UDC [338.1:336.531.2]:519.246.85
JEL Classification: O47; H54; C22; C53

PUBLIC INVESTMENT AND GROWTH: THE VECM RESULTS FOR UKRAINE

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Public Investment and Growth: the VECM Results for Ukraine

The article examines public investment impact on the economic growth in Ukraine applying VECM instruments. The aim of the study is to reexamine the influence of public investment on GDP dynamics in Ukraine in the short- and long-run using VAR modeling. There given characteristics of the crowding-in and crowding-out effects of public investment shock for developed and developing economies in the context of typical methods for studying the issue. The empirical review proves that public investment is a significant growth driver in the short-run. The VECM results verified a positive impact of public investment with maximum GDP growth 0.8 percentage points in Ukraine detected at the end of the first year after the shock. There determined a persistent crowding-in effect starting from the second quarter of the carried out impulse response scenario estimation and corresponds to an increase in the private investment to GDP ratio by 0.4 percentage points. Based on the results of modeling the internal public debt shock, there proved the presence of the crowding-out effect, which becomes more noticeable in the first quarter resulting in a sharp decline in the private investment to GDP ratio by -0.5 percentage points. The actual phase of the crowding-out effect lasts during the period of one year and a half. Summing up the empirical results, the governing authority of Ukraine has to take into account crowding-in and crowding-out effects while setting up a pro-investment fiscal policy in the short- and medium-run.

Keywords: *economic growth, public investment, crowding-in effect, crowding-out effect, VECM.*

Fig.: *5.* ***Tbl.:*** *3.* ***Formulae:*** *4.* ***Bibl.:*** *20.*

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УДК [338.1:336.531.2]:519.246.85
JEL Classification: O47; H54; C22; C53

Швець С. М. Державні інвестиції та економічне зростання: результати VECM моделювання для України

Статтю присвячено дослідженню впливу державних інвестицій на економічне зростання в Україні з використанням VECM інструментарію. Метою дослідження є тестування впливу державних інвестицій на динаміку ВВП в Україні у розрізі коротко- і довгострокового періодів за допомогою VAR моделювання. У роботі подано характеристику ефектів залучення і витіснення як побічних наслідків проінвестиційної державної експансії у розвинених країнах і країнах, що розвиваються, /у контексті типових методів дослідження з обраної тематики. Аналітично обґрунтовано, що державні інвестиції є вагомим чинником зростання у короткостроковому періоді. Результати VECM моделювання підтвердили позитивний ефект державної інвестиційної експансії, який у максимумі додає 0,8 відсоткових пункти до зростання ВВП /у кінці першого року генерованої імітаційної реакції на шок зростання державних інвестицій. Задекларовано присутність ефекту залучення, який залишається стійким починаючи з другого кварталу проведеної імпульсної сценарної оцінки і відповідає збільшенню приватних інвестицій у відсотках до ВВП на 0,4 відсоткові пункти. Підтверджено існування ефекту витіснення, який набуває помітних ознак у першому кварталі, зумовлюючи зниження приватних інвестицій у відсотках до ВВП на -0.5 відсоткових пункти за підсумками моделювання імітації шоку внутрішнього державного боргу. Ефект витіснення залишається актуальним упродовж півторарічного періоду. Підсумовуючи результати проведеного емпіричного дослідження, керівний істеблішмент України повинен взяти до уваги ефекти залучення і витіснення при розробці проінвестиційної фіскальної політики на коротко- і середньострокову перспективи.

Ключові слова: *економічне зростання, державні інвестиції, ефект залучення, ефект витіснення, VECM моделювання.*

Рис.: *5.* ***Табл.:*** *3.* ***Формул:*** *4.* ***Бібл.:*** *20.*

УДК [338.1:336.531.2]:519.246.85
JEL Classification: O47; H54; C22; C53

Швец С. М. Государственные инвестиции и экономический рост: результаты VECM моделирования для Украины

Статья посвящена исследованию влияния государственных инвестиций на экономический рост в Украине с использованием VECM инструментария. Целью исследования является тестирование влияния государственных инвестиций на динамику ВВП в Украине в разрезе краткосрочного и долгосрочного периодов с помощью VAR моделирования. В работе приведена характеристика эффектов привлечения и вытеснения как побочного следствия проинвестиционной государственной экспансии в развитых и развивающихся странах в контексте типичных методов исследования касательно выбранной тематики. Аналитически обосновано, что государственные инвестиции являются важным фактором роста в краткосрочном периоде. Результаты VECM моделирования подтвердили положительный эффект государственной инвестиционной экспансии, который в максимуме добавляет 0,8 процентных пункта к росту ВВП в конце первого года сгенерированной имитационной реакции на шок роста государственных инвестиций. Задекларировано присутствие эффекта привлечения, который остается устойчивым начиная со второго квартала проведенной импульсной сценарной оценки и соответствует увеличению частных инвестиций в процентах к ВВП на 0,4 процентных пункта. Подтверждено существование эффекта вытеснения, который приобретает заметные признаки в первом квартале, вызывая снижение частных инвестиций в процентах к ВВП на -0.5 процентных пункта по результатам моделирования имитации шока внутреннего государственного долга. Эффект вытеснения остается актуальным в течение полуторагодовалого периода. Подводя итоги результатов проведенного эмпирического исследования, руководящий истеблишмент Украины должен принять во внимание эффекты привлечения и вытеснения при разработке проинвестиционной фискальной политики на кратко- и среднесрочную перспективы.

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Ключевые слова: экономический рост, государственные инвестиции, эффект привлечения, эффект вытеснения, VECM моделирование.

Рис.: *5.* ***Табл.:*** *3.* ***Формул:*** *4.* ***Библ.:*** *20.*

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Introduction

Despite the fact that hardly anything left in advancing the research topic dedicated to a particular place of the capital factor in economic growth, public investment is still in the center of the world economic debates. The debates usually focus on productivity-enhancing public investment in short- and long-run growth in relation to incentives of private capital accumulation. Normally, the public investment can sustain growth in two ways: directly and indirectly. The direct impact on the growth considers public capital as a driving force of aggregate demand in short-run, and as a factor of production in a longer perspective. The indirect impact of public investment is proved by augmenting investments capability of the private sector. Among spillovers of the public investment expansion are crowding-in and crowding-out effects. The crowding-in effect measures adjustment rate of infrastructure facility by reducing private start-up costs. The infrastructure cost is usually associates with installation and development of health, education, airports, roads, water supply, power generation and transmission, etc. A well-developed infrastructure facility increases the marginal productivity of private capital and encourages undertaking more business projects to boost the private sector development. The crowding-in effect usually compares with growth in the case of economic slack, accommodative financial conditions, sizable investment needs, and sound infrastructure [1, p. 27].

The crowding-out effect opens up a case when in the money market the demand for loans to fund public capital expenditures reduces investment capacity of the private sector. If demand for credits rises, the cost of loans services rises too, so there is a less incentive for the private sector to borrow in the financial market. The crowding-out effect has a distinct position if a high fiscal deficit, tight monetary policy, large government debt, and limited economic slack are present. The other possible results of the growing burden of public debt are excessive taxes levied on business that objectively limit a rate of public investment return and postpone or even decline longer-term strategic projects. Apparently, there are more spillovers of the crowding-out effect concerning the expansion of public products to compete with those produced by commercial firms. The negative consequences of the effect can be more powerful when subsidized public enterprises are not so efficient in comparison with their private counterparts [1, p. 28].

Public investment as a share of capital factor endowment has a noticeable demand-side effect in the short-run and supports a stronger growth (supply-side effect) in the longer term. The demand-side effect is usually compared with a fiscal multiplier, which is country region, time, and episode-specific. A common practice is that the fiscal multiplier is relatively higher during an economic slump and matches a lower point during an economic slack corresponding to weak public finances. The source of financing is also an important issue. There are different stories of whether to support the public investment growth by using a debt instrument, or increasing revenues, or cutting other expenditures, or mixing the mentioned measures. Another stipulation to be taken into account is the efficiency of public investment. The efficiency increases if the project selection is more strategically planned, well-prioritized, rigorous, transparent, and implemented by several strengthened institutions [2].

In respect to a large number of empirical results, there is still no final conclusion of whether public investment impact on growth is positive or negative. Basically, the results are different in terms of time period, country region, capital data, and methods applied. For the purpose to address such a particular issue, Bom and Ligthart in their complex influential study, based on a sample of 578 estimates taken from 68 papers between 1983–2008, determined an output elasticity of public capital, the elasticity being equal to 0.083 on average in the short-run with a rate of return 17 % and to 0.122 in the long-run with a rate of return 25 %. The declared estimates fell in the vicinity of zero, the vast majority of them being positive (464 positive values compared to 114 negative ones) [3]. The presented outcomes emphasized a profound role of public capital as a constituting item of the total value of capital factor endowment, which corresponded to a persistent supply-side effect. A new study of the same authors based on a sample of 127 estimates from 19 papers published in 2009-2016 confirmed the previous results with more reliable conclusions. The average output elasticity of the public capital, weighted between short- and long-term horizon, after filtering out publication bias, amounted to 0.128 and was slightly higher compared to 0.102 in the previous work [4]. Another recent study based on 2000 estimates from 145 papers has reported the average value of the short- and long-term elasticity being equal to 0.13 and 0.16 respectively. In particular, the study emphasizes a critical role of the methodology chosen and publication bias, which affects the divergence of results (Fig. 1).

There are three common approaches to estimating public investment impact on economic growth: production and cost function procedure, macroeconomic structural models, and Vector Auto-Regressive (VAR) instruments. The production and cost function approach demonstrates good results, assuming that the more investment is made, the better. The

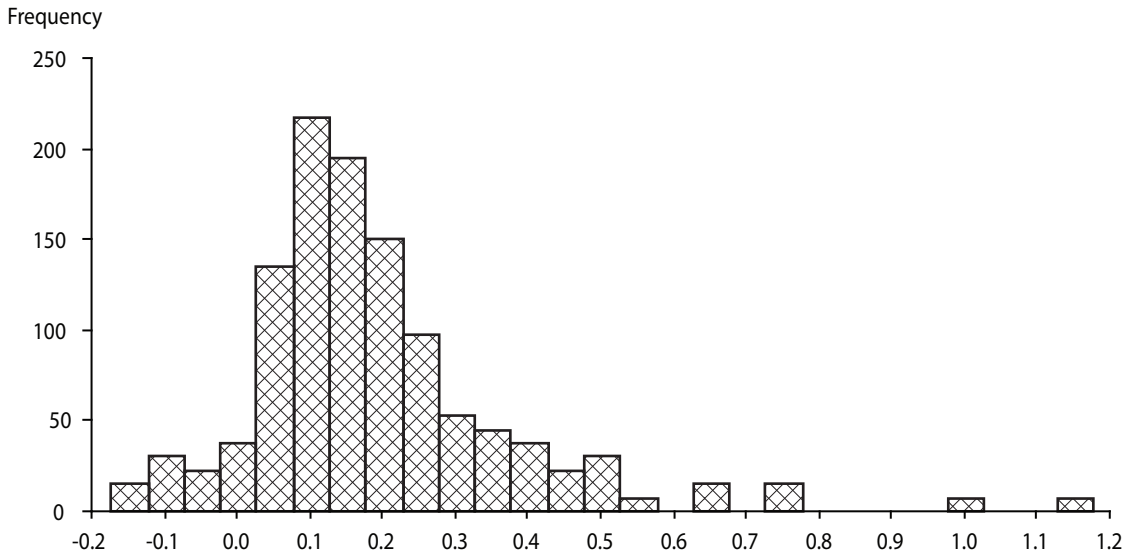

Fig. 1. Histogram of the output elasticity of public capital

Source: [20]

given statement is more effective if imposing no restrictions on investment capacity, and the only problem is how to invest in the most productive way. As a result, the elasticity of output with respect to public investment doesn't take into account possible consequences of capital accumulation while using different sources of funds, including debt burden and fiscal policy dilemma between current and capital expenditures. There also may be different feedback on public investment growth at the macro level. In case the government authority initiates a rise of tax rates to finance additional public capital expenditures, the expected macro effect will be mixed and the output growth mitigated.

Starting to consider the above-mentioned cases and allowing for a possible macro-level response, the two methods are commonly used: structural models and VAR instruments. Based on different theories of growth, the massive class of macroeconomic structural models has no detrimental outcomes associated with feedback allowance. It is because the method incorporates public capital stock as an additional production factor. To achieve the study goal, the public capital factor is often ranked using calibration or imposing specific restrictions on the data. The overall effect of empirical verification frequently transforms into distortions of real linkages among the indications. As a result, the public capital is proved to be a little more productive compared to the results obtained using other methods. The given problem deals with the shortcoming of adjusting procedure and demonstrates new qualities of the indicators, basically being a matter of discussion.

VAR-models stand for an estimation approach with a direct (reduced form) and indirect order. The inherent causal links of production function procedure allow for feedback in VAR-models. Thus, the causal links transform into relationships in multiple directions. The essential quality of VAR-models is their ability to develop scenarios in short- and long-term horizons simultaneously. The other benefits of the VAR approach are a flexible number of relationships in the long-run estimation, and evolvement of all interactions of the variables in response scenarios. The shortage of the given method is the imposing of data limitation on the number of regressors that is not critical, and occasional problems to follow the results with consideration for a distinct economic framework.

Public investment study and VAR results. The VAR approach, proposed by Sims, has been widely used since 1980. The method is remarkable, imposing as little of economic theory as possible with no functional dependencies. One of the empirical applications of this instrument to study public investment impact on growth was efficiently used by Pereira in 2000. The incentive of putting aside a well-known OLS estimation because co-integration shortage forced the author to apply VAR-instrument in verifying different effects of public investment and its compound variables. The results based on annual USA data from 1956 to 1997 have demonstrated a common positive effect with the highest rate of return of 16.1 % for sewage systems and the lowest one 8.9% – for public buildings [5]. In the following work, Pina and Aubyn slightly modified the technique by expanding the study topic and incorporating private investment. Having limited public investments as the only influential factor, the results logically fit into half of the specified sample of consolidated studies [6].

The other paperwork study was aimed at considering Sweden economy and focused on a revision of the Solow model. The VAR results verified a mixed indication of public investment impact when testing positive influence by boosting private investment growth [7]. The positive impact of public investment on growth was also determined using VAR approach in the study prepared by Kamps for a range of 22 OECD countries for 1988–1991. The empirical results of impulse-response scenarios proved to be positive for the most countries up to 25 year horizon.

The values for the quantitative characteristics were not so high in the case of using the production function procedure. The resulting characteristics of changes in production volumes

are statistically significant in half of the cases within the confidence interval of 68%. In contrast, the long-term employment dynamics, as an impulsive response to the public investment shock, is not a statistically significant value [8]. The group of other researchers in the more recent study based on a sample of 20 OECD countries selected by Kamps, but for a protracted period up to 2013, have reexamined importance of public capital for a long-run growth using country-specific recursive VARs. Despite the negative impact of the global financial crisis, including the spread of the latter on the euro zone and the aggravation of the sovereign debt problem, the final assessment legitimizes the positive consequences of the shock from the pro-investment state expansion, taking into account the inability to retain a low level of capital investment over a long period. [9]. In another paper, scientists Afonso and Aubyn explored crowding-in and crowding-out effects for 17 OECD economies using VAR analysis for 1960-2014. Taking into account a common positive impact of public investment on growth for the most countries, the results of impulse-response scenarios have confirmed an evidence of the crowding-out effect only for six countries: Belgium, Ireland, Finland, Canada, Sweden, UK. At the same time, the marked crowding-in effect was found to be present in 15 OECD economies [10].

There should be mentioned an interesting VAR approach suggested by Auerbach and Gorodnichenko in 2011, under which public investment shock is associated with forecast errors in connection with the ratio of GDP to public investment spending. The method explores fiscal multiplier data varied in terms of economic regimes (especially for the economy in recession and expansion), and state issues [11]. In a complex IMF study based on the suggested approach, the researchers tested the public investment productivity on a sample of 17 OECD economies for 1985–2013. As indicated in the study, among the main factors to be taken into account in addressing the issues were: the degree of economic slack, monetary accommodation, efficiency of public investment, and way of financing the public investment (using debt instrument or being budget neutral)[2] [12, p. 5].

In the context of the empirical results obtained in the above mentioned paperwork study, during the periods of low growth the rise of government investment spending by one percentage point of GDP has brought to 1.5 % of output increase in the first year and 3.0 % – in the medium term. On the contrary, during the periods of high growth, the long-term effect of public investment shock was not statistically significant. The public-debt-to-GDP ratio was not a critical issue (especially during periods of low growth), since the ratio shifted lower by 0.9 percentage points in the short-run and 4.0 percentage points in the medium-run. Nonetheless, in periods of high growth, the public-debt-to-GDP ratio was larger and not statistically significant. So, the boosting effect of GDP growth in advanced economies was higher compared to the public debt expansion [12, p. 10–11].

The crowding-in effect of public investment was not statistically significant, being moved rather by the drivers of GDP growth. The crowding-out effect became noticeable only if the economy had a high growth rate. The positive impact on growth was on average four times larger in countries with high efficiency of public investment followed by reduction of public-debt-to-GDP ratio when the reinforcing debt burden issue in economies with low efficiency. The expansion of debt-financed public investment was more productive in all cases compared to the ones using budget-neutral projects. The rise of private investment followed by crowding-in effect proved to be more distinct in a medium-term, assuming the public investment was debt-financed, while the effect was almost neutral for the different modes of financing in the short-run [12, p. 11–14].

The case for developing economies was somewhat different from that for developed ones in terms of economic dynamics, monetary condition, and efficiency of public investment. To that extent, the main features for developing economies were a lack of economic stability, weak monetary accommodation, and low efficiency of public investment. The mentioned factors did a false favor in lessening the productivity of public investment in developing economies. Along with the obtained in the work simulation results, the short- and medium-run output effects proved to be lower, and there was a statistically significant augment of public-debt-to-GDP ratio. If the ratio was very high with no clarity in identifying infrastructure needs, the public investment returns were vague and financial costs rose followed by a growing debt burden. There was considered an issue of infrastructure bottleneck, which can be used in a more efficient way depending on rational appraisal and proper projects selection. In the most cases for developing economies, the selection procedure was engaged in temporary political gains and low transparency, moving away from a priority of productive projects [13, p. 85, 89–90]. The analytical summary Fiscal Monitor prepared by IMF, dated April 2014, states reducing all inefficiencies in public investment projects by 2030 would provide the same boost to capital stock as increasing public investment by 5 percentage points of GDP for emerging market economies, and 14 percentage points – for low-income countries [14, p. 36].

Public investment in Ukraine: the stylized facts. There were two deep recessions along the recent decade in Ukraine, which are linked to the crises of 2008–2009 and 2014-2015. The decrease of GDP over the given four years amounted in total to more than -30 %. The situation is not so optimistic because in the period between the crises from 2010 and 2013 the cumulative uplift of the GDP was about three times lower – 9.6 %. After the crisis of 2014-2015, the GDP growth in 2016- 2017 did not cross 3 percentage points (2.4 % and 2.5 % respectively), while the same indicator in 2010 after the crisis of 2008–2009 was 4.1 %. So, under the current situation, quick and proactive measures are in urgent need to accelerate economic growth. One of the active instruments used to boost economic growth is the deployment of investment. In view of a present risk associated with the local military conflict in the Eastern region of the country, foreign investment is unlikely to be welcomed at full extent in the near future.

The real hope for the domestic investment is an immediate agenda, and the public share of them is of great importance because of the demand-side effect which augments a positive short-run impact on output.

In practice, the investment dynamics usually accompanies the GDP trend that comes from production function approach. According to retrospective analysis, the investment

[2] Budget-neutral means the public investment is financed by raising taxes or cutting other budget expenditures.

dropped down to roughly -70 % during the two following crises in 2008–2009 and 2014–2015 in Ukraine. After objective retardation, the public investment followed the common downward trend and dropped down to -41.5 % in 2009. However, it should be noted that the highest growth rate of 22.4 % of the public investment during the recent decade was in 2011 when the share of public funds in investment classification by types of financing was the greatest (Fig. 2). The last statement confirms a significant place of public investment in the range of factors which can facilitate capital accumulation in Ukraine. In line with the survey conducted by the Economic Department of the European Investment Bank in 2013, the public funds share in the investment structure within the EU region was approximately 12 % during the relatively stable period 2004-2007. The given data corresponded with those for Ukraine in 2011, while the share of public funds in the investment structure by types of financing were 11 % [15, p. 143].

Against the backdrop of economic slump accompanying the recent crises, the rapid public debt growth in Ukraine came out to the fore. The debt increased more than 3.5 times in 2008-2016 up to 70 % of GDP, and the internal share grew more than 4.5 times, exceeding 28 % of GDP. Given rapid progress and negative consequences of the crises of 2008-2009 and 2015-2016, which formed a common downward trend in output, a more detailed attention was paid to Ukraine by the international research organizations. In this respect, there was an outstanding data comparison in the regional economic bulletin prepared by the IMF in November 2016 and dedicated to the public administration efficiency and sustainable growth in the central, eastern and south-eastern Europe. According to the ranking indicator calculated in the bulletin in terms of public investment as a percent of GDP, Ukraine occupied the last place in the region with 1 % at the end of 2015. In this group, the average EU-15 amounted to 3.8 %, while the score of Russia and Moldova was 2.5 % [16, p. 34]. As stated another IMF study, the index of public investment efficiency in Ukraine in 2011 reached 1.9 points out of 4 possible, which corresponded to the 21st place in the ranking among 71 developing countries falling behind such economies of the former Soviet bloc as Serbia, Belarus, Moldova, Kazakhstan, and Armenia [17, p. 27].

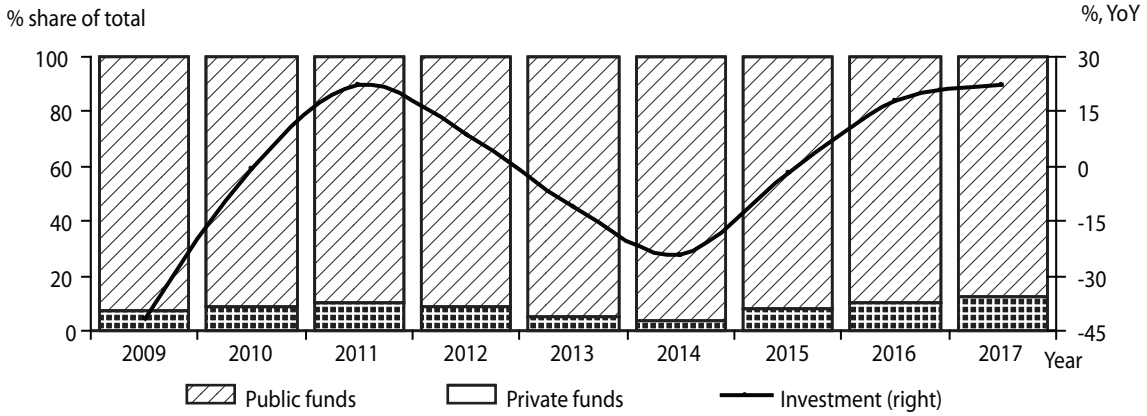

Fig. 2. Investments structure by types of financing in Ukraine for 2009–2017

Source: State Statistics Service of Ukraine

Methodology and data. The methodology used to study public investment and growth is based on the VAR approach – widely distributed instrument in quantitative macroeconomic modeling and practically examined in details in the paper of Ouliaris et al. [18]. The generic algorithm consists of some main steps from stationary diagnostics to short- and long-run estimation procedures. In most cases, the stationary diagnostic procedure resembles the tests known as Augmented Dickey-Fuller (ADF) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS). By obtaining the results of the tests, if the result is positive and variables are stationary, it is possible to develop Ordinary Least Squares (OLS) models or employ Vector Auto-Regression (VAR) and Structural Vector Auto-Regression (SVAR) frameworks.

In case the chosen variables are not stationary at I(0) but cointegrated at I(1)[3], it is possible to use Vector Error Correction Model (VECM) or Structural Vector Error Correction Model (SVECM). While proceeding with VAR (VECM) model, it is necessary to determine a critical lag structure to be aware the chosen variables are correlated up to the very lag order. The given lag order is used while transforming individual time series to a VAR (VECM) model or more complex structural one. The algorithm of applying VAR (VECM) frameworks considers the verification of VAR inverse roots and determination of cointegration order (for VECM); the latter is performed by using Johansen and Engle-Granger tests. The Johansen test permits more than one cointegrating relationship and is more widely applicable than the Engle-Granger one. The final action of VAR (VECM) modeling is the development of impulse-response scenarios to determine long-run after effects as a result of short-run shocks. This operation deals with Cholesky decomposition procedure, so the results of the impulse-response scenarios follow an order of variables in the decomposition list.

There are several positive and negative issues of using OLS, VAR and VECM models. The weakest side of the simplest one, the OLS technique, is the inability to capture both short-run and long-run dynamics. In other words, it is difficult to build a good OLS regression to be useful in evaluating short-run and long-run dynamics at the same time. On the contrary, according to the VAR (VECM) approach, what is addressed

[3] I(1) means that variables are transformed using mathematical operations like first difference, taking natural logarithm etc.

is not an actual problem, and it is possible to elaborate policy measures based on the results obtained for the timeline from the short- to long-term horizon. That is why the VAR (VECM) instrument was used to analyze the scope and upshots of public investment impact on the economic growth in Ukraine.

There are at least three different definitions to be considered in selecting public capital data. The first one deals with the capital property of public authorities at all levels of administration. The second one is associated with productive capital, commonly aimed at health, education, housing, energy, communication, and transport infrastructure. The last definition of public capital usually concerns infrastructure facilities. In the current study, the capital data of public investment are represented by quarterly time series and classified as state and local government funds in the capital investment structure by types of financing. The private investment is obtained by subtracting the given sum of the state and local government funds from the total amount of the capital investment. In modeling, the internal public debt is rendered by the component of government bonds in circulation, since it comprises a significant share (about 98 %) of the given debt indicator.

The data retrospective fits the sample from Q1 2006 to Q4 2017. The goal of the empirical part of the study is to assess public investment impact on GDP dynamics. For this purpose, the mentioned impact factor should be examined in terms of different aspects. According to the first scenario, it is important to inspect public investment as a capital factor of economic growth. There are two possible spillovers of the given scenario implementation concerning the presence of crowding-in and crowding-out effects. If the possibility is a case, the second and third scenarios are set to examine the mentioned effects. The purpose of the second scenario implementation is to verify the crowding-in effect by testing the relationship between public and private investments. The third scenario is used to prove public debt impact on private investment. The given scenario conditions contemplate public investment growth and internal public debt to finance increasing budget expenditures.

According to the prescribed scenarios, three VAR equations are specified and can simplistically be represented as[4]:

$$VAR1 = (GDPr\_sa, InvPb\_sa), \quad (1)$$

$$VAR2 = (Inv\,Pr\_sa, InvPb\_sa), \quad (2)$$

$$VAR3 = (Inv\,Pr, DebtInt, sd). \quad (3)$$

Where: *GDPr_sa* is a seasonally adjusted[5] data of GDP measured Y-o-Y, *InvPb_sa* is a seasonally adjusted data of the ratio of public investment to GDP, *InvPr_sa* is a seasonally adjusted data of the ratio of private investment to GDP, *DebtInt* is a ratio of the amount of internal public debt for the calculated quarter and the amount of GDP for the four quarters before, including the current one, *sd* is seasonal dummies.

We performed the check procedure for stationarity using ADF and KPSS tests[6]. The results obtained in two cases including constant, and constant and deterministic trend have indicated the five selected variables managed to be I(1), being stationary for the most part in the first difference form (Tab. 1). That is why to proceed the empirical part of the study we followed VECM approach.

The general form of a VECM model can be written as follows:

$$\Delta Z_t = \Pi Z_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Z_{t-i} + \eta_t + \mu_t, \quad (4)$$

Where: ΔZ_t is a vector of endogenous I(1) variables in first difference form, Π is the long-run parameter matrix, whose rank determines the long-run relationship between the variables, p is the chosen VAR order, Γ_i is the estimable parameters, η_t is a disturbance term assumed to be an i.i.d of a Gaussian process with zero mean and variance Ω (symmetric positive definite matrix), μ_t is a vector of white noises with zero mean and constant variance.

To determine the VAR order (p) for VECM models corresponded to equations (1-3), we employed three criteria proposed in the econometric literature based on AIC (Akaike information criterion), BIC (Bayesian information criterion), and HQC (Hannan-Quinn information criterion). We also performed specification tests to check whether for the chosen lag length (equaled two) the residuals were normally distributed and free from autocorrelation and homoscedastic. The results of the autocorrelation test were negative for all VAR at 1 % level and better. The presence of homoscedastic could be rejected at 10 % level for VAR2 and at 1 % level and better for VAR3 but could not be rejected for VAR1. The residuals were normally distributed at least at 5 % level for all VAR (Tab. 2).

According to Johansen test, both trace and max-eigenvalue statistics indicated two cointegrations at least at 5 % level of significance for VAR1, and 10% and 1% for VAR2 and VAR3 respectively. So, with 10 % significance level we could suggest there are two long-run cointegrating equations for three VAR with lag length equaled two.

Results. The benchmark field encountered three variants of VECM models to study public investment impact on the economic growth in Ukraine. The purpose of VECM1 implementation, which consisted of VAR1 components, was to verify public investment impact on GDP dynamics. The upshot of impulse-response scenario has represented a positive impact of public investment with maximum GDP growth by 0.8 percentage points in the fourth quarter. The value was close to the similar results (about 0.7) for the case of Poland obtained for the sample of 1999-2007 [19]. The only difference was the duration of the positive mark of the impulse-response scenario, which was shorter in Poland (3 quarters opposed to 4 in Ukraine). The significant positive effect lasted over five quarters in consequence and collapsed with a small oscillation. The presented results represented confirmed the demand-side short-run effect of public investment impact on output. Thus,

[4] The sources of statistics of the descriptive data are: the State Statistics Service of Ukraine, the State Treasure of Ukraine, and the Ministry of Finance of Ukraine.

[5] Here and afterward the seasonal adjustment procedure performed using TRAMO/SEATS algorithm.

[6] All modeling computations produced in the work were carried out in the environment of applied econometric programming tool GRETL. It is a complex free of charge (GPL license) econometric package that include almost all the necessary programming operations to maintain quantitative macroeconomic modeling.

Table 1

Unit Root Test

Variables	ADF				KPSS			
	Level		1st Difference		Level		1st Difference	
	Without Constant	With Constant & Trend	Without Constant	With Constant & Trend	Without Constant	With Linear Trend	Without Constant	With Linear Trend
GDPr_sa	-3.249***	-3.244*	-3.524***	-3.682**	0.189***	0.075***	0.051***	0.039***
InvPb_sa	-2.408**	-3.812**	-9.148***	-9.002**	0.973	0.127**	0.173***	0.072***
InvPr_sa	-1.597	-4.725***	-2.46**	-8.01***	1.092	0.074***	0.109***	0.077***
InvPr	-1.694*	-3.466**	-2.921***	-4.364***	1.049	0.079***	0.257***	0.203***
DebtInt	0.745	-2.763	-4.56***	-4.784**	1.298	0.119***	0.12***	0.108***

Note: ADF test for stationary is performed using Akaike criterion for maximum lag order and MacKinnon critical values. KPSS test for stationary is performed using lag truncation parameter equaled 3. "*", "**", and "***" denotes rejection of the null hypothesis of a unit root for ADF test correspondingly at the 10 %, 5 %, and 1 % levels of significance, and not rejection of the null hypothesis of stationarity for KPSS test correspondingly at the 1 %, 5 %, and 10 % levels of significance

Table 2

Specification of VAR orders

	Order minimizing			Chosen order	Specification tests (p-values)		
	AIC	BIC	HQC		Autocorre-lation[a]	Heterosce-Dasticity[b]	Norma-lity[c]
VAR1	2	2	2	2	0.3257	0.0033	0.0413
VAR2	2	1	2	2	0.2974	0.0264	0.0007
VAR3	2	1	2	2	0.5196	0.9299	0.0172

Notes: the maximum order considered equals 4. The underline VECM models contain constants, trends, and seasonal dummies: VAR1 contains unrestricted constant and trend, and VAR3 contains unrestricted constant, trend and seasonal dummy dq4 (1 if quarter equals 4, and 0 otherwise) as an exogenous variable.

[a]Based on LM test (null hypothesis: no serial correlation). [b]Based on autoregressive conditional heteroscedasticity (ARCH) test (null hypothesis: there is no ARCH). [c]Based on Doornik-Hansen test (null hypothesis: there is a multivariate normality).

Table 3

Johansen Cointegration Test

	Trace[a]		Lmax[b]	
	$H_0: r = 0$	$H_0: r = 1$	$H_0: r = 0$	$H_0: r = 1$
VAR1	25.303 [0.0038]	5.5922 [0.018]	19.711 [0.0185]	5.5922 [0.018]
VAR2	16.417 [0.009]	3.1611 [0.0876]	13.256 [0.0201]	3.1611 [0.0895]
VAR3	42.645 [0.0000]	7.9677 [0.0048]	34.678 [0.0000]	7.9677 [0.0048]

Notes: p-values in square brackets.

[a]Trace test checks the null hypothesis of r cointegrating vectors against the alternative hypothesis of n cointegrating vectors. [b]The maximum eigenvalue test checks the null hypothesis of r cointegrating vectors against the alternative hypothesis of (r + 1) cointegrating vectors.

the public investment proved to be a very profound factor of economic growth in the short-run in Ukraine. Furthermore, the one-quarter delay in the simulation results was due to a possible presence of the crowding-out effect of public investment to be completed later (Fig. 3).

The VECM2 model which consisted of VAR2 components was developed to examine the crowding-in effect of public investment. According to the obtained results of impulse-response scenario, it appeared to be a decent crowding-in effect fully accelerated after the first quarter of the shock in public investment measured as a ratio to GDP. In the first quarter, a small decline in private investment measured also as a ratio to GDP was presented due to a possible presence of a crowding-out effect to be completed later. The transmission mechanism was rather persistent after two years of the shock, contributing 0.4 percentage points to the ratio of private investment to GDP, during four years of the protracted forecast horizon (Fig. 4).

The reason to develop the VECM3 model which consisted of VAR3 components was to detect a crowding-out effect

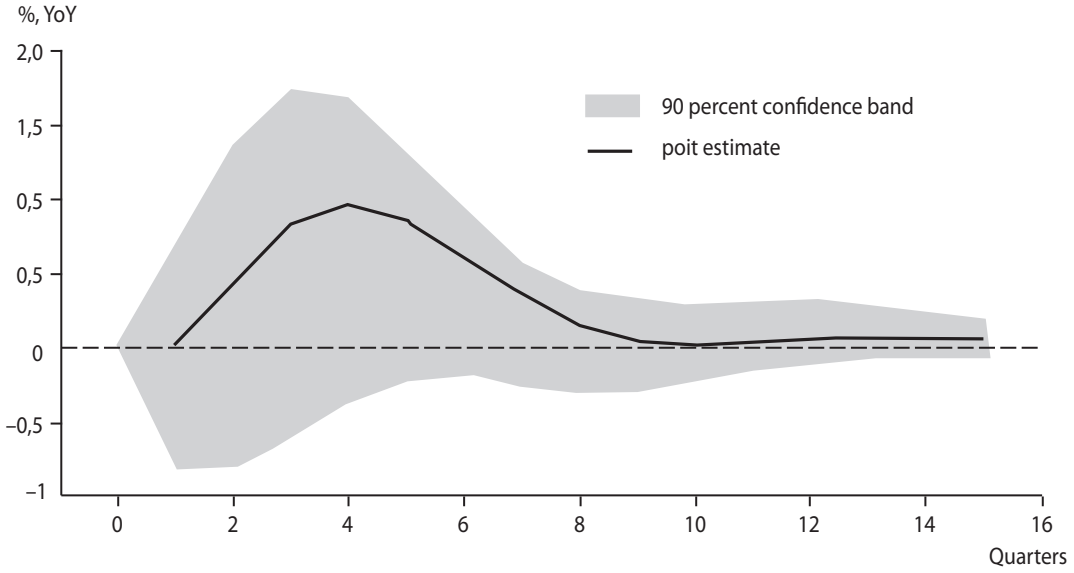

Fig. 3. Response of GDP to the shock in public investment

Source: the results of VECM1 impulse-response scenario.

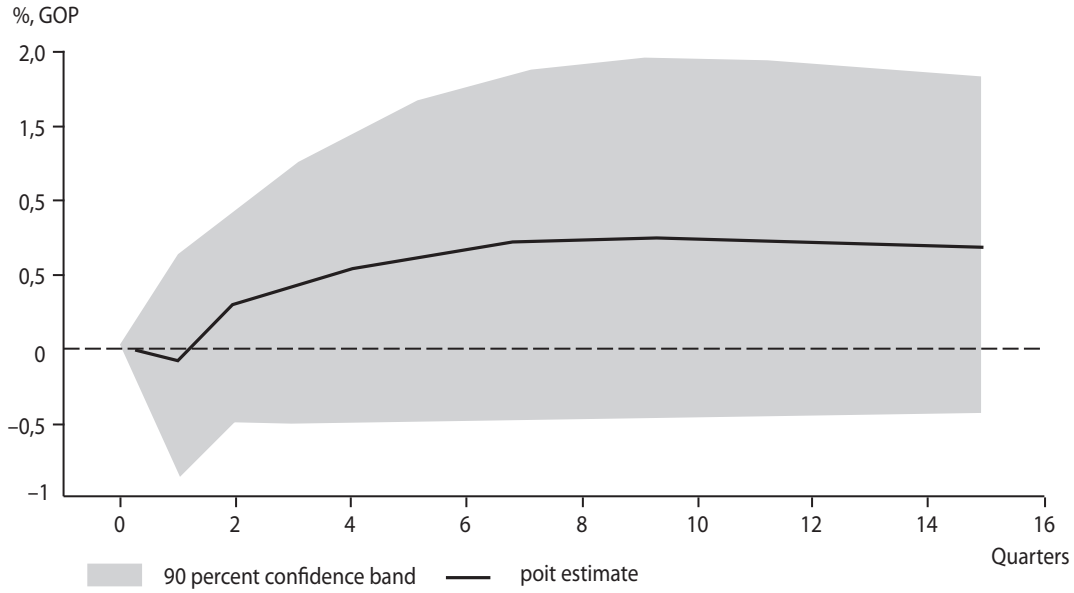

Fig. 4. Response of private investment to the shock in public investment

Source: the results of VECM2 impulse-response scenario.

in terms of impact scope and duration. In case of VECM1 and VECM2 implementations, it was an evidence of the given effect in the first quarter of impulse-response scenario. The VECM results of the third variant have confirmed a presence of the crowding-out effect. The private investment as a ratio to GDP demonstrated a sharp decline down to -0.5 percentage points in the first quarter after the shock in an internal public debt induced by expansion of public investment. The overall negative effect stretched out over one and a half year in consequence and collapsed with a small oscillation (Fig. 5).

However, it should be noted that persistent results of the crowding-out effect, obtained in VECM3 impulse-response scenario, may be debatable considering the rate of private investment decline followed by appropriate internal public debt growth. The verified level of the mentioned growth in Ukraine as of the end of 2017 may hardly cross the point of a tenth of a percent and the corresponding decrease of private investment ratio to GDP is expected to be no more than -0.1 percentage points. The given outcome is very similar to that, obtained in VECM2 impulse-response scenario.

Conclusion. Public capital as one of the production factors is of great importance for economic growth. Complex studies performed by various researchers have verified that a prevailing positive elasticity of public capital to output amounted 0.1 on average. There is a difference of public investment impact on growth in developed and developing econo-

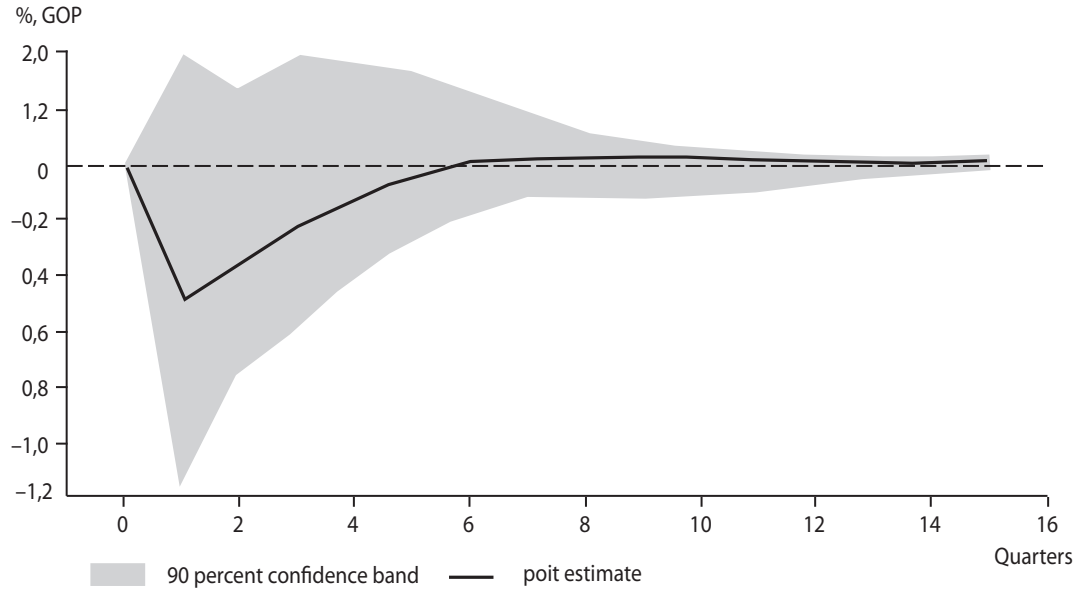

Fig. 5. Response of private investment to the shock in internal public debt

Source: the results of VECM3 impulse-response scenario.

mies in terms of economic dynamics, monetary condition, and efficiency of public investment. The least stable and more magnified economic dynamics of developing economies proves a demand-side factor to be very productive in short-run.

The public capital impact appears to be more significant in developed countries, while the accommodation is better than that in developing economies. The efficiency of public investment is usually poor in developing economies, which results in weak performance in covering infrastructure needs. There is an issue of infrastructure bottleneck that may be used in a more effective way depending on rational appraisal and proper project selection. According to the ranking indicator calculated by the IMF staff in terms of public investment as a percent of GDP, Ukraine occupied the last place among the countries of in the central, eastern and south-eastern Europe with 1 % at the end of 2015.

The VECM results obtained in the study have confirmed a positive correlation between public investment and economic growth in Ukraine. The public investment proves to be a very profound factor of growth in short-run. The upshot of impulse-response scenario has represented a positive impact of public investment with maximum GDP growth by 0.8 percentage points detected at the fourth quarter. The crowding-in effect became persistent starting from the second quarter of the impulsive response to public investment shock, contributing 0.4 percentage points to the growth of the ratio of private investment to GDP over the four-year period of the forecast horizon. According to the impulse-response scenario, the crowding-out effect was an issue up to the first quarter. It was a sharp drop down up to -0.5 percentage points of private investment ratio to GDP after internal public debt shock. The active phase of the crowding-out effect lasted no more than one year and a half.

Concerning the obtained VECM results, the crowding-in and crowding-out effects have to be taken into account by the governing authority of Ukraine while setting up a pro-investment fiscal policy in the short- and medium-run.

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