{it}^{POT} + \hat{\beta}_{l,d} l_{it}^{POT}, \tag{3}$$

$$y_{it}^{POT\ K} = \hat{\beta}_{u,d} u_{it} + \hat{\beta}_{k,d} k_{it}^{POT} + \hat{\beta}_{l,d} l_{it}, \tag{4}$$

$$y_{it}^{POT\ L} = \hat{\beta}_{u,d} u_{it} + \hat{\beta}_{k,d} k_{it} + \hat{\beta}_{l,d} l_{it}^{POT}, \tag{5}$$

$$y_{it}^{POT\ U} = \hat{\beta}_{u,d} u_{it}^{POT} + \hat{\beta}_{k,d} k_{it} + \hat{\beta}_{l,d} l_{it}, \tag{6}$$

where u_{it}^{POT}, k_{it}^{POT}, and l_{it}^{POT} are the logs of U_{it}^{POT}, K_{it}^{POT}, and L_{it}^{POT}, respectively

Micro-founded Output Gaps

- firm-level output gap:

$$\hat{x}_{it} = \hat{y}_{it} - \hat{y}_{it}^{POTUKL} = \hat{\beta}_{u,d}\left(u_{it} - u_{it}^{POT}\right) + \hat{\beta}_{k,d}\left(k_{it} - k_{it}^{POT}\right) + \hat{\beta}_{l,d}\left(l_{it} - l_{it}^{POT}\right) \tag{7}$$

- micro-founded output gaps:

$$\widehat{x}_{s,t}^{UKL} = \log \widehat{Y}_{st} - \log Y_{st}^{POT,UKL} \quad s \in \{S,d,r\} \tag{8}$$

$$\widehat{x}_{s,t}^{K} = \log \widehat{Y}_{it} - \log Y_{it}^{POT,K} \quad s \in \{S,d,r\} \tag{9}$$

$$\widehat{x}_{s,t}^{L} = \log \widehat{Y}_{it} - \log Y_{it}^{POT,L} \quad s \in \{S,d,r\} \tag{10}$$

$$\widehat{x}_{s,t}^{U} = \log \widehat{Y}_{it} - \log Y_{it}^{POT,U} \quad s \in \{S,d,r\} \tag{11}$$

where for $j = U, K, L, UKL$ the aggregate empirical and potential outputs: and for sector/economy S, NACE division d, and region r:

$$\widehat{Y}_{St} = \sum_d \hat{Y}_{dt} = \sum_r \hat{Y}_{rt} \qquad \widehat{Y}_{St}^{POTj} = \sum_d \hat{Y}_{dt}^{POTj} = \sum_r \hat{Y}_{rt}^{POTj} \tag{12}$$

$$\widehat{Y}_{dt} = \sum_{i \in S_d} \hat{Y}_{it}, \qquad Y_{dt}^{POT,j} = \sum_{i \in S_d} Y_{it}^{POT,j} \tag{13}$$

$$\widehat{Y}_{rt} = \sum_{i \in S_r} \hat{Y}_{it}, \qquad Y_{rt}^{POT,j} = \sum_{i \in S_r} Y_{it}^{POT,j} \tag{14}$$

$$\widehat{x}_t^{UKL} = \widehat{x}_t^{U} + \widehat{x}_t^{K} + \widehat{x}_t^{L} + res_t \tag{15}$$

res_t reflects the mixed or interaction effect.

Main, Regional, and Sectoral Output Gap Decompositions

- micro-founded output gap decompositions:

$$\widehat{x}_{S,t}^{UKL} = \widehat{x}_t^U + \widehat{x}_t^K + \widehat{x}_t^L + res_t \tag{16}$$

$$\widehat{x}_{S,t}^{UKL} = \sum_d w_{t,d} \widehat{x}_{t,d}^{UKL} + res_{sec,t} \tag{17}$$

$$\widehat{x}_{S,t}^{UKL} = \sum_r w_{t,r} \widehat{x}_{t,r}^{UKL} + res_{reg,t} \tag{18}$$

where $w_{t,d}$ and $w_{t,r}$ are value-added-based weights of i company, d NACE division, and r region in the economy-wide or sector-wide output (S), res_t reflects the mixed or interaction effect.

Synchronization and similarity of output gaps

- we use measures of synchronization and similarity proposed by Mink, Jacobs and De Haan 2012 :
  - synchronicity between region r (or sector d) with the micro-founded output gap in Poland S :

$$\varphi_{r,t} = \frac{\widehat{x}^{UKL}_{r,t}\widehat{x}^{UKL}_{S,t}}{|\widehat{x}^{UKL}_{r,t}\widehat{x}^{UKL}_{S,t}|}, \quad \varphi_{s,t} = \frac{\widehat{x}^{UKL}_{s,t}\widehat{x}^{UKL}_{S,t}}{|\widehat{x}^{UKL}_{s,t}\widehat{x}^{UKL}_{S,t}|}, \tag{19}$$

$$\varphi^R_t = \frac{1}{n_r}\sum_r \varphi_{r,t}, \quad \varphi^D_t = \frac{1}{n_d}\sum_d \varphi_{d,t} \in [-1+\frac{2}{n}, 1] \tag{20}$$

  - similarity between region r (or division d) with the micro-founded output gap in Poland S:

$$\gamma_{r,t} = 1 - \frac{n_r|\widehat{x}^{UKL}_{r,t} - \widehat{x}^{UKL}_{S,t}|}{\sum_r |\widehat{x}^{UKL}_{r,t}|} \quad \gamma_{d,t} = 1 - \frac{n_r|\widehat{x}^{UKL}_{d,t} - \widehat{x}^{UKL}_{S,t}|}{\sum_d |\widehat{x}^{UKL}_{d,t}|} \tag{21}$$

$$\gamma^R_t = \frac{1}{n_r}\sum_r \gamma_{r,t}, \quad \gamma^D_t = \frac{1}{n_d}\sum_d \gamma_{d,t} \in [2-n, 1] \tag{22}$$

Data

- Firm-level Dataset covering small, medium, and large Polish companies in the manufacturing, construction, and service sectors from 2008 to 2022
- All data are reported in the Annual Non-Financial Enterprises Survey (ANFES) and Business Tendency Survey (BTS) conducted by Statistics Poland.
- final samples (BTS∩ANFES):
  - Manufacturing 47,465 observations; 9,548 companies ,
  - Construction 47,748 observations; 10,173 companies
  - Services 48,483 observations; 13,047 companies,
  - Sample covers entities from section C (Manufacturing), F (Construction) and Services (G-S) of the NACE Rev. 2 .

Variable	Final sample (ANFES∩BTS)			
	Total economy	Manufacturing	Construction	Service
Employment	20.31	45.95	34.68	17.09
GVA	16.78	36.96	20.61	14.37

Table 1: Sample coverage

Source: Own computations based on the Statistical Yearbook of the Republic of Poland (2009-2022) and Eurostat data.

Data

- gross value added (Y) of the enterprise is defined as the difference between its global output and intermediate consumption,
- capital (K) is defined as the average annual level of fixed and intangible assets,
- labour (L) is defined as the number full-time equivalent employees at the end of period t,
- the final measurement of variables Y and K is determined by calculating the real gross value added and real capital of the enterprise at constant average prices in two digits NACE sectors from 2015.
- as an approximation of the capacity utilization (U) we use the BTS-based measure, i.e. the question regarding the capacity utilization in the company: *What percentage of your company's total production capacity is currently used?*,
- BTS is carried out based on the monthly questionnaire and includes additional questions about U asked in January, April, July and October.

Capacity utilization

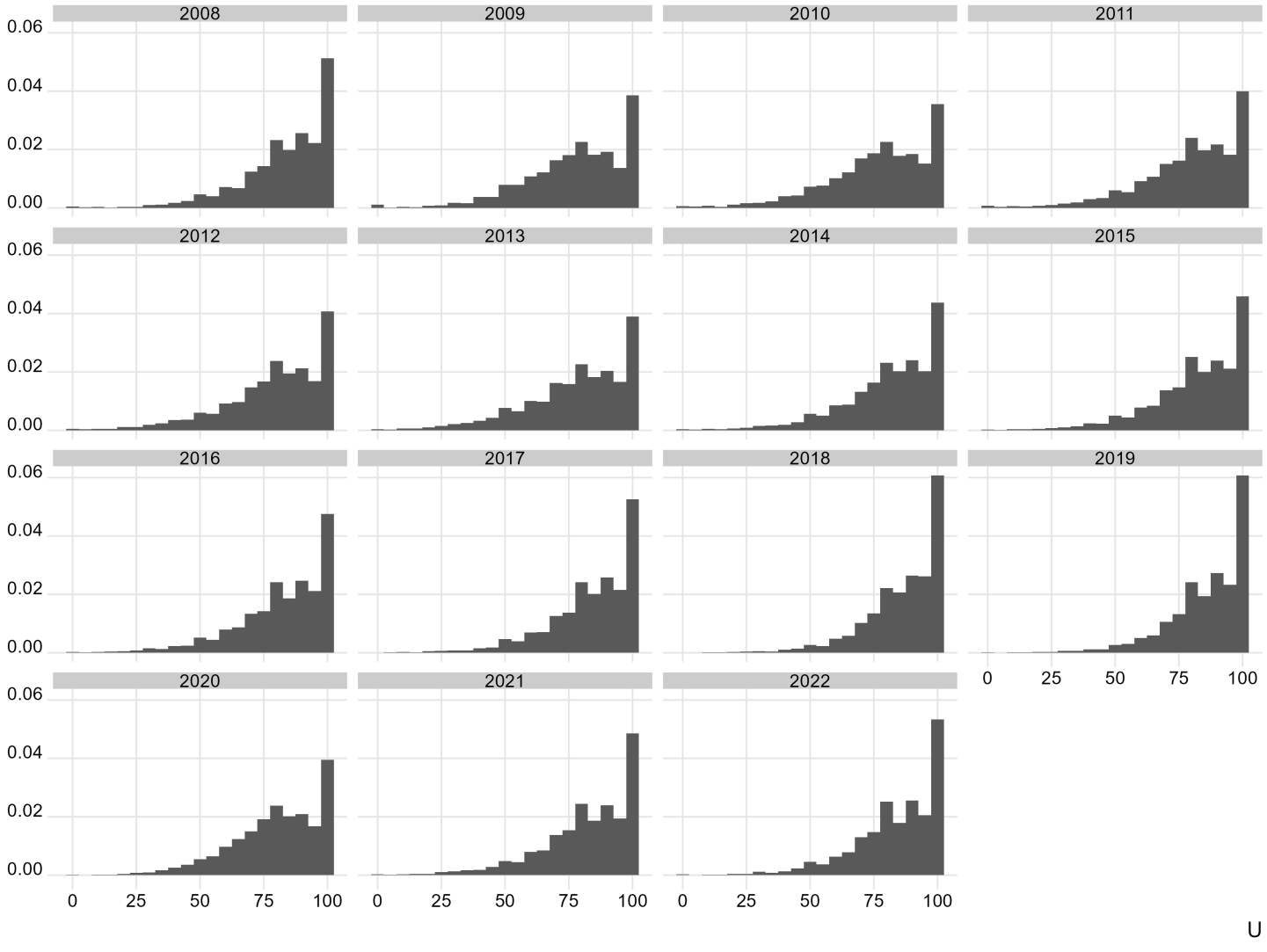

Figure 2: Empirical distributions of capacity utilization in cross-sections defined by years

Gross value added

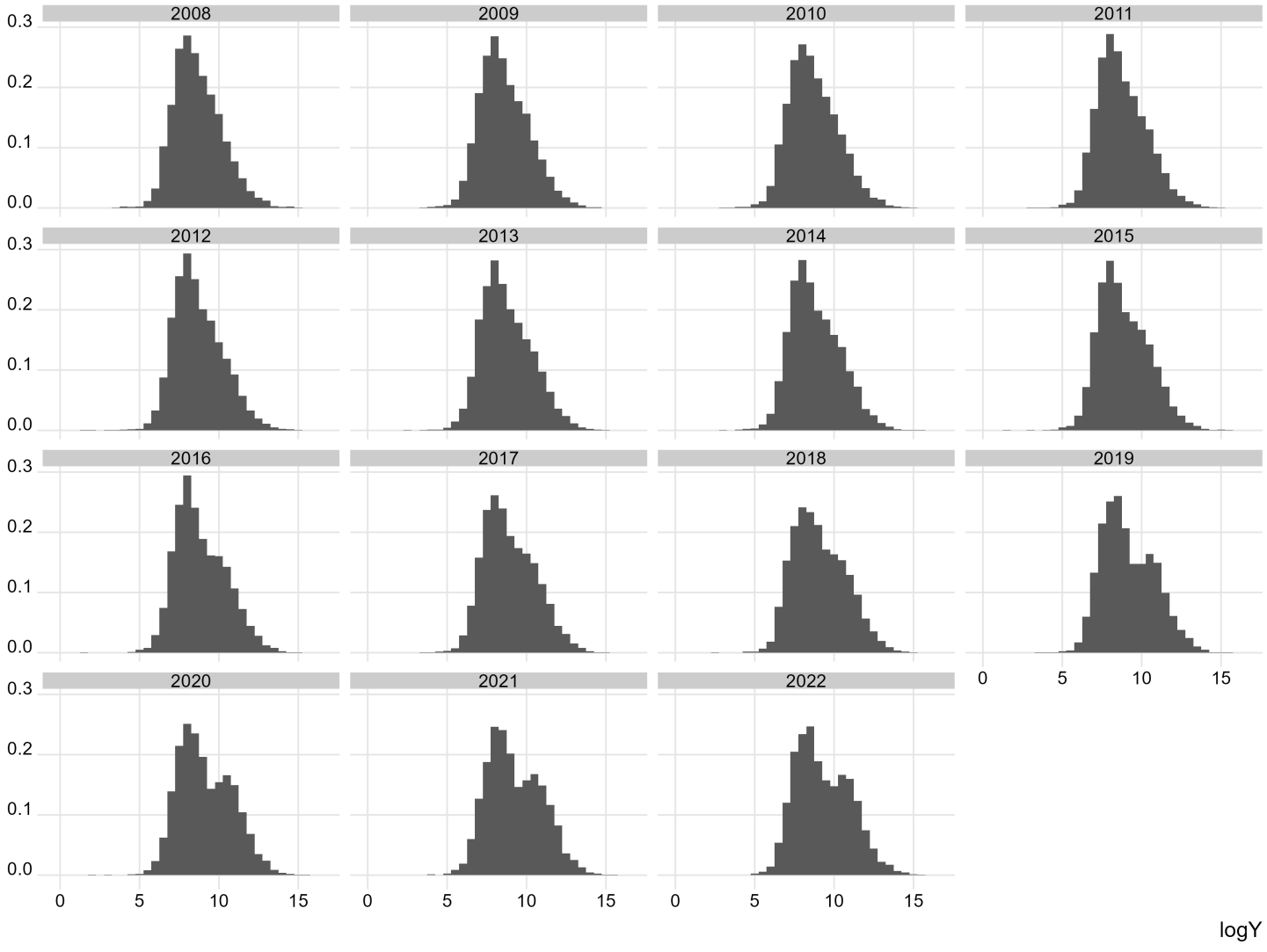

Figure 3: Empirical distributions of gross value added in cross-sections defined by years

Capital

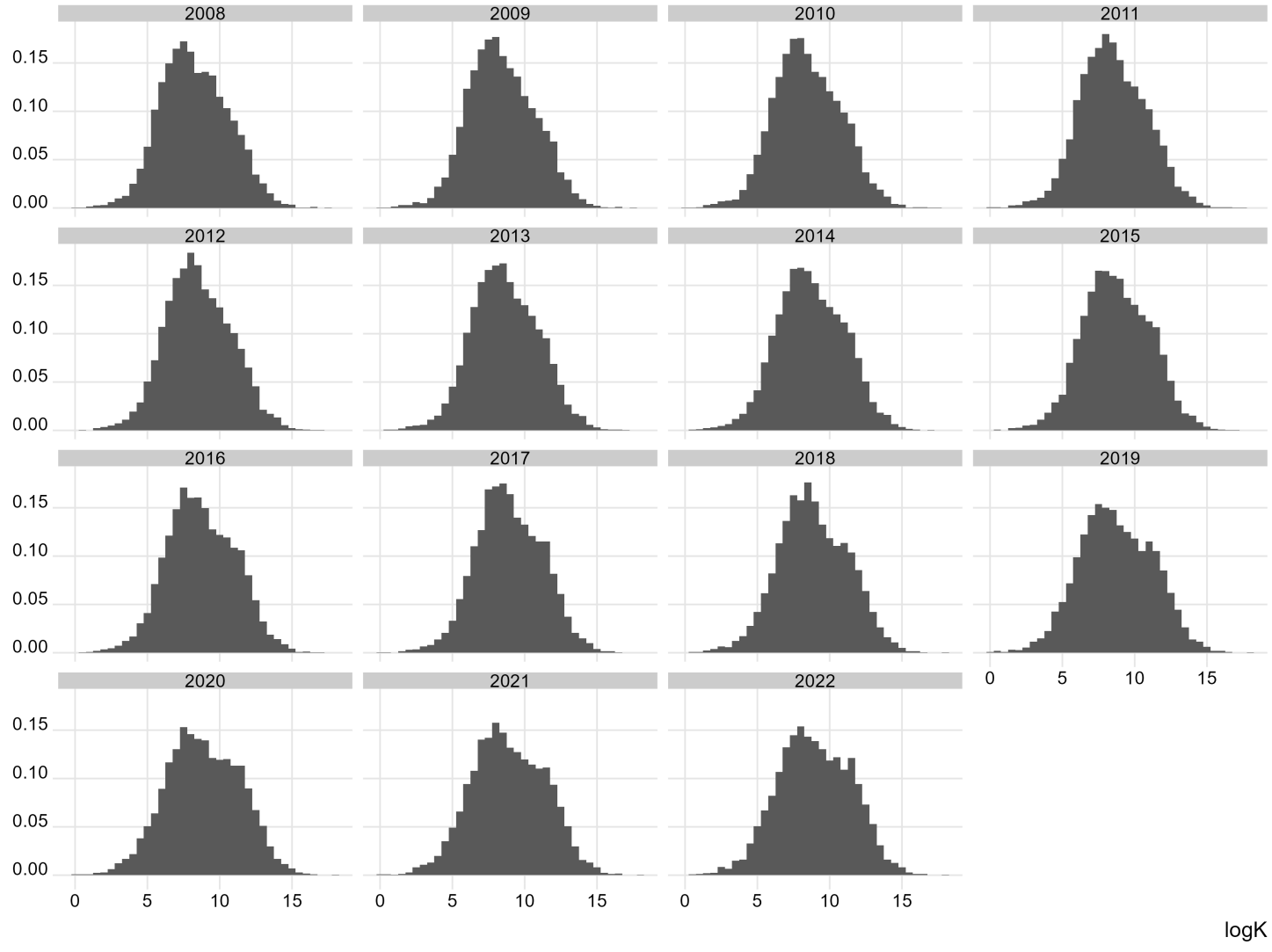

Figure 4: Empirical distributions of capital in cross-sections defined by years

Employment

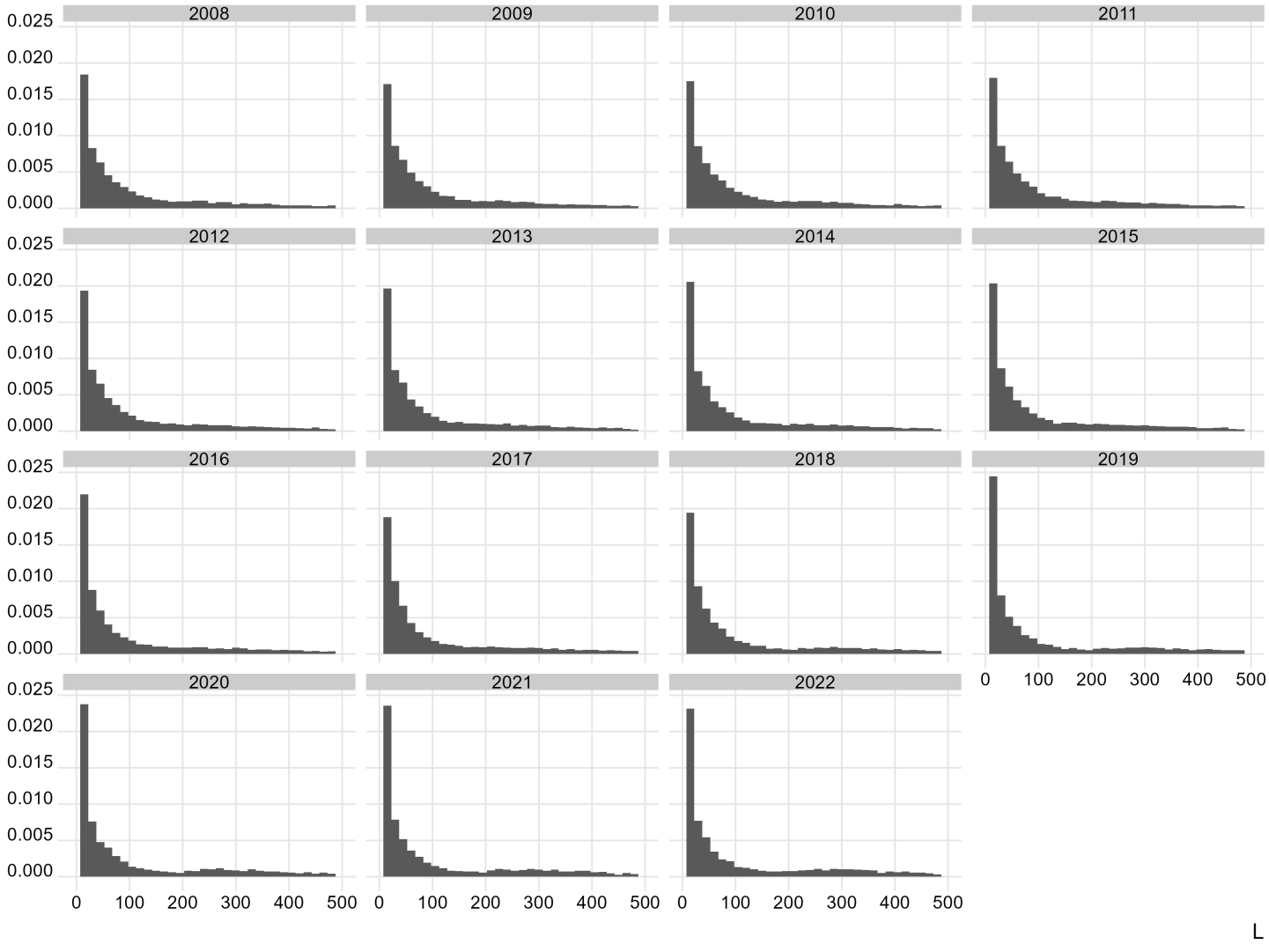

Figure 5: Empirical distributions of labour in cross-sections defined by years

Production function estimation

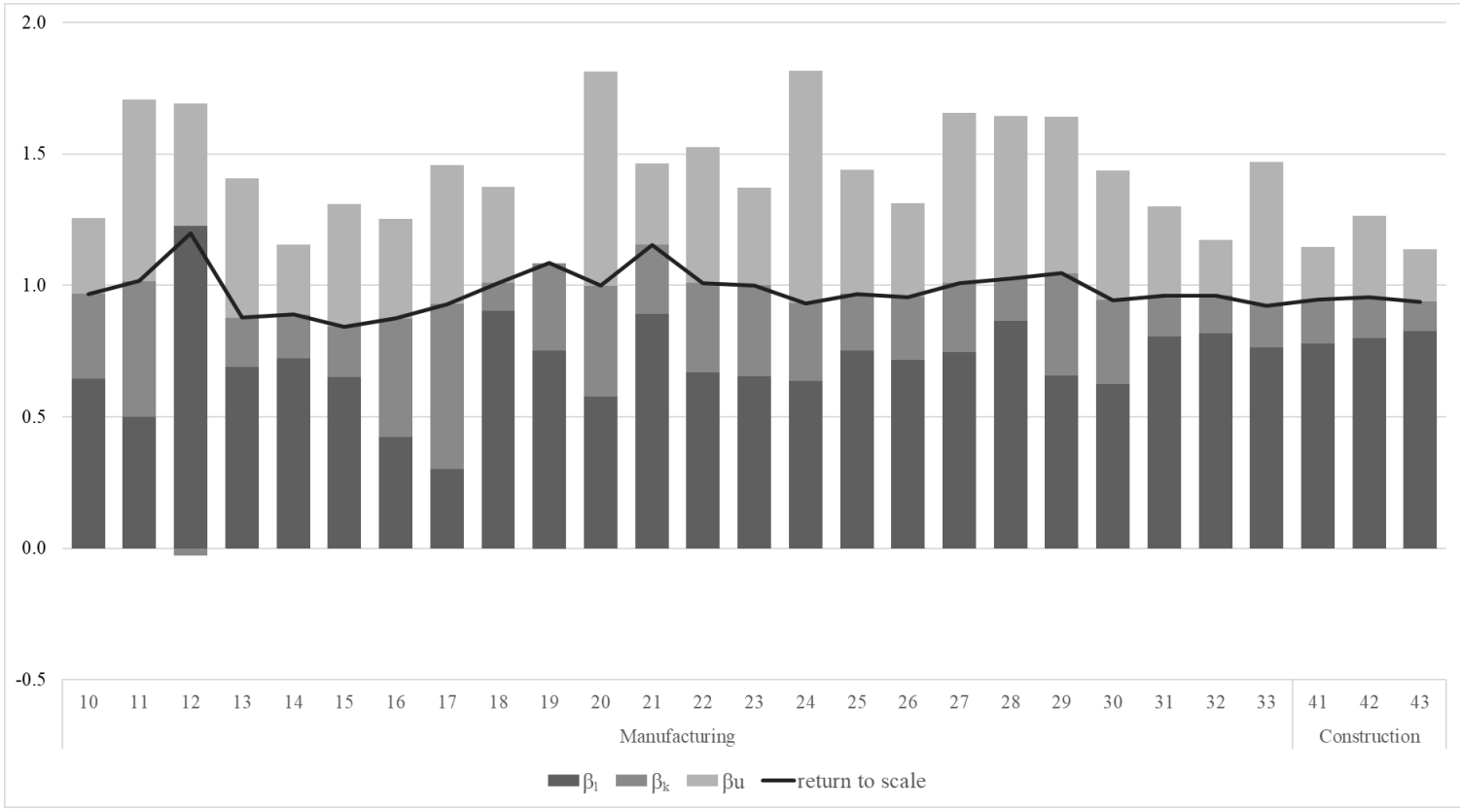

Figure 6: Production function estimation in NACE divisions for the Manufacturing and Construction sectors, $y_{it} = \hat{\omega}_{it} + \hat{\beta}_{u,d} u_{it} + \hat{\beta}_{k,d} k_{it} + \hat{\beta}_{l,d} l_{it}$

Production function estimation

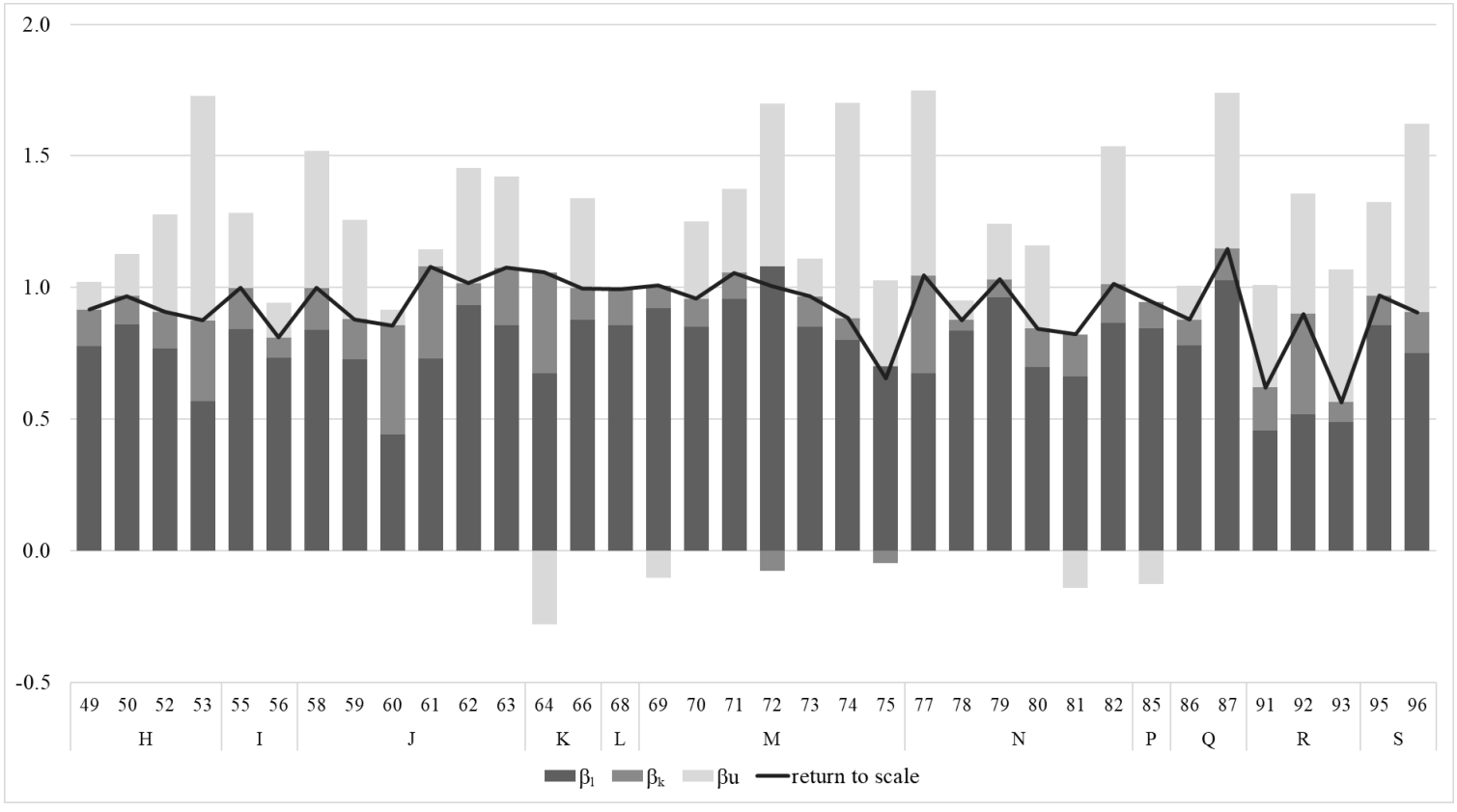

Figure 7: Production function estimation in NACE divisions for the Service sector,
$y_{it} = \hat{\omega}_{it} + \hat{\beta}_{u,d} u_{it} + \hat{\beta}_{k,d} k_{it} + \hat{\beta}_{l,d} l_{it}$

Micro-founded Output Gaps

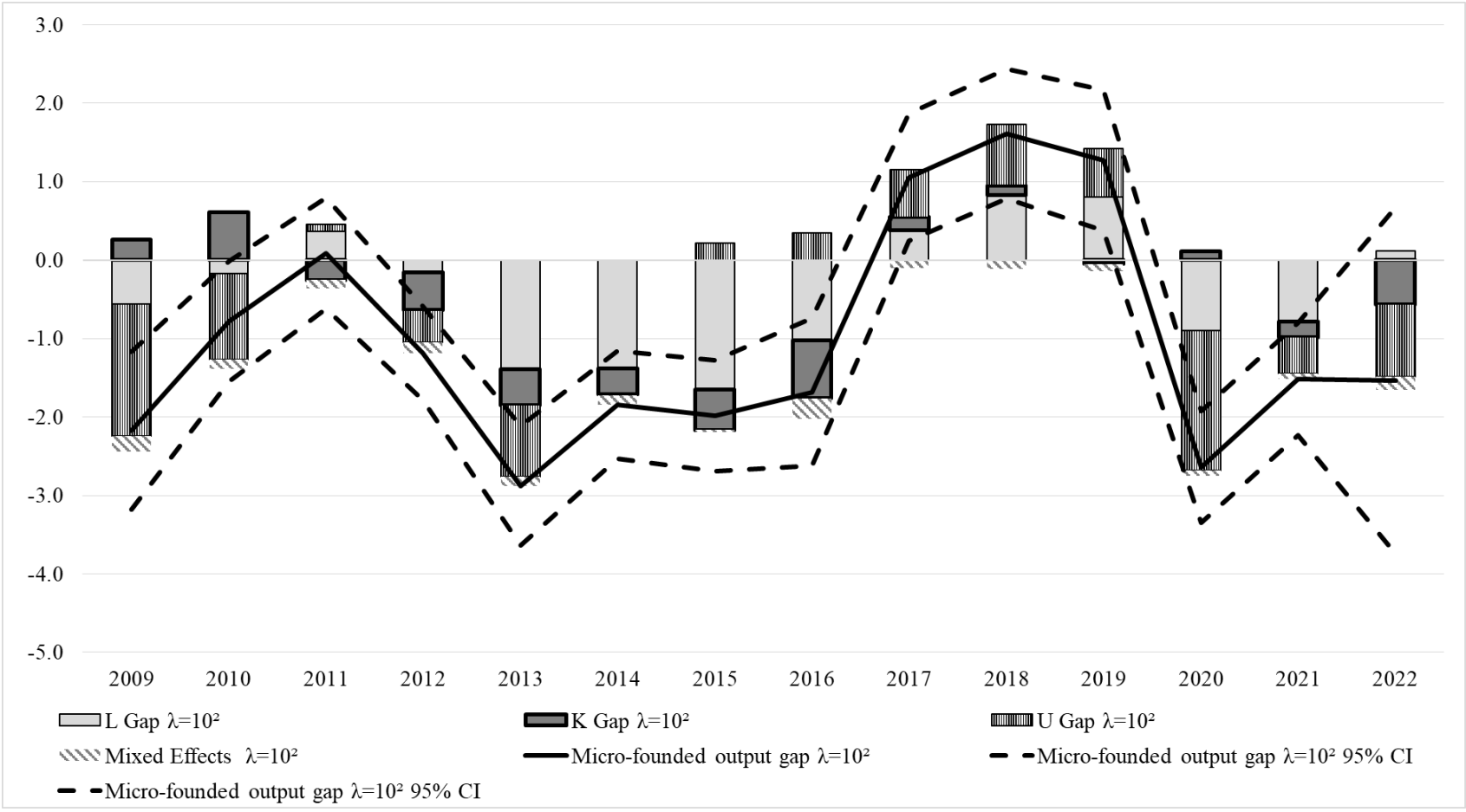

Figure 8: Micro-founded Output Gaps in Poland

Macro- vs. Micro-founded Output Gaps

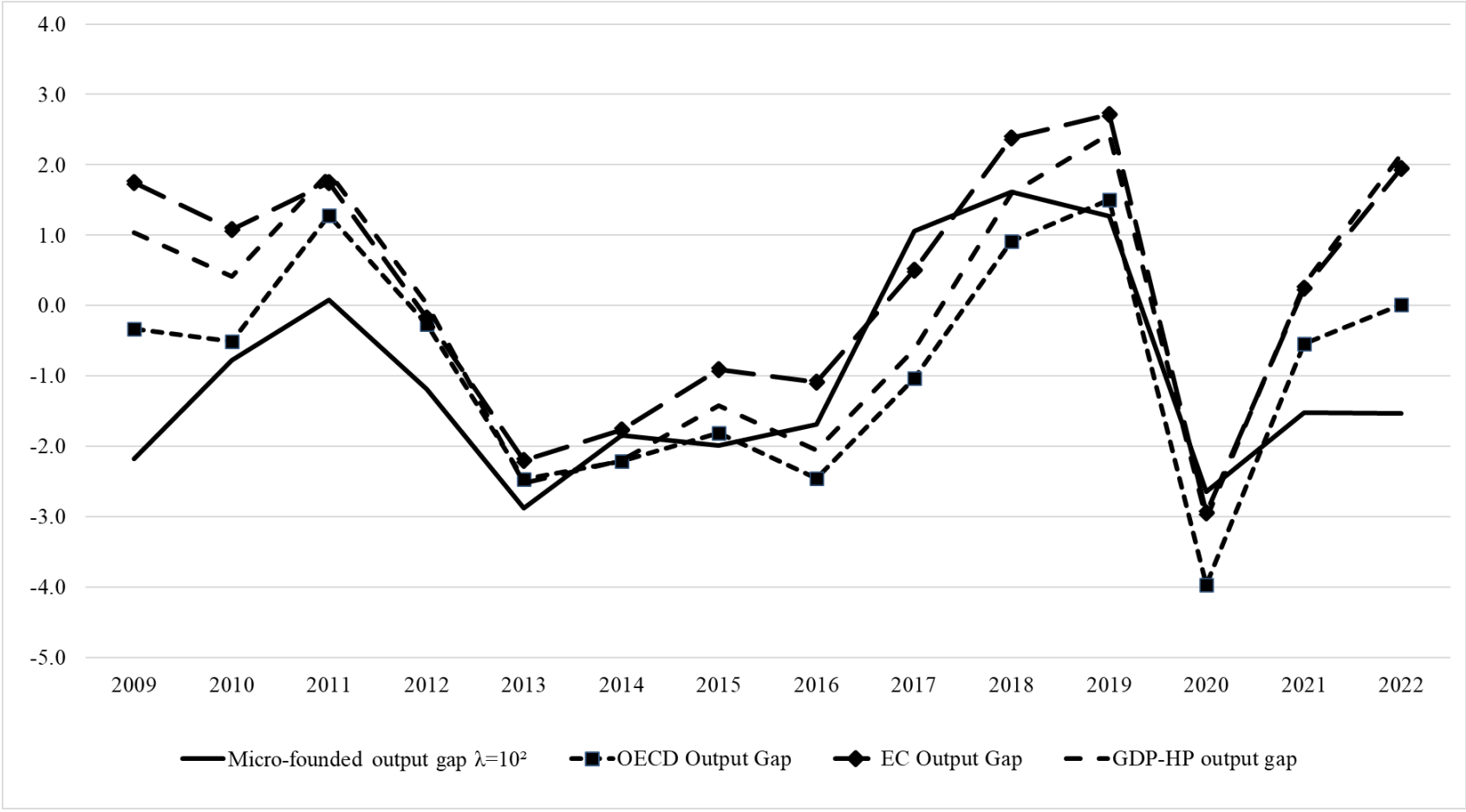

Figure 9: Micro-founded output gaps for $\lambda = 10^2$ (solid lines), the output gaps from the European Commission's model (EC Output Gap - black dashed line with diamond markers), the OECD model (OECD Output Gap - black dashed line with square markers), based on the Hodrick-Prescott trends in the macroeconomic times series of GDP in Poland (GDP-HP Output Gap, dashed line).

Sectoral Decomposition of Micro-founded Output Gap

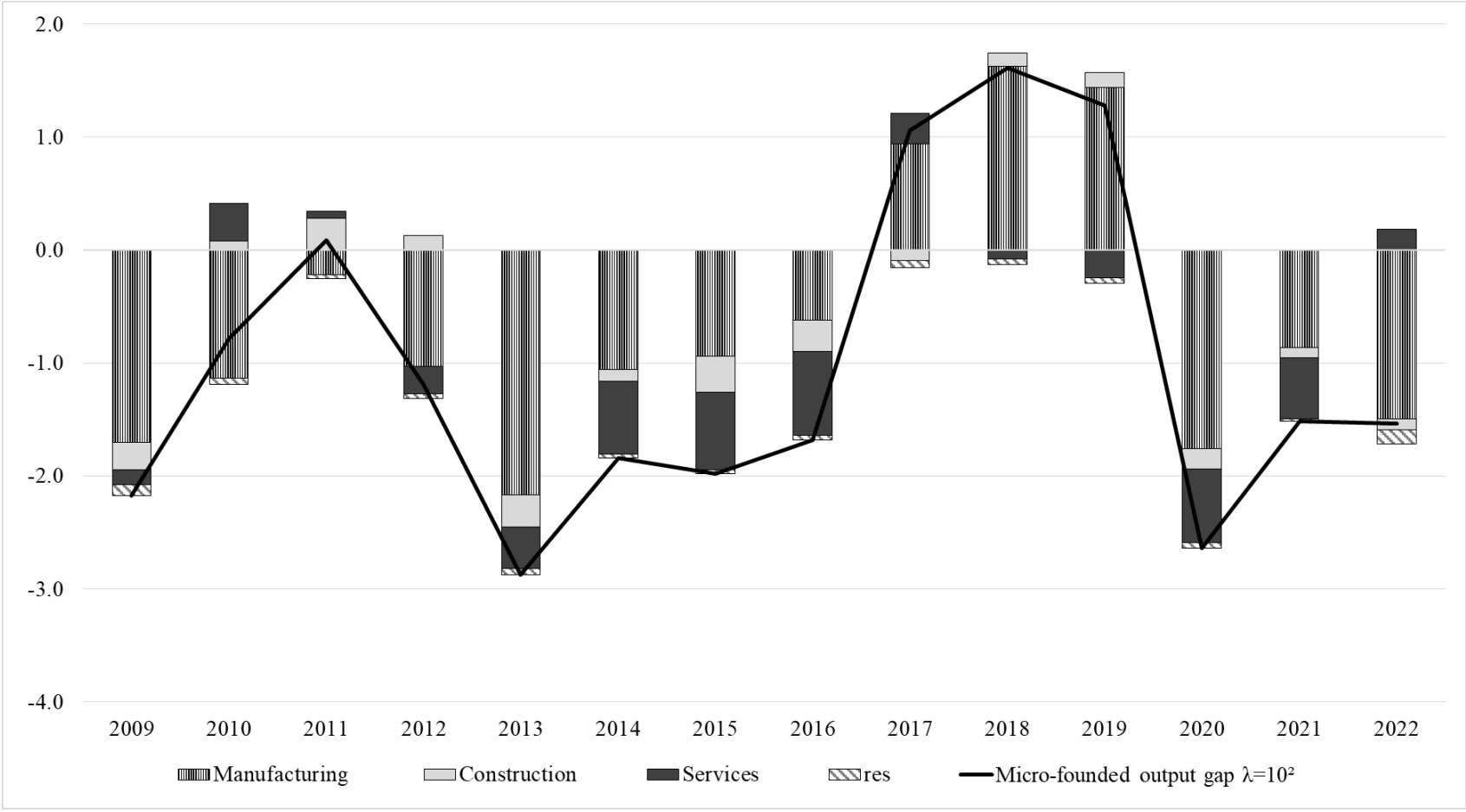

Figure 10: Sectoral output gap decomposition in Poland

Regional Decomposition of Micro-founded Output Gap

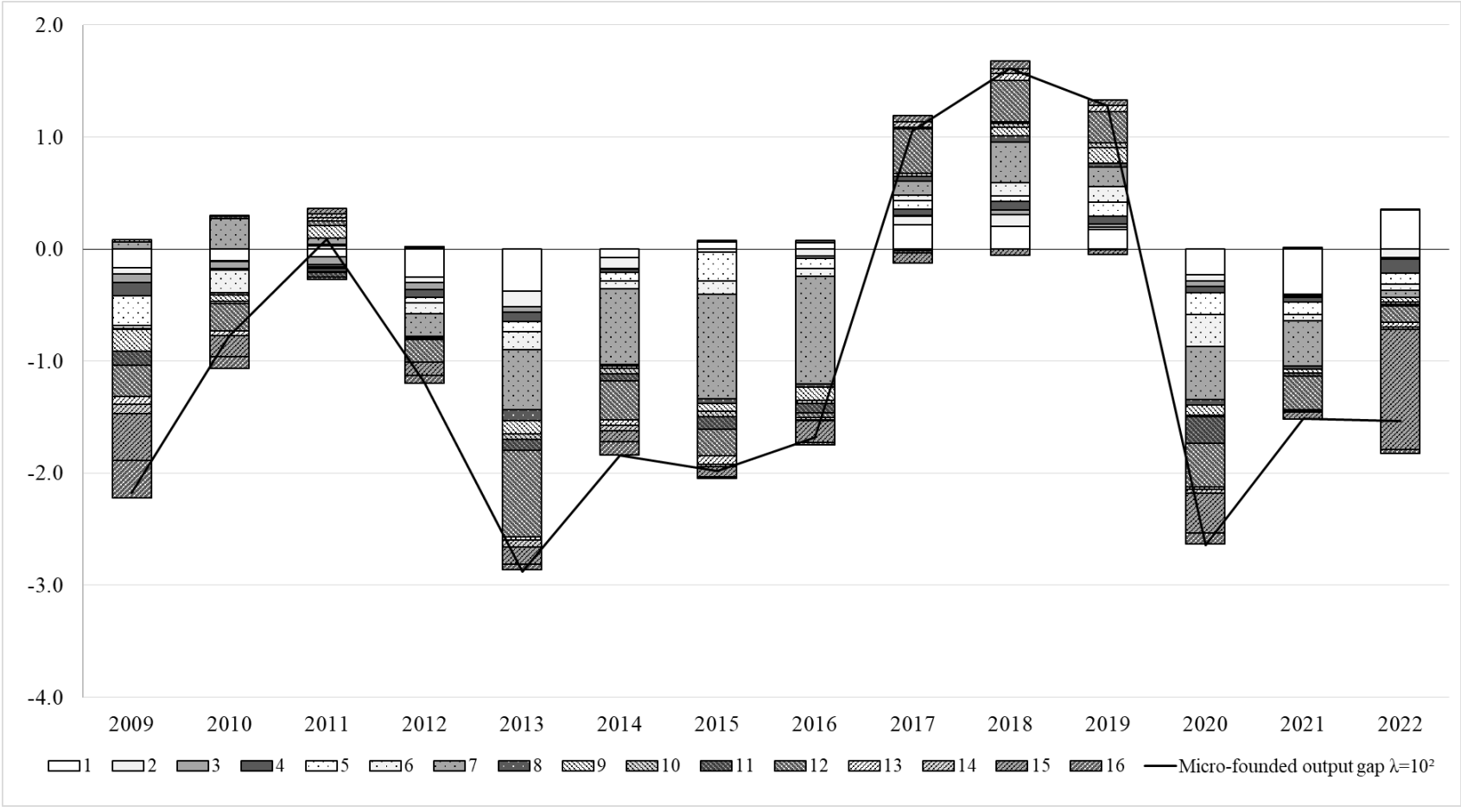

Figure 11: Regional output gap decomposition in Poland

Synchronization and Similarity of Sectoral Output Gaps

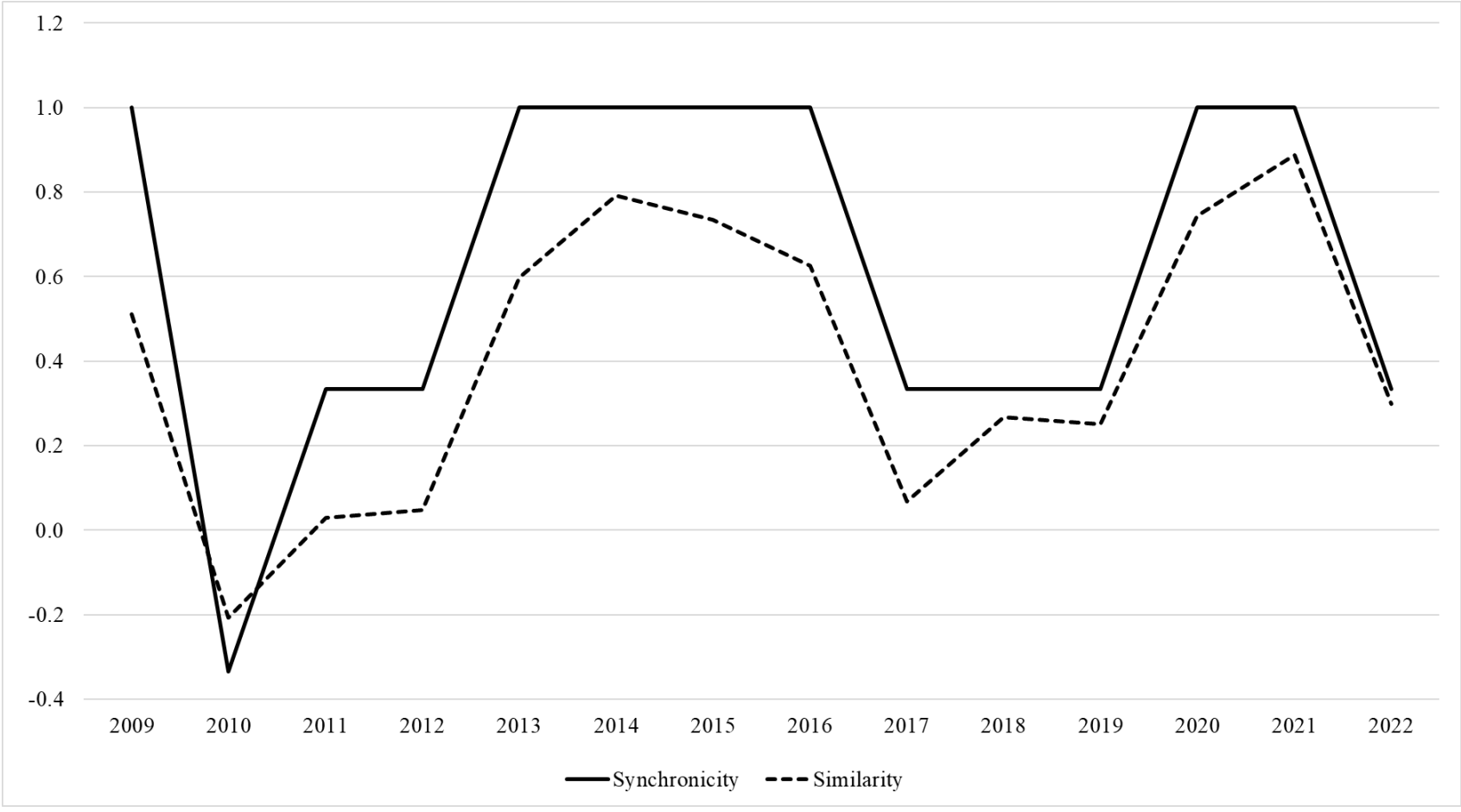

Figure 12: Sectoral output gaps synchronization in Poland

Synchronization of Sectoral Output Gaps

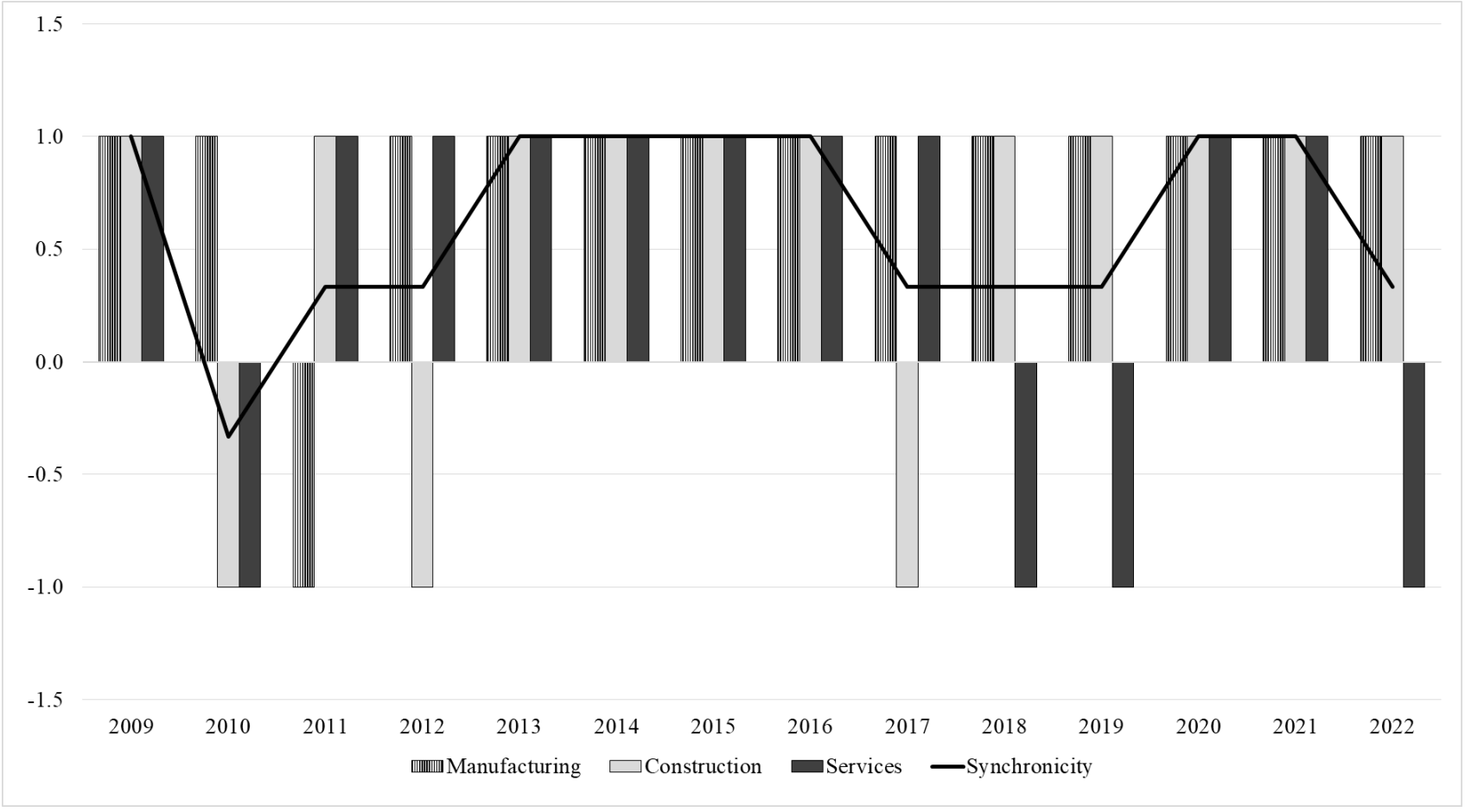

Figure 13: Sectoral output gaps synchronization and similarity in Poland

Similarity of Sectoral Output Gaps

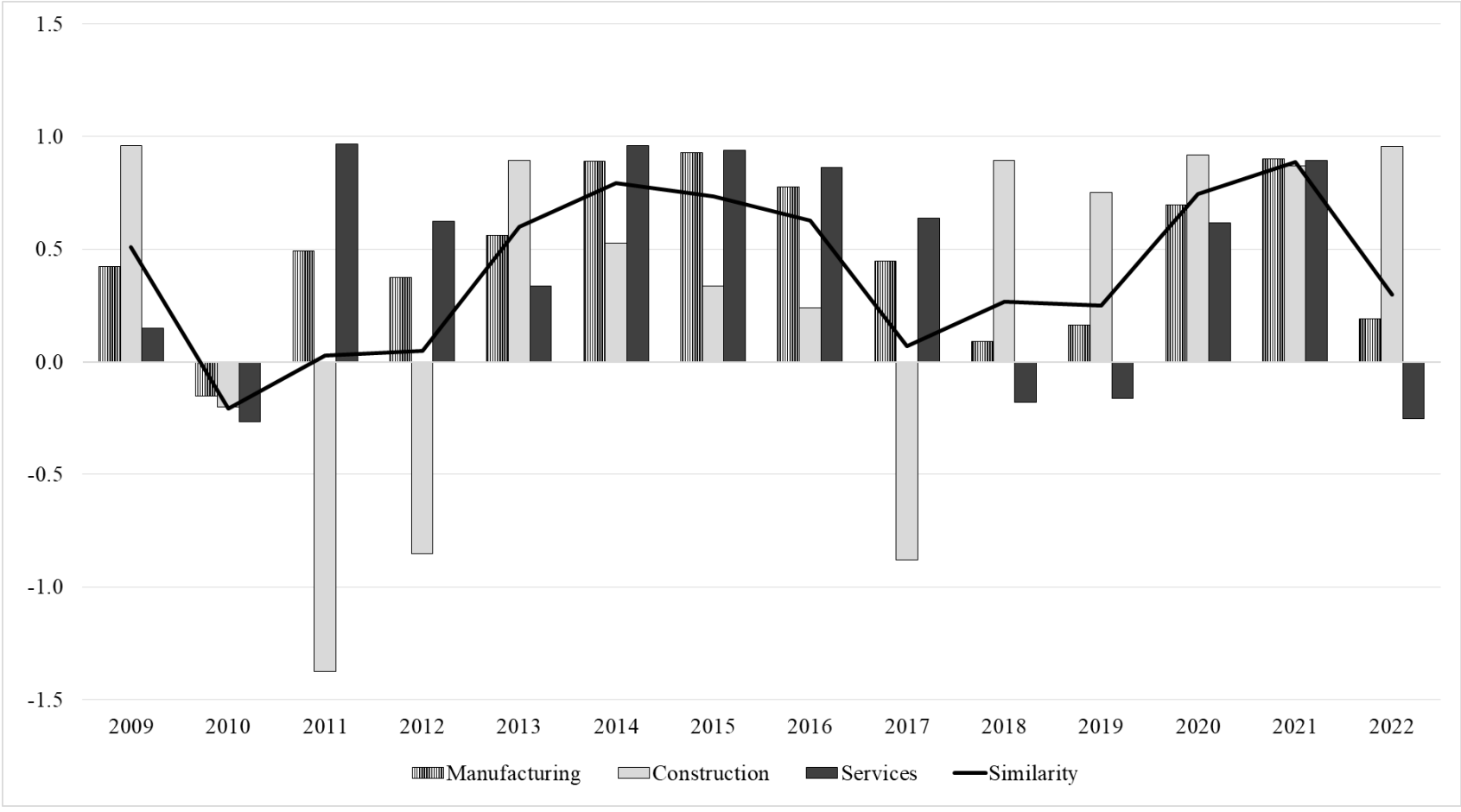

Figure 14: Sectoral output gaps similarity in Poland

Synchronization and Similarity of Regional Output Gaps

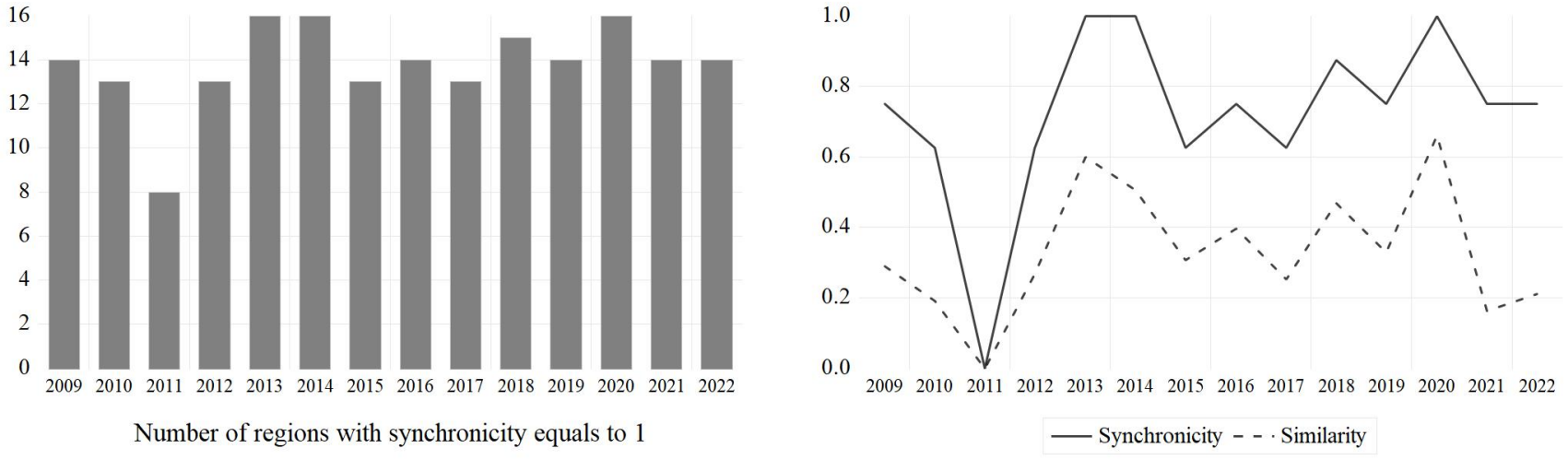

Figure 15: Regional output gaps synchronization and similarity

Synchronization of Regional Output Gaps

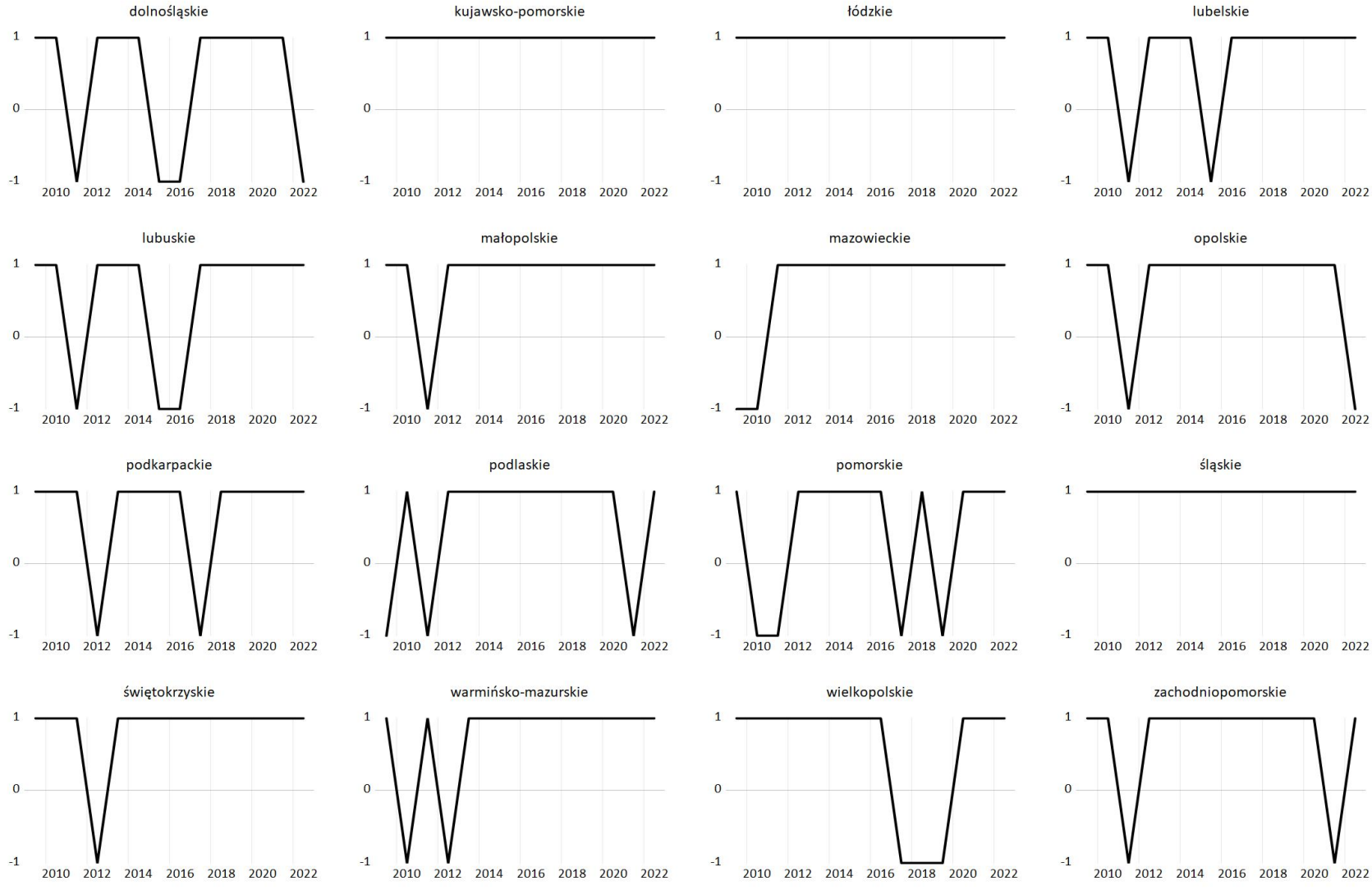

Figure 16: Regional output gaps synchronization

Similarity of Regional Output Gaps

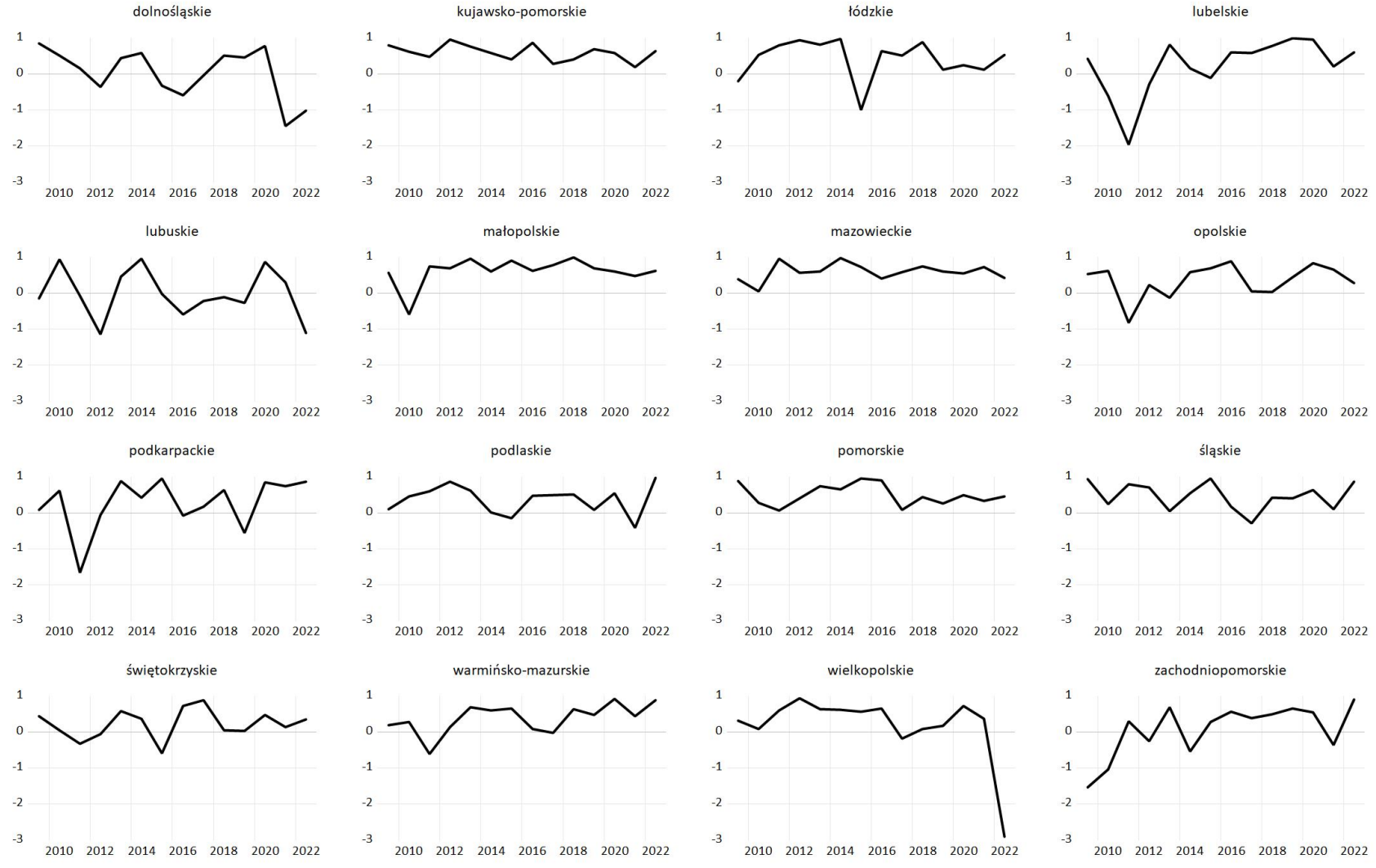

Figure 17: Regional output gaps similarity

Conclusions

- A new two-stage micro-econometric procedure to estimate the output gap based on BTS and ANFES:
  - sector-specific production functions estimation in the augmented OP model,
  - potential inputs extraction and potential output calculations,
- we offer a new method relevant to both policy and firm perspectives
- we recognised that in Poland:
  - the labour and capacity utilisation components dominate in generating the total output gap,
  - the micro-founded output gap in the manufacturing sector is the component of the business cycle
  - the micro-founded output gaps in mazowieckie, ślaskie and wielkopolskie are the main drivers of the business cycle fluctuations,
  - sectoral and regional output gaps present different time patterns.

Thank you for your attention!

- Mirosław Błażej, e-mail: `m.blazej@stat.gov.pl`
- Mariusz Górajski, e-mail: `m.gorajski@stat.gov.pl`
- Magdalena Ulrichs, e-mail: `m.ulrichs@stat.gov.pl`

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Evaluation of the output gap estimates

- It should possess forecasting power. Proper estimates of output gap should predict inflation, unemployment and GDP, both "in-sample" and "out-of-sample"
- It should be correlated with capacity utilization or other economic activity measures.
- A minimal requirement for a output gap measure to be robust for adding new observations, e.g. it does not change significantly from its initial estimate when additional information becomes available over time.
- We address the question of whether capacity utilisation augmented output gap helps to predict inflation in Poland by estimating Phillips curves with different output gaps.
- We compare our results with OECD estimates and the standard univariate filter approach (the ESM filter with $\lambda = 100$).
- We also compare the results for different values of HP-λ parameter: $\lambda = 6.25, \lambda = 10^5$.

Phillips curve

The general form of the estimated model is as follows:

$$\pi_t = \delta_0 + \delta_\pi \pi_{t-1} + \delta_x x_t^k + \varepsilon_t,$$

where:

- where π_t inflation rate in Poland in year t, consumer price index
- x_t^k stand for output gap, where $k = UKL, U, K, L, HP, OECD$
- The models are estimated on the sample 2009-2019
- We use GMM estimator with following instruments: ToT, import prices, REER, GDP.

Phillips curve - results

output gap measure	$\hat{x}_t^{OECD}$	$\hat{x}_t^{HP}$ $\lambda = 10^2$	$\hat{x}_t^{UKL}$ $\lambda = 10^2$	$\hat{x}_t^{UKL}$ $\lambda = 10^5$	$\hat{x}_t^{UKL}$ $\lambda = 6.25$
$\hat{\delta}_0$	0,01	0,01	0,01	0,01	0,01
$\hat{\delta}_\pi$	0,62**	0,47**	0,58***	0,61***	0,53***
$\hat{\delta}_x$	0,71**	0,59**	0,84***	0,76***	1,12***
R^2	0,69	0,73	0,83	0,84	0,72
$J - stat$ p.val	0,19	0,25	0,25	0,24	0,69

Note: *** p<0.01, ** p<0.05, * p<0.1

Quasi-Real Time Estimates of Micro-Founded Output Gaps

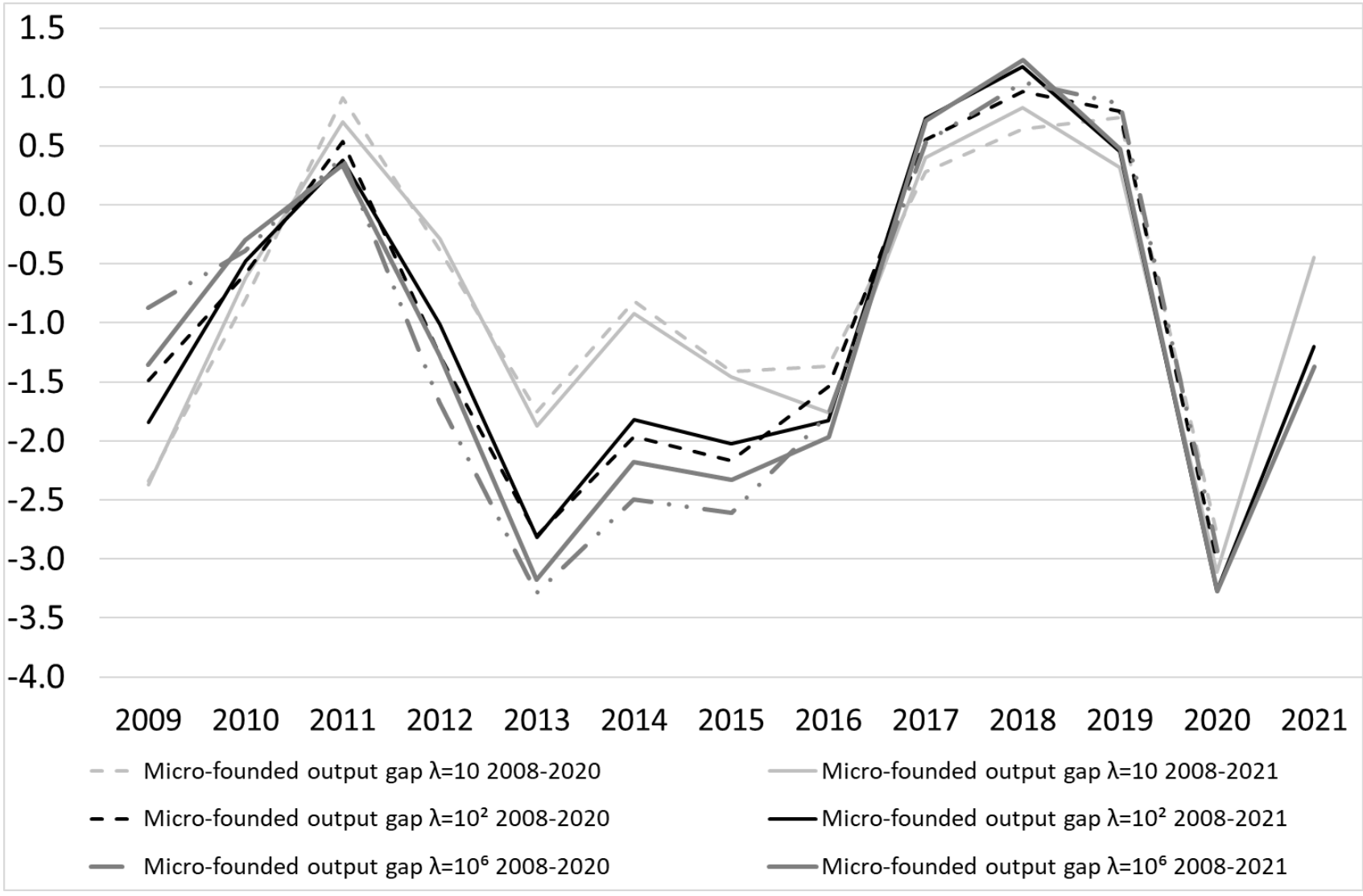

Figure 18: Quasi-real time estimates of the micro-founded output gap in Poland.

Quasi-Real Time Estimates of Micro-founded Output Gaps

Output Gap	$\hat{x}_t^{UKL}$	$\hat{x}_t^{UKL}$	$\hat{x}_t^{UKL}$
	$\lambda = 10$	$\lambda = 10^2$	$\lambda = 10^6$
RMSE	0.22	0.23	0.28
Output Gap	$\hat{x}_t^{GDP-HP}$	$\hat{x}_t^{GDP-HP}$	$\hat{x}_t^{GDP-HP}$
	$\lambda = 10$	$\lambda = 10^2$	$\lambda = 10^6$
RMSE	0.16	0.26	0.41

Table 1: Root mean-squared error of output gap estimates

Note: The root mean-squared errors of the output gap estimates using sample window 2009-2020 relative to the full-sample estimates (2009-2021), log deviations multiplied by 100. The micro-founded output gaps $\hat{x}_t^{UKL}$ are calculated for $\lambda = 10$, $\lambda = 10^2$, $\lambda = 10^6$). $\hat{x}_t^{GDP-HP}$ is the Hodrick-Prescott trends in the macroeconomic times series of GDP in Poland.

Economic significance of the output gap estimates

Output Gap	GDP	Unempl.	CPI
OECD output gap	0.50	-0.30	0.73^{**}
EC output gap	0.56^{**}	-0.49	0.64^{**}
$\hat{x}_t^{GDP-HP}, \lambda = 10^2$	0.52^{*}	-0.45	0.70^{**}
$\hat{x}_t^{UKL}, \lambda = 10^6$	0.73^{**}	-0.57^{*}	0.52^{*}
$\hat{x}_t^{UKL}, \lambda = 10^2$	0.75^{***}	-0.58^{*}	0.47
$\hat{x}_t^{UKL}, \lambda = 10$	0.67^{**}	-0.41	0.41^{***}

Table 2: Correlation coefficients between macroeconomic variables and different measures of the output gap

Note: For the description of micro-founded output gaps $\hat{x}_t^{UKL}$, and macro-founded output gaps $\hat{x}_t^{GDP-HP}$ see notes under Table 1. Columns: *GDP* is the GDP growth rate, Unempl. is unemployment rate, *CPI* is the consumer price index. The p-values for the t-test of the correlation coefficient's significance, *** $p-values < 0.01$, ** $p-value < 0.05$, and * $p-value < 0.1$.

Economic Significance of Micro-founded Output gap

The backward-looking Phillips curve:

$$\pi_t = \delta_0 + \delta_\pi \pi_{t-1} + \delta_x x_t + \varepsilon_t, \pi_t = \delta_0 + \delta_\pi \pi_{t-1} + \delta_x x_t^k + \varepsilon_t, \tag{23}$$

where π_t is the inflation rate in Poland in year t; x_t is the output gap measure.

statistics	$\hat{x}_t^{UKL}, \lambda = 10^6$	$\hat{x}_t^{UKL}, \lambda = 10^2$	$\hat{x}_t^{UKL}, \lambda = 10$	$AR(1)$
$\hat{\delta}_0$	0.68	0.53	0,62	0.4
$\hat{\delta}_\pi$	0.90^{***}	0.92^{***}	0.83^{***}	0.75^{***}
$\hat{\delta}_x$	0.77^{**}	0.82^{**}	0.78	-
R^2	0.72	0.70	0.67	0.45
$J-stat\ p-value$	0.33	0.29	0.24	0.33
$RMSE$	0.89	0.92	0.96	1.24

statistics	*OCED* output gap	*EC* output gap	$\hat{x}_t^{GDP-HP}, \lambda = 10^2$	
$\hat{\delta}_0$	0.87	0.07	-0.17	
$\hat{\delta}_\pi$	0.69^{***}	0.70^{***}	0.82^{***}	
$\hat{\delta}_x$	0.90^{***}	0.60^{***}	0.98^{***}	
R^2	0.62	0.68	0.49	
$J-stat\ p-value$	0.45	0.42	0.57	
$RMSE$	1.03	0.95	1.01	

Table 3: The Phillips curve estimates in Poland in 2009-2019 for different output gap measure.