Non-Cyclical Fluctuations in GDP Growth in Poland

Abstract: The aim of the study presented in the paper is to verify the hypothesis of non-cyclical economic fluctuations; in particular, the hypothesis concerning the irregularity of causes and the hypothesis concerning the regularity of rebalancing the economy. Slow past GDP growth is taken as a symptom of disequilibrium, that is, the occurrence of either fixed asset bottlenecks or demand shortages. These two causes of disequilibrium arise irregularly in the economy. The hypothesis tested states that the slower the economic growth that occurred in the past, the stronger the compensatory GDP growth that will occur in the future. This is the regularity of rebalancing.

The method of least squares was used to estimate a modified Solow model for Poland's GDP in the years 1994–2019. The most important modification consisted in replacing the dynamics of net physical capital, which is not available in Polish statistics, with the investment rate. The second reason for this modification is the inaccuracy of statistical data on gross physical capital, which cannot be avoided. Another modification was the introduction of lagged GDP growth into the model as an indicator of disequilibrium.

The hypothesis that the intensified occurrence of bottlenecks results in greater investment efficiency after 3–5 years has been confirmed. On the other hand, a slowdown in GDP growth results after 1–2 years in the accumulation of unused capacity, which enables a compensatory acceleration of economic growth. Thus, the hypothesis of the occurrence of non-cyclical economic fluctuations in the Polish economy has been confirmed.
1. Introduction

The market can be in one of the three states: equilibrium of demand and supply, disequilibrium with excess demand or disequilibrium with excess supply. Each type of disequilibrium slows the growth of a partial market and the corresponding segment of the economy.

States of undersupply or shortages of fixed assets will be equated with the occurrence of bottlenecks, while unused capacity will be equated with shortages of demand. An attempt will be made to build an economic growth model to describe the mechanism of restoring equilibrium by eliminating bottlenecks or reducing unused capacity. The greater the imbalance, the greater the growth effect should be produced by the return to equilibrium, which requires investment. In other words, there occurs the phenomenon of hysteresis, that is, the dependence of current economic growth on past growth.

In short, the elimination of disequilibrium can occur either based on investment or in a non-investment manner. In both situations, there occurs an economic slowdown, and then a corresponding acceleration. It can be assumed that the greater the disequilibrium, the greater the slowdown, and the stronger the effects of compensatory measures. Thus, it seems that economic fluctuations are not characterised by a regular course over time, since the occurrence of disequilibrium in the economy is irregular in nature. On the other hand, regularity can be observed in the recovery from irregularly occurring shortages of fixed assets (shortages of supply) or shortages of demand.

The purpose of the presented research is to answer the question of whether Poland’s economy experiences non-cyclical, i.e. irregular, economic fluctuations. The analysis covers the years 1994–2019. A modified Solow economic growth model with a Cobb-Douglas production function, which describes the mechanism of restoring equilibrium by eliminating bottlenecks or stimulating demand to activate unused production capacity, will be applied.

Economic growth (GDP dynamics) will depend on the investment rate, the employment rate and the lagged GDP growth. The model will use annual data from Statistics Poland (the Central Statistical Office of Poland). Data on GDP and investment come from the CSO's macroeconomic data bank (https://bdm.stat.gov.pl/). Data on employment (employed), in addition to the above, will also come from the CSO's Statistical Yearbooks and the author’s own calculations.
Earlier studies confirmed hypothesis $H_1$ that the greater the slowdown in economic growth, that is, the greater the severity of fixed asset bottlenecks, the greater the efficiency of investment after two, three and even six years (Sztaudynger, Sztaudynger, 2022). This sort of acceleration and growth was called the investment type. In this paper, after refining the model, the hypothesis will be tested again.

In the current study, the following modifications have been made compared to the previous model (Sztaudynger, Sztaudynger, 2022):

1) the elimination of disequilibrium occurs not only through investment but also through adjustments to fluctuations in demand;
2) employment (employed)\(^1\) growth rate was introduced and the lags in its impact on GDP growth were determined;
3) one of the assumptions of the Solow model was transformed to replace the dynamics of physical capital with the rate of investment.

The economic growth achieved by increasing the utilisation of existing production capacity will be called the non-investment economic growth. Such growth is the subject of the following new hypothesis:

$H_2$: the slower the GDP growth that occurred one and two years ago, the faster the compensatory non-investment growth that will occur in the current year in addition to the growth resulting from capital expenditures.

Verifying hypotheses $H_1$ and $H_2$ is the primary objective of the paper. These hypotheses address the key issue of economic growth, namely the mechanism of economic fluctuations, in particular whether they are regular or not. This important question still remains unanswered. Are the economic fluctuations occurring in the Polish economy cyclical or not?

The growth modelling literature does not differentiate the effects of investment based on the presence of bottlenecks preceding the investment (e.g.: Cobb, Douglas, 1928; Romer, 1994; Baranowski, 2008; Tokarski, 2009). According to hypothesis $H_1$, such differentiation does occur. Similarly, economic growth does not depend on the magnitude of previous demand shortages. According to hypothesis $H_2$, such dependence occurs.

If hypotheses $H_1$ and $H_2$ are confirmed, that is, if the causes of economic fluctuations turn out to be, among others, bottlenecks in fixed assets and unused production capacity, which appear in the economy in an irregular or random way (structural changes, transformations, armed conflicts, or pandemics), this will lead to the conclusion that economic fluctuations do not have a regular cyclical pattern over time.

Another, less significant, hypothesis is that:

\(^1\) In Polish statistics, the category that best describes the volume of people’s involvement in production processes is the number of persons employed in the national economy (according to Statistics Poland, this group comprises employed workers, employers and the self-employed). Growth models use the term ‘employment.’ In this paper, these terms will be used interchangeably to avoid the ambiguous term ‘employment dynamics.’
Employment growth impacts GDP growth not only in the same year but also with lags.

The structure of the paper is as follows: Section 2 presents the classical Cobb-Douglas production function from the Solow growth model with references to the literature. Then, one of the assumptions of the Solow model is transformed, which allows us to replace the dynamics of net physical capital with the rate of investment. In Section 3, the model presented in Section 2 is modified taking into account the impact of demand shortages. Section 4 presents the results of estimating this model, which will be used to verify hypotheses $H_1$ and $H_2$ concerning non-cyclical economic fluctuations and hypothesis $H_3$ regarding the lagged effect of employment on GDP growth. Sections 5 and 6 include a discussion of the results obtained and conclusions.

2. The Cobb-Douglas production function in the literature and a proposal for its modification

The starting point for the study is the classical Solow model with the Cobb-Douglas production function (Cobb, Douglas, 1928; Solow, 1956; 1988; Douglas, 1976; Jones, 2000; Aghion, Howitt, 2009, pp. 21–29; Sasaki, 2017; Dykas, Tokarski, Wisła, 2022, pp.16–24) in its dynamic form:

$$GDP_t = \alpha_0 + \alpha_1 \dot{L}_t + \alpha_2 \dot{K}_t,$$

where:

- $GDP$ – the volume of production (GDP) at constant prices,
- $GDP_t$ – GDP growth at constant prices,
- $\dot{L}_t$ – employment dynamics–working people in the national economy (%) as of the end of the year compared to the beginning of the year,
- $\alpha_0$ – the rate of technical and organisational progress,
- $\alpha_1$ and $\alpha_2$ – the elasticity of GDP with respect to $L$ and $K$,
- $\alpha_1 + \alpha_2 = 1$ – is therefore a homogeneous function of degree one.

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2 Net physical capital dynamics is not reported in Polish statistics.
3 This point was taken from the author’s publication (Sztaudynger, 2022).
4 This is a supply-oriented model which does not explain physical capital dynamics and investments. Kalecki’s model makes GDP dynamics dependent on consumption and capitalist investment, which means it is demand-oriented (see Kalecki, 1958). The Solow model with the Cobb-Douglas production function is the subject of various modifications, including the use of Kalman filters to make the parameters of this Cobb-Douglas model time-varying (Munguía, Davalos, Urzua, 2019).
\( \dot{K}_t \) – physical capital (fixed assets) dynamics, net value at constant prices.\(^5\)

It is a very difficult statistical problem to separate the increase in the value of fixed assets into a part related to their improvement/modernisation and a purely inflationary part, and to express in constant prices fixed assets with very different degrees of wear and tear. Therefore, the dynamics of physical capital at constant prices \( \dot{K}_t \) will be replaced by the investment output (production) ratio \( \frac{I_t}{GDP_t} \) (the numerator and denominator expressed in current prices).

In the neoclassical Solow model, this substitution can be derived from the net capital growth equation\(^6\):

\[ \Delta K_t = s_t GDP_t - \delta K_t, \]

where:

\( \Delta K_t \) – net capital growth at constant prices,

\( s_t \) – the savings rate is equal by assumption in the Solow model to the investment rate \( \frac{I_t}{GDP_t} \) (both numerator and denominator expressed in current prices),

\( \delta \) – capital depreciation rate.

Dividing both sides of the above equation by \( K_t \), we obtain:

\[ \dot{K}_t = \frac{\Delta K_t}{K_t} = \frac{s_t GDP_t}{K_t} - \delta, \]

where:

\( GDP_t / K_t \) – capital productivity.

\(^5\) However, the CSO publishes the gross (initial) value of fixed assets at constant prices (more information on the dynamics of this value can be found in an email of Ewa Śliwka from the Department of Capital Expenditures and Fixed Assets, 1.12.2022). The CSO does not calculate or publish the dynamics of net capital at constant prices, and such a variable is present in the Solow model. The problem of calculating the value of physical capital was already recognised by Cobb and Douglas (1928, p. 142). They state that La Verne Beals, who was responsible for business statistics in the census, claimed that entrepreneurs reported the value of capital based on initial value rather than net value: ‘original cost rather than cost of reproduction.’ Cobb and Douglas’ way of measuring capital was criticised as early as 1927 by S. Slichter. Firstly, the Aldrich Committee found the fixed asset investment data for the years 1880–1889 in the US unreliable. Secondly, Douglas’ method of calculating investment prices is inaccurate as it assumed a constant share of wages in construction, while it was, in his view, declining (Slichter, Black, 1928, p. 166; cf. Biddle, 2012, p. 231). One rationale for calculating \( K \) depreciation is the fact that the productivity of fixed assets tends to decline with age. Therefore, the net value of fixed assets should better express the contribution of physical capital to production value creation.

\(^6\) When seeking an answer to the question whether the model should include capital dynamics (net, at constant prices) or the investment rate, it is worth noting that the problem is the availability of data. Data on net capital dynamics are not available from CSO statistics. This is probably due to the necessarily conventional calculation of depreciation rates. These considerations do not seem to imply a need to change the CSO’s calculation procedures. The rationale for replacing physical capital dynamics was proposed by Baranowski (18.11.2022).
Under the assumption that in the long term the productivity of capital is constant \( \frac{GDP_t}{K_t} = PR_c \), we obtain:

\[ \dot{K}_t = \frac{\Delta K_t}{K_t} = PR_c(1/GDP)_t - \delta. \]

And after substitution into (1):

\[ GDP_t = \alpha_0 + \alpha_1 \dot{L}_t + \alpha_2 \left[ PR_c \left( \frac{1}{GDP} \right)_t - \delta \right] \]

and ordering:

\[ GDP_t = \alpha_0 - \alpha_2 \delta + \alpha_1 \dot{L}_t + \alpha_2 PR_c \left( \frac{1}{GDP} \right)_t. \]

If we additionally assume that the absolute value term can change over time, we obtain the following:

\[ GDP_t = \dot{A}_t + \beta_1 \dot{L}_t + \beta_2 (1/GDP)_t, \]

where:

\( \dot{A}_t \) – the equivalent of Total Factor Productivity (TFP) – not only the level of technology, in the Solow model, it is either an exogenous variable or a constant,\(^7\)

\( \beta_1 \) – the elasticity of GDP with respect to the employment,

\( \beta_2 \) – the elasticity of GDP with respect to the investment rate.

As it can be seen, the equivalent is reduced by the rate of capital depreciation in the product of the elasticity of production with respect to capital.

In earlier studies (Sztaudynger, Sztaudynger, 2019; 2022), a model was verified in which the TFP equivalent was constant \( \dot{A}_t = \beta_0 \) and the parameter \( \beta_2 \) was time-varying \( \beta_2 = \beta_2 - \beta_2 GDP_{t-i} : \)

\[ GDP_t = \beta_0 + \beta_1 \dot{L}_t + (\beta_2 - \beta_2 GDP_{t-i}(1/GDP)_t). \]

This provided a confirmation of hypothesis \( H_1 \), stating that if there was a slowdown in GDP growth in earlier years, then this year’s (current) investment efficiency expressed by the time-varying parameter \( \beta_2 = \beta_2 - \beta_2 GDP_{t-i} \) will be higher. This is a way

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\(^7\) The problems of measuring TFP were analysed, among others, by Sztaudynger (2005, pp. 17–18), Baranowski (2008, pp. 33–35) and Tokarski (2009, pp. 27–37). The sources of TFP growth were sought in self-improvement of the employed through learning by doing, spillovers of knowledge, technology, and skills (Arrow, 1962; Romer, 1986), innovation, education, as well as in the growing skills of group interaction in economic and social networks. The absolute value term should not be interpreted as TFP dynamics since on the right side we do not have only production factor dynamics, as in the production function, but also lags and products of those with past dynamics. If we find that changes over time, then the time-varying absolute value term will no longer be equivalent to TFP, as the change in investment efficiency should be ‘within’ TFP, and not be related to investment.
of describing the mechanism of economic fluctuations by compensating for the past slowdown in GDP with higher current investment efficiency. This result can be viewed as a description of non-cyclical, irregular economic fluctuations.

3. The proposed modification of the GDP growth model

Model (2) does not describe the situation of falling demand. At that time, fixed assets are fully utilised. After demand increases and GDP grows in the next period, no bottlenecks will appear (see W. Zatoń cited after: Sztaudynger, Sztaudynger, 2019). Acceleration is then not related to the elimination of bottlenecks, but it will be based on meeting the restored level of demand, based on unused production capacity, i.e. in a way that does not require investment. The decline in demand and its reconstruction generally requires less time than eliminating a bottleneck in fixed assets.

The rationale will be similar: if there was a slowdown in GDP growth a year or two ago, caused by a decline in demand (e.g.: due to a banking crisis or epidemic), and if in the current year it is possible to rebuild this demand (eliminate these imbalances) without investment in fixed assets, there will also be an increase in GDP that will not require investment, which I propose to see as the equivalent of TFP, i.e., total factor productivity $\dot{A}_t$. Hence, the following formula of the analysed model is obtained:

$$ G\dot{D}P_t = \beta_0 - \beta_0 G\dot{D}P_{t-1} + \beta_1 \dot{L}_{t-1} + (\beta_2 - \beta_2 G\dot{D}P_{t-1})(1 / GDP)_t, $$

(3)

$H_2, H_3, H_1$ – are given under the parameters expressing the hypotheses.

On the formal side, in equation (3), the absolute value term is time-varying $\beta_0 - \beta_0 G\dot{D}P_{t-1}$. The slower the GDP growth occurred in the past, the greater the time-varying absolute value term. Thus, the non-investment equalisation of growth dynamics, the balancing of capacity utilisation rate, is modelled.

This is an unusual autoregressive model. Most often in autoregressive models with lagged endogenous variables there are positive parameters. In this case, these models describe the inertia of the dependent variable. In model (3), parameters at $G\dot{D}P_{t-1}$ are negative. This is a peculiar hysteresis – high lagged economic growth values slow down current GDP growth, while slow past GDP growth accelerates current GDP growth. Good
past growth slows current growth, and vice versa.\footnote{This phenomenon can be called negative inertia. The role of this variable is to equalise economic fluctuations. In model (3), the rebalancing takes place in the following order: 1) through the non-investment elimination of demand constraints (new and restored markets, increased customer demand – e.g.: after the COVID pandemic); 2) through investment in fixed assets to eliminate bottlenecks. The component $\beta_0 - \beta_0 GDP_{t-1}$ expresses the impact of demand adjustments which are expected to occur relatively quickly, over 1–2 years. Widening bottlenecks through investments is manifested in changes in the parameter $\beta_2 - \beta_2 GDP_{t-1}$, which requires more time – lags of 3–5 years.

The question arises whether the role of this variable is not too large: that with a lag of 1–2 years it should map the underutilisation of production capacity – demand shortages, and then with a lag of 3–5 years it should reflect supply constraints – fixed asset bottlenecks. Seeking argument in favour of this approach, it should be noted that the grand aggregate of GDP encompasses both underutilised capacity (insufficient demand) and insufficient supply. These imbalances are resolved with different lags depending on what type of goods or services we are dealing with.

The stages of adjustment are listed below, showing why a period of 3–5 years is needed to respond to a bottleneck through investments:

1) determining the occurrence of a bottleneck;
2) investment project preparation;
3) fulfilment of formal requirements;
4) gathering the necessary financial and material resources;
5) commissioning (technical, organisational aspects) and execution of the investment;
6) achieving the target level of production or services and organisational activities associated with it (reaching customers, gaining market share).\footnote{The adoption of the assumption concerning the occurrence of regular fluctuations in the economy also makes the current value, such as GDP, dependent on past values in accordance with the adopted formula of cyclical fluctuations.}

According to the estimated linear weights 4, 3, 2 (main variant, Table 1): GDP growth after three years ($t – 3$) dominates in the ‘response’ to the bottleneck of the parameter at the investment rate, then the response to GDP growth declines linearly to end after five years (from three to five years). The difference also lies in the fact that in the real business cycle model there are lagged investments (the investment-based elimination of supply shocks takes more than one period, time-to-build). In the model (Sztaudynger, Sztaudynger, 2019), the effect of current investment depends on the severity of lagged supply shocks.\footnote{Some similarity can be drawn here to Kydland and Prescott’s (1982) RBC Real Business Cycle with time-to-build. The time required to respond to a supply shock and to build an investment, and the accompanying lag, is the cause of business (cyclical) fluctuations in this model (Krawiec, Szydłowski, 2017). In model (3), the cause of economic fluctuations is a lag of up to five years in response to supply bottlenecks, of which past GDP dynamics is an indicator. The response consists in fluctuations in current investment efficiency. Thus, we assume here that a supply bottleneck causes a lagged response of investments (put into operation) resulting in GDP growth after several years (from three to five years). The difference also lies in the fact that in the real business cycle model there are lagged investments (the investment-based elimination of supply shocks takes more than one period, time-to-build). In the model (Sztaudynger, Sztaudynger, 2019), the effect of current investment depends on the severity of lagged supply shocks.}
years; it is then 50% weaker than after three years. The time that elapses from the determination that there is a bottleneck to the completion of the investment and the ‘harvesting’ of the full effects of this investment is up to five years.\(^\text{10}\)

On the other hand, the stages of a non-investment response to a demand shortfall are as follows:
1) determining the occurrence of demand shortfall;
2) taking steps to increase market share;
3) drafting a non-investment production restructuring project;
4) gathering the necessary financial and material resources to launch a promotional campaign;
5) achieving the target level of production or range of services.

4. Results of estimating the proposed GDP growth model

Model (3) describes non-cyclical economic fluctuations that occur due to irregular bottlenecks, resulting in changing investment efficiency described by the parameter \(\beta_2 = \beta_2^i - \beta_2^t G\hat{D}P_{t-i}\) (according to H\(_1\)).

Another source of non-cyclical economic fluctuations can be found in irregular declines in demand and accompanying changes in the rate of capacity utilisation described by the changing equivalent of the absolute value term \(\beta_0 = \beta_0^i - \beta_0^t G\hat{D}P_{t-i}\) (according to H\(_2\)).

4.1. The main variant of the GDP growth model

The table below shows the results of estimating, with the use of the least squares method, of the parameters of model (3), testing hypotheses H\(_1\) and H\(_2\) that show balancing, non-cyclical acceleration or deceleration of economic growth with lags of one to five years, and verifies hypothesis H\(_3\) on the lagged effects of employment dynamics on GDP dynamics.

\(^{10}\) Comparable results were obtained for lags of up to six years: \(G\hat{D}P_{t-i}\) 3–6 years.
Table 1. GDP growth model (1994–2019). Main variant

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter</th>
<th>Hypothesis</th>
<th>Parameter estimate</th>
<th>t-statistic</th>
<th>ADF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endogenous GDP growth rate</td>
<td>$\beta_0^*$</td>
<td>$H_2$</td>
<td>$-0.69$</td>
<td>$3.8$</td>
<td>$-4.8^{***}$</td>
</tr>
<tr>
<td>Average GDP growth rate $t-1$, $t-2$</td>
<td>$\beta_0^*$</td>
<td>$H_2$</td>
<td>$-0.69$</td>
<td>$3.8$</td>
<td>$-4.8^{***}$</td>
</tr>
<tr>
<td>Employment rate $t$</td>
<td>$\beta_1$</td>
<td>$H_3$</td>
<td>$0.31$</td>
<td>$6.0$</td>
<td>$-3.0^{**}$</td>
</tr>
<tr>
<td>Employment rate $t-1$</td>
<td>$\beta_1$</td>
<td>$H_3$</td>
<td>$0.21$</td>
<td>AA</td>
<td>AA</td>
</tr>
<tr>
<td>Employment rate $t-2$</td>
<td>$\beta_1$</td>
<td>$H_3$</td>
<td>$0.10$</td>
<td>AA</td>
<td>AA</td>
</tr>
<tr>
<td>Investment/ GDP</td>
<td>$\beta_2$</td>
<td>$H_1$</td>
<td>$0.68$</td>
<td>$5.2$</td>
<td>$-4.1^{***}$</td>
</tr>
<tr>
<td>$GDP_{t-3} \times \left( \frac{I}{GDP} \right)_t$</td>
<td>$\beta_2^*$</td>
<td>$H_1$</td>
<td>$-0.0025^{*4}$</td>
<td>$5.7$</td>
<td>$-5.8^{***}$</td>
</tr>
<tr>
<td>$GDP_{t-4} \times \left( \frac{I}{GDP} \right)_t$</td>
<td>$\beta_2^*$</td>
<td>$H_1$</td>
<td>$-0.0025^{*3}$</td>
<td>AA.</td>
<td>AA</td>
</tr>
<tr>
<td>$GDP_{t-5} \times \left( \frac{I}{GDP} \right)_t$</td>
<td>$\beta_2^*$</td>
<td>$H_1$</td>
<td>$-0.0025^{*2}$</td>
<td>AA</td>
<td>AA</td>
</tr>
<tr>
<td>Dummy 2012–2016$^a$</td>
<td></td>
<td></td>
<td>$-2.9$</td>
<td>$6.6$</td>
<td>–</td>
</tr>
</tbody>
</table>

$^a$ From 2012 to 2016, GDP was at a lower level than estimated by the model. This can be explained as follows: after Poland’s accession to the EU, the VAT rate averaged 7.8% of GDP between 2005 and 2019, except for 2012–2016, when it was lower by about 0.8 percentage points. The corresponding figures for the total tax rate are 16.1% and 14 percentage points, respectively. Both tax reductions: VAT and total taxes, are statistically significant $P < 0.001$ (Student’s t-statistic values above 4). This was a significant reduction in budget revenues, which reduced the spending of the state and local budgets, decreased demand, and thus slowed economic growth. Several variants of variables 0 1, related to Poland’s accession to the EU, were also analysed. No significant estimates were obtained.

Adjusted $R^2 = 0.799$, $Se = 0.74$, $JB = 0.84$, $DW = 1.89$, ADF (residuals) = $-4.79^{***}$. ADF test significant at the level of: $*** 0.001$, $** 0.05$ or $* 0.1$.

The parameters $\beta_1$ and $\beta_2^*$ were estimated from the Almon polynomial distributed lag model; a polynomial of degree one (linear). Alternative estimation results are provided in the Appendix.

Source: own calculations based on CSO data.
From 1994 to 2019, the average growth rate of $GDP_{t-i}$ was 4.3%. A peculiar feature of this model is the occurrence of a series of lags of up to five years. Based on the above schedules, lags were indicated, which were then verified using F-statistics, Student’s t-statistic and the adjusted $R^2$ coefficient.

Since the issue of lags may be questionable, let us note the explanations in the paper Sztaudynger and Sztaudynger (2022). Stigum (2003: 388) says that: “Economic theory rarely provides a basis for specifying the lag lengths in empirical macro-models” (as well as Nerlove, 1972 and Holden, 2005: 467). In addition, there is another argument: Hendry stresses that the theory lacks precision in determining the length of the lag (Hendry, 2009: 29). With the aid of the model, we will attempt to determine the length of these lags in a way that enables statistical verification.

Since the above-presented model includes variables that are only GDP growth and investment dynamics, the model is short-run in nature. In such a model, non-stationarity appears sporadically (Majsterek, 2008). Since there are three-year averages in the model, the model seems to take on a medium-term character.

In contrast, the ADF test shows that the variables in the main variant are stationary, as are the residuals: the GDP growth rate is stationary with a probability of 94%. The remaining variables with a probability above 95%. Thus, stationarity and the JB test allow for the use of Student’s t-test.

Due to the use of linear lag distributions, only six parameters were estimated. Attempts to employ a parabolic lag distribution did not improve the results, allowing the simplest linear distribution to be used.

The model shown in Table 1 can be regarded as a special – non-cyclical – representation of economic fluctuations. GDP dynamics lagged by 3–5 years (four years on average) is in the opposite position to the state in the year $t$. Therefore, a certain similarity of specific eight-year ‘cyclical’ fluctuations can be found here. $GDP_t$ is negatively correlated with $GDP_{t-4}$, which is lagged on average by four years. This result to some extent confirms the occurrence of fluctuations similar to the Juglar cycle. Bottlenecks, however, appear irregularly. The model shows a specific kind of regularity – it is regularity in eliminating bottlenecks and reducing imbalances. However, this is not a cyclical regularity, involving accelerations and decelerations in growth that are regular over time.

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11 This interpretation is similar to (Sztaudynger, Sztaudynger, 2022, p. 133). The length of Juglar’s investment cycle is 7–11 years. Assumption that “[…] by simple elimination of the excesses, the crisis will bring the system back to a state of stable […] equilibrium” is adopted (Besomi, 2005, p. 32).

12 This result seems to support the view that the economy does not experience regular cyclical fluctuations: “Since no two cycles are the same in detail, some economists question the existence of cycles and use the word ‘fluctuations’” (Nagakawa, 2008, p. 1). According to Romer (2008,) “[…] in reality, there is no regularity in the timing of the cycles” (the views quoted above are cited after Sztaudynger, Sztaudynger, 2022, p. 34). More than seventy years ago, Burns and Mitchell, concluding a monograph on economic growth, argued that the dispute over whether business fluctuations are or are not cyclical is ongoing. In their opinion, difficulties in establishing cyclicality stemmed, among
Figure 1 shows the parameter $\beta_2$ with GDP dynamics (over three years, from $t-3$ to $t-5$) interacting with the investment rate (it is significant at the 0.999 level). Therefore, if GDP growth was slow (1%) in the previous three years, then investment efficiency, as measured by the parameter $\beta_2$, was 0.65. In the case of rapid GDP growth (5%), the estimate of $\beta_2$ was 0.55.

![Graph showing the elasticity of $\beta_2$ with respect to average lagged GDP dynamics](image)

**Figure 1.** The elasticity of $\beta_2$ with respect to average lagged GDP dynamics (with a lag of 3–5 years)

*Source:* own calculations based on the main variant.

According to the estimation results, in response to investment, economic growth follows a specific pattern related to the previous imbalance. For example, in the main variant (Tab. 1), as a result of slowing GDP growth in the year $t$ by 1 pp, we obtain:

- an increase in the parameter $\beta_2$ in the years $t+3$, $t+4$, and $t+5$ equal to 0.02, and
- acceleration of GDP growth of 0.4 pp in these three years combined (assuming an investment rate of 20%).

As it seems, this result confirms hypothesis $H_1$, stating that the effects of investment depend not only on the investment rate – the investment/GDP ratio – but also on the extent to which the investment was preceded by a bottleneck characterised by the average GDP dynamics of three years ($t-5$, $t-4$, $t-3$). The result is described by the following formula:

others, from the differences of individual economic activities (Burns, Mitchell, 1946, p. 506). As written in (Sztaudynger, Sztaudynger, 2022, p. 118), the proposed approach is similar to the ‘plucking model’ proposed by Friedman in 1964. Friedman (1993, p. 171) stated that the magnitude of an expansion is “[...] related systematically to the magnitude of the succeeding contraction.” He “suggested a model of business fluctuations that stresses occasional events producing contractions and subsequent revivals rather than a self-generating cyclical process.”
\[
\hat{\beta}_2 = 0.68 - 0.0025 \sum_{i=3}^{5} w_i GDP_{t-i}
\]

\[
w_3 = 4, \ w_4 = 3, \ w_5 = 2,
\]

where: parameter estimates were taken from the main variant – Table 1.

The parameter \( \hat{\beta}_2 \) (beta_2) took values in the range of 0.54–0.66. In the years 1998–2001, which were not preceded by bottlenecks, the parameter values were the lowest – in the 0.54–0.56 range. In contrast, the years 2004–2005 and 2015–2017 were preceded by slower GDP growth (and intensified bottlenecks) in 2000–2001 and 2011–2013, respectively. Therefore, in the years 2004–2005 and 2015–2017, the efficiency of investments measured by the parameter \( \hat{\beta}_2 \) was relatively high (\( \hat{\beta}_2 \) above 0.62).

Summing up the impact of past investment and non-investment imbalances on GDP growth (approximated by past GDP dynamics), the greatest slowdown can be observed in the years 1998–1999 and the greatest acceleration was recorded in the years 2003–2004 and 2014–2017. The differences between the years of slowdowns and accelerations are at the level of 4 pp. Given the average GDP growth of 4.3% during the period under review, this impact can be considered very large.
4.2. The impact of employment dynamics on GDP growth

According to hypothesis H₃, employment growth affects GDP growth not only in the same year but also with lags. The possibility of lags is indicated by the staggered response of GDP to employment growth:

1) when employment grows (as of the end of the year), part of the growth effect is observed in the current year and part in the following year;
2) due to the time needed to onboard new employees and improve coordination within teams of co-workers, this period lengthens, and the effects of productivity growth fade. As can be seen from the linear distribution of lags, the effect in the year t is three times greater than after two consecutive years.

There are indirect, gradually fading multiplier effects. An increase in employment (and the accompanying increase in the income of the population) entails an increase in demand, and this results in an increase in GDP. These relationships are called the employment multiplier.¹³

Hypothesis H₃, therefore, raises the question whether it is advisable to introduce lags in employment growth into the analysed model. This hypothesis was tested by comparing the main variant, in which employment dynamics occur for t, t – 1 and t – 2, with the variant in which this dynamics is not lagged. In both cases, the studied variable is significant, but much better results were obtained for the variant with lags (R² 0.80 and 0.75 respectively and also Student’s t-statistics). This confirms hypothesis H₃. The estimation of the elasticity of GDP with respect to labour was 0.62¹⁴ (including for t, t – 1 and t – 2: 0.31, 0.21 and 0.10 respectively) using Almon’s linear distributed lag. Below we compare this result with results obtained in other studies.

---

¹³ Richard F. Kahn is considered to be the originator of the multiplier concept. In 1931, he published the article entitled The Relation of Home Investment to Unemployment (reprinted in Selected essays on Employment and Growth, 1972). "The multiplier is a relation between the increase in exogenous aggregate expenditure and the increase in net national product thereby generated (and thus also in employment...)" (Pasinetti, 2008, p. 7196). An increase of expenditure equivalent to 1 extra job will finally generate 1/(1 – c) extra jobs, where c is the fraction of any increase in income that consumers tend to spend (Kahn, 1931, p. 183; Pasinetti, 2008, p. 7196). This is Kahn's employment multiplier. Kahn claims that "[...] if there is ever any justification for expenditure on "public works" as a means of reducing unemployment, the justification is greatest when depression is most severe" (Kahn, 1972, p. 182). Kahn's concept was further developed by Keynes, who collaborated with him.

¹⁴ If we omit the variable dummy 2012-2016 from the main variant of the model, the elasticity with respect to the number of employed falls to an evidently too low level of 0.38. This is yet another argument in favour of the fact that these were distorted years, in such a way that GDP responded very inelastically to changes in the employed.
5. Discussion

In macro studies, output-employment elasticities in the range of 0.60–0.66 are considered typical (Tab. 2). In studies on 19 developed countries, this range is wider: 0.55–0.77.

For Poland, studies of the elasticity of production with respect to labour and physical capital have been conducted for several years. Based on micro-data from 82,000 enterprises (576,000 observations) in the years 2002–2016, Gradzewicz, Mućk (2019) estimated $\beta_1$ at the level of 0.83. The authors point out that this elasticity is well above the 0.66 that is commonly assumed in macro studies. They draw attention to the fact that, in macro approaches, the elasticity with respect to labour is usually calibrated according to the long-run characteristics of the labour factor’s share of output. They refer to somewhat earlier studies of their own covering several long-run measures of the labour share of GDP in the United States at the level of 0.61–0.67 (Gradzewicz, Mućk, 2019, footnote, pp.14–15).

In a similar Polish study on micro data, Górajski and Błażej (2020: 307) obtained $\beta_1 = 0.76$ (the years 2005–2016, 585,000 observations).

Measures of the elasticity of GDP with respect to employment are higher on a micro-data basis (0.76 to 0.83) than those calculated on a macro-data basis (0.61 to 0.67). Determining the reasons for this difference is problematic. One possible explanation is the usually short time series of micro data.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Macro/Micro data</th>
<th>Period</th>
<th>$\hat{\beta}_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usually acc. Gradzewicz, Mućk (2019)</td>
<td>Macro</td>
<td>–</td>
<td>0.66</td>
</tr>
<tr>
<td>Gradzewicz, Mućk (2019)</td>
<td>Micro, Poland</td>
<td>2002–2016</td>
<td>0.83*</td>
</tr>
<tr>
<td>Mućk, McAdam, Growiec (2018)</td>
<td>Macro, USA</td>
<td>Different periods</td>
<td>0.61–0.67</td>
</tr>
<tr>
<td>Górajski, Błażej (2020)</td>
<td>Micro, Poland</td>
<td>2005–2016</td>
<td>0.76</td>
</tr>
<tr>
<td>Autor, Salomons (2018: 5)</td>
<td>Macro, 19 developed countries</td>
<td>1970–2007</td>
<td>0.55–0.77</td>
</tr>
<tr>
<td>Easterly, Levine (2001: 183)</td>
<td>Macro, 6 OECD</td>
<td>1960–1990</td>
<td>0.58–0.62</td>
</tr>
</tbody>
</table>
The results obtained for 31 provinces differ significantly from the elasticities described above (Xu et al., 2022, p. 793 and pp. 796–797). First, the elasticities with respect to employment are significantly lower, averaging 0.38. Moreover, they are lower than the elasticities with respect to capital. The World Bank, on the other hand, estimated the analysed elasticities at around 0.6, which Xu explains by WB’s assumption that these elasticities are constant over time. Meanwhile, that elasticity recorded a declining trend in the surveyed years 1993–2015.

An explanation for the different elasticities of GDP with respect to changes in employment, both over time and between countries, may be the different levels of employment infrastructure, education and wage levels. Workers who are less productive (less skilled or having access to inferior technology) or relatively low-paid (income is only enough to meet basic needs) are less of a stimulus to GDP growth than in the opposite situation.

The sum of the elasticities with respect to labour for $t$, $t - 1$ and $t - 2$ in my model is 0.62 and falls within the above-mentioned ranges for macro data of developed countries. This can be considered as an argument in favour of the model proposed in the paper. None of the measures of elasticity reported in the literature considers lags in the response of GDP to changes in employment.

### 6. Conclusions

Based on the improved model, hypothesis $H_1$, concerning the varied impact of the investment rate on economic growth, has been confirmed yet again. The greater the slowdown in economic growth, the more intense the severity of fixed asset bottlenecks, the greater the investment efficiency after several years. The period of increased investment efficiency was previously estimated with lags of two to six years (Sztaudynger, Sztaudynger, 2022). This also applies to the reverse situation, where acceleration of lagged economic

<table>
<thead>
<tr>
<th>Authors</th>
<th>Macro/Micro data</th>
<th>Period</th>
<th>$\hat{a}_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stylised Easterly, Levine (2001: 182)</td>
<td>Macro</td>
<td>–</td>
<td>0.60*</td>
</tr>
<tr>
<td>Xu et al. (2022: 796)</td>
<td>31 eastern China provinces</td>
<td>1993–2015</td>
<td>0.36–0.52 Average 0.38 **</td>
</tr>
<tr>
<td>The proposed model in Table 1</td>
<td>Macro, Poland</td>
<td>1994–2019</td>
<td>0.62</td>
</tr>
</tbody>
</table>

* Share of employment in GDP.  
** GWR geographically weighted regression.  
Source: own elaboration.
growth results in a reduction in current investment efficiency. After the model verification presented in the paper, we find that lags of three to five years result in increased investment efficiency. The validity of hypothesis $H_1$, stating that the effects of investment depend not only on the investment rate – the investment/GDP ratio – but also on the extent to which the investment was preceded by a bottleneck characterised by the three-year average GDP growth rate($t-5$, $t-4$, $t-3$), has been therefore confirmed.

By formulating hypothesis $H_2$, an attempt was made to examine non-investment growth: the slower the GDP growth occurring one and two years ago, the faster the growth that will occur in the current year, regardless of investment. Hypothesis $H_2$ has also been confirmed: GDP growth lagging one and two years directly – not through investment – and negatively affects economic growth.

We interpret the confirmation of hypotheses $H_1$ and $H_2$ as a confirmation that the causes of economic fluctuations are bottlenecks in fixed assets and unused production capacity. Since they occur randomly or irregularly in the economy (transitions, armed conflicts, or the COVID epidemic), economic fluctuations are not characterised by regular cyclical over time.

It is worth adding that $H_1$ and $H_2$ describe a kind of regularity in the way equilibrium is pursued. However, this is not a sufficient argument for the cyclicity of sinusoidal economic growth, with regular fluctuations over time. In other words, irregular bottlenecks that occur and irregular excess capacity (demand deficits) do not generate GDP cycles that are regular over time.

Hypothesis $H_3$ has also been confirmed. Employment (labour) growth impacts GDP growth not only in the same year, but also with lags of one and two years. The current impact is three times stronger than with a lag of, for example, two years.

The research presented in this paper attempts to describe non-cyclical economic fluctuations. Two sources of cyclical fluctuations were distinguished: bottlenecks of fixed assets and insufficient demand with unused production capacity. To distinguish between demand shortages and supply bottlenecks, the analysis can be expanded to include the inflation rate. In a free-competitive economy, when prices rise relatively quickly, we experience a bottleneck or supply shortage. When prices rise relatively slowly and economic growth slows, we are dealing with unused production capacity. In further research, we will attempt to introduce inflation and transportation infrastructure investment into the model and replace the Cobb-Douglas production function with the CES function (Dykas, Tokarski, Wisła, 2022, pp. 31–32).  

15 If the elasticity of substitution between labour and capital is less than one and there is a decline in population, then, based on the CES function, the long-term growth rate of GDP per capita is determined by the exogenous rate of technical progress. In contrast, if the elasticity of substitution rate is one, then the production function takes the Cobb-Douglas form, and the long-term growth rate of GDP per capita is positive, even without technical progress and with a negative population
The model of non-cyclical economic fluctuations presented in the paper can be applied to other countries, but only for the period up to 2019, as it is doubtful whether it will be possible to describe the deep COVID slowdowns of 2020 and 2021. GDP lags for other countries may differ from the results obtained for Poland. Shorter ones will indicate a faster response of the economy to emerging bottlenecks or demand shortfalls. On the other hand, due to the lack of sufficiently long time series, it is impossible to conduct such a study by voivodeships.

I would like to thank Janina Witkowska, Paweł Baranowski, Michał Majsterek, Wojciech Zatoń, and my father Jan Jacek for their valuable advice and significant remarks.
### Appendix

Table 3. The main model (3) and alternative estimation results of the Cobb-Douglas function in which capital dynamics is replaced by the investment rate

<table>
<thead>
<tr>
<th></th>
<th>Simple</th>
<th>Almon distribution of the employed</th>
<th>Almon distribution of the employed – bottlenecks</th>
<th>The employed with no lags – bottlenecks</th>
<th>Main</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Coefficient</td>
<td></td>
<td>t-statistic</td>
<td>t-statistic</td>
<td>t-statistic</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1.1</td>
<td>0.6</td>
<td>3.9</td>
<td>1.8</td>
<td>−1.1</td>
</tr>
<tr>
<td>GDP growth rate</td>
<td></td>
<td></td>
<td>−1.1</td>
<td>−0.5</td>
<td>−2.6</td>
</tr>
<tr>
<td>Growth rate of the employed</td>
<td>0.56</td>
<td>4.8</td>
<td>0.45</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>Growth rate of the employed Almon distributed lag</td>
<td>−</td>
<td>−</td>
<td>0.57</td>
<td>3.8</td>
<td>0.47</td>
</tr>
<tr>
<td>I/GDP ratio</td>
<td>0.15</td>
<td>1.6</td>
<td>0.02</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>I/GDP Almon distributed lag</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>0.22–0.31</td>
</tr>
<tr>
<td>U2012_2016</td>
<td>−2.3</td>
<td>−4.3</td>
<td>−2.4</td>
<td>3.9</td>
<td>−2.1</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.59</td>
<td>0.49</td>
<td>0.67</td>
<td>0.71</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Source: own calculations with the use of the method of least squares.
As we can see, replacing the simple variant 1 (investment rate, employed growth rate) with models with supply bottlenecks and demand shortfalls (variants 3, 4, 5) significantly increases the model fit.

Variants 4 and 5 (the main one) can be considered the best. The advantages of both variants are significant estimations of structural parameters (except for the absolute value term in variant 4).

Advantages of variant 4: a simpler design, one less variable, the employed growth rate without lags, and more typical values of the investment rate parameter.

Advantages of main variant 5: more typical parameter with the growth rate of the employed, a higher $R^2$ coefficient, allows for the verification of $H_2$. Based on the above-presented comparison, I have decided to choose variant 5 (main) of the model.

References


Jan Marek Sztudynger  
Non-Cyclical Fluctuations in GDP Growth in Poland


Niecykliczne wahania wzrostu PKB w Polsce

Streszczenie: Celem artykułu jest weryfikacja hipotezy o niecyklicznych wahaniach koniunkturalnych, w szczególności o nierregularności przyczyn oraz o regularności przywracania równowagi w gospodarce. Powolny przeszły wzrost PKB jest traktowany jako symptom nierównowagi, czyli występowania wąskich gardeł w środkach trwałych albo niedoboru popytu. Te dwa przyczyny nierównowagi pojawiają się w gospodarce nierządnie. Weryfikowano hipotezę, że im wolniejszy wzrost gospodarczy występował w przeszłości, tym silniejszy będzie wzrost PKB. Jest to regularność przywracania równowagi.

Metodą najmniejszych kwadratów oszacowano zmodyfikowany model Solowa dla PKB Polski w latach 1994–2019. Najważniejszą modyfikacją było zastąpienie dynamiki kapitału fizycznego netto, niedostępnej w polskiej statystyce, stopą inwestycji. Drugim powodem...
tej modyfikacji była niedokładność danych statystycznych o kapitałe fizycznym brutto, której nie można uniknąć. Kolejną modyfikacją było wprowadzenie do modelu opóźnionej dynamiki PKB jako indykatora nierównowagi.

Potwierdzono hipotezę, że nasilone występowanie wąskich gardeł, powoduje, że po 3–5 latach efektywność inwestycji jest większa. Natomiast spowolnienie wzrostu PKB po 1–2 latach powoduje kumulację niewykorzystanego potencjału, co umożliwia wyrównujące przyspieszenie wzrostu gospodarczego. Potwierdzono zatem hipotezę o występowaniu w polskiej gospodarce niecyklicznych wahań koniunkturalnych.

Słowa kluczowe: wzrost ekonomiczny, model Solowa, inwestycje w kapitał fizyczny, wąskie gardła, wykorzystanie mocy produkcyjnych, wahania koniunkturalne

JEL: E13, E22, E32, O40