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IS PUBLIC CAPITAL MORE PRODUCTIVE THAN PRIVATE CAPITAL: EVIDENCE FROM LATVIA 1995-2009

The purpose of this article is to estimate private and public capital contribution to economic growth in Latvia 1995 - 2009 using production function approach. It was found that both private and public capital have positive and statistically significant impact on economic growth and labour productivity. Moreover, public capital is 1.6 times more productive than private capital. Nevertheless, private capital accumulation affects technical progress through "learning by doing" externality. It was shown that total factor productivity and private capital formation were the main driving forces of economic growth in Latvia 1995 – 2009. It was pointed out that production function should be augmented with cyclical variables when output is constrained by the aggregate demand which is a case for Latvia in 2008-2009.
JEL: C5; H4; H54; 047; 052

1. Private and Public Capital Role in Economic Growth

Since Barro [1, 1988] introduced an augmented production function by dividing physical capital stock into private capital and public capital, much empirical research has been made on this topic. However, by this time no clear-cut answer was found on whether public capital statistically significant affects economic growth and whether it is more productive than private capital. In dependence of production function form, assumptions about returns to scale, data and a country considered, researchers came to different results. As Naqvi put it, "at least as many studies report that public capital is more productive than private capital, as report the reverse" [11, 2003, page 4]. For example, according to Naqvi [11, 2003, page 2], "public capital is at least as productive as private capital under the assumption of exogenous technology, and significantly more productive than private capital under the alternative assumption of endogenous technology evolving as an externality to capital accumulation". Moreover, Khadharoo and Seetanah [8, 2000] argue that public capital positively affects private capital accumulation. On the contrary, Holtz-Eakin [7, 1994] concludes that GDP elasticity to public capital is close to zero and is not statistically significant. Besides, Macdonald [9, 2008] says that public capital

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role in economic growth could be underestimated because of its strong correlation with total factor productivity. At the same time, Henderson and Kumbhakar [6, 2005] claim that GDP elasticity to public capital is not constant over time and proposed non-parametric production factors elasticity estimation methods.

This paper provides an empirical evidence on the public and private capital contribution to economic growth in Latvia during 1995-2009 period using production function approach. The remaining of this section provides theoretical foundations while section 2 focus on data and section 3 shows production function estimates and discuss an outcome.

Production function shows gross domestic product (Y) dynamics in respect to capital stock (K) and labour (L). Technical progress is usually considered exogenous and depends only to time period. This paper estimates eight production function specifications, constructed by the other researchers in order to examine important insights of the production process and choose the best specification among alternatives for Latvia.

Most frequently production function is estimated in the following form:

$$\ln Y = \hat{\beta}_0 + \hat{\beta}_1 t + \hat{\alpha}_K \ln K + \hat{\alpha}_L \ln L \qquad (1)$$

where $\hat{\alpha}_K$ is estimated GDP (Gross Domestic Product) elasticity in respect to capital,

$\hat{\alpha}_L$ - estimated GDP elasticity in respect to labour,

t - time period,

$\hat{\beta}_0$ - positive constant that shows country initial technology level,

$\hat{\beta}_1$ - estimated average technical progress contribution to economic growth during one period, percentage points.

Empirical research usually assumes constant returns to scale in respect to capital and labour together $(\alpha_K + \alpha_L = 1)$. According to this assumption, if capital and labour grow by 1% each and technological progress remains constant, GDP grows exactly by 1%. In its turn, if only either labour or capital grows by 1%, GDP grows by less than that. Production function in this case becomes:

$$\ln Y = \hat{\beta}_0 + \hat{\beta}_1 t + \hat{\alpha}_K \ln K + (1 - \hat{\alpha}_K) \ln L \qquad (2)$$

Estimating both equations (1) and (2) could help to clear up whether constant return to scale restriction is binding in the case of Latvia. Bradley and Morgenroth [2, 2004] mention that there is a possibility that some specialization possibilities are not exhausted in small open economies, therefore it could exhibit increasing returns to scale. So, if constant return to scale restriction will appear to be binding then production function (2) is not correctly specified and equation (1) should be used in the subsequent analysis.

Further equation (1) could be augmented dividing physical capital into private and public components:

$$\ln Y = \hat{\beta}_0 + \hat{\beta}_1 t + \hat{\alpha}_{KP} \ln K_P + \hat{\alpha}_{KG} \ln K_G + \hat{\alpha}_L \ln L \qquad (3)$$

where $\hat{\alpha}_{KP}$ is estimated GDP elasticity in respect to private capital,

$\hat{\alpha}_{KG}$ is estimated GDP elasticity in respect to public capital.

According to constant returns to scale assumption in respect to private capital, public capital and labour, we obtain:

$$\ln Y = \hat{\beta}_0 + \hat{\beta}_1 t + \hat{\alpha}_{KP} \ln K_P + \hat{\alpha}_{KG} \ln K_G + \left(1 - \hat{\alpha}_{KP} - \hat{\alpha}_{KG}\right) \ln L \qquad (4)$$

Moreover, some authors tested alternative specifications as well. For example, Macdonald [9, 2008] used an assumption about constant returns to scale only to private inputs and regarded public capital is additional factor which ensure positive returns to scale from production factors altogether:

$$\ln Y = \hat{\beta}_0 + \hat{\beta}_1 t + \hat{\alpha}_{KP} \ln K_P + \hat{\alpha}_{KG} \ln K_G + \left(1 - \hat{\alpha}_{KP}\right) \ln L \qquad (5)$$

Macdonald [9, 2008] also mentions that there is strong correlation between public capital and total factor productivity, so exogenous technical progress may underestimate public capital productivity. Therefore the following specification should be estimated:

$$\ln Y = \hat{\beta}_0 + \hat{\alpha}_{KP} \ln K_P + \hat{\alpha}_{KG} \ln K_G + \left(1 - \hat{\alpha}_{KP} - \hat{\alpha}_{KG}\right) \ln L \qquad (6)$$

Some authors study how public capital affects labour productivity. For example, Naqvi [11, 2003] tests whether technical progress is "learning by doing" externality from physical capital accumulation. Specification with endogenous technical progress is the following:

$$\ln\frac{Y}{L} = \hat{\beta}_0 + \hat{\alpha}_{KP}\ln\left(\frac{K_P}{L}\right) + \hat{\alpha}_{KG}\ln\left(\frac{K_G}{L}\right) + \hat{\alpha}_L\ln(L) \tag{7}$$

where $\frac{Y}{L}$ is labour productivity

$\frac{K_P}{L}, \frac{K_G}{L}$ is private and public capital per employed, respectively

$\hat{\alpha}_{KP}$ and $\hat{\alpha}_{KG}$ is labour productivity elasticity in respect to private and public capital stock per employed, respectively.

If $\hat{\alpha}_L$ in the above equation is positive, than labour productivity is positively affected by the number of employed indicating to positive returns to scale in respect to labour, and the opposite is true if $\hat{\alpha}_L$ is negative. Alternative specification (without externalities) includes exogenous technical progress:

$$\ln\frac{Y}{L} = \hat{\beta}_0 + \hat{\beta}_1 t + \hat{\alpha}_{KP}\ln\left(\frac{K_P}{L}\right) + \hat{\alpha}_{KG}\ln\left(\frac{K_G}{L}\right) + \hat{\alpha}_L\ln(L) \tag{8}$$

The presence of learning by doing externality from physical capital accumulation is then tested by comparing $\hat{\alpha}_{KP}$ and $\hat{\alpha}_{KG}$ between equations (7) and (8). For example, if $\hat{\alpha}_{KP}$ in equation (7) is significantly higher than in equation (8), than learning by doing externality from private capital accumulation is present.

2. Data

This research uses quarterly data from Q1 1995 to Q2 2009, therefore the data set consists of 58 observations. The sample was constrained by data availability since there is no reliable statistics prior to 1995. All time series were seasonally adjusted using Census X12 multiplicative method. Monetary indicators (GDP and capital) were used in real terms (2000 year prices). As capital stock data from national accounts were available on annual basis and are subject to methodological revisions, the capital stock on quarterly basis was estimated, assuming that capital level at the end of each quarter (K_{t+1}) is equal to accumulated capital at the beginning of this quarter (K_t) plus investments I_t (gross fixed capital formation, P51 in national accounts) apart from depreciation $(\delta \cdot K_t)$:

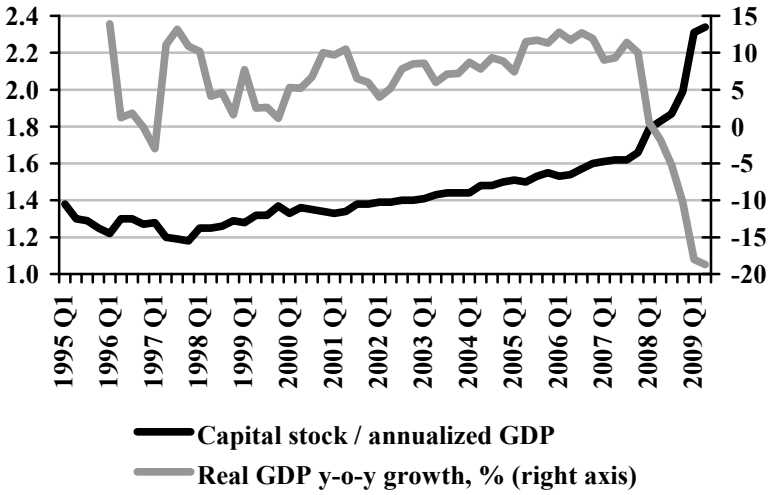
$$K_{t+1} = (1-\delta)\cdot K_t + I_t \qquad (9)$$

Various authors use different physical capital depreciation (δ) rates. Stikuts [12, 2003] assumes depreciation rate to be 2% per quarter, but Naqvi [11, 2003] – to be 2.5% per quarter, which is roughly equal to 8% and 10% during the year, respectively. Both depreciation rates were used and results are broadly similar (estimates with 2.5% depreciation rate are posted in this paper).

Next, initial capital level was defined. According to national accounts data, capital level at the end of 1994 was 3.6 billion lats at current prices – this corresponds to 4.8 billion lats at 2000 year prices, which was about 130% of country real GDP. Based on Dadhan and Zahedi capital level estimation for some countries [4, 1986] this capital / output ratio could be considered reliable. Figure 1 shows that capital stock / GDP ratio gradually increased from the end of 1990s and rose significantly during the last two years partly because of the GDP contraction (denominator effect).

Figure 1

Physical Capital Stock to GDP Ratio and GDP y-o-y Growth Rate in Latvia during 1995-2009

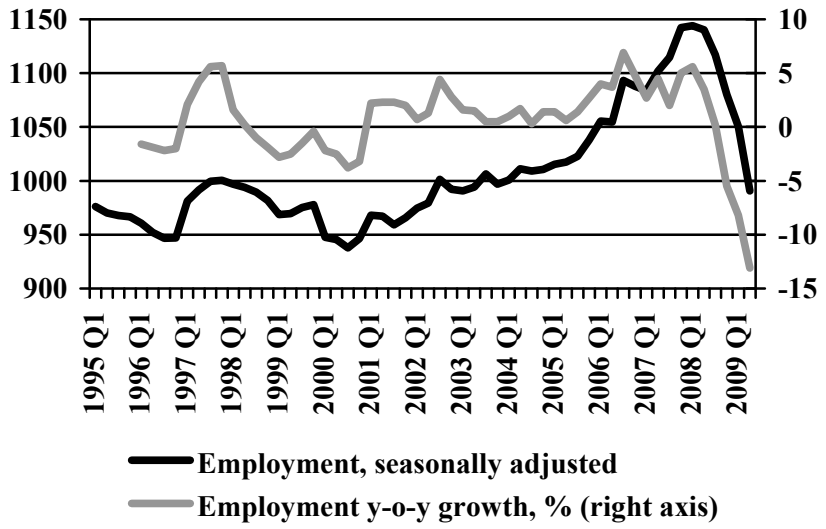


Source: Central Statistics Bureau of Latvia [3, 2009]; author's calculations.

It was assumed that labour is equal to the number of employed. Labour survey data on quarterly basis are available only from 2002, so we used employment figures from national accounts. No adjustments were made in respect to education length and working hours as quarterly data for the former are not available, for the latter it is available only from the year 2000. Moreover, according to World Bank report [14, 2005] these effects can cancel each other. The number of employed was not adjusted for the cycle (for example, by subtracting non-accelerating inflation rate of unemployment from the labour force) since we believe that the number of employed

is more relevant labour input measure except for measuring an output gap. Figure 2 shows that the number of employed was broadly stable in the first part of the sample, but increased considerably during the 2005-2007 (period of labour shortage) and decreased sharply from the second half of 2008.

Figure 2
Employment according to National Accounts Methodology (thousand; y-o-y growth rate)



Source: Eurostat [5, 2009]; author's calculations.

One of the main challenges here was to estimate public and private capital stock since government gross fixed capital formation expenditures are available as from 1999 and only in nominal terms. Moreover, private and public capital dynamics is dependent on assumption about initial share of public capital in total physical capital.

Public capital time series in real terms were constructed in three steps:

1. Public investments share for each quarter during 1999-2009 was calculated by dividing public investments to total investments (both in nominal terms). Than it was extrapolated for 1995-1998 using four-quarter moving average method. In result, public investments share in 1995 Q1 was estimated at 6%, which could be regarded as a realistic result.

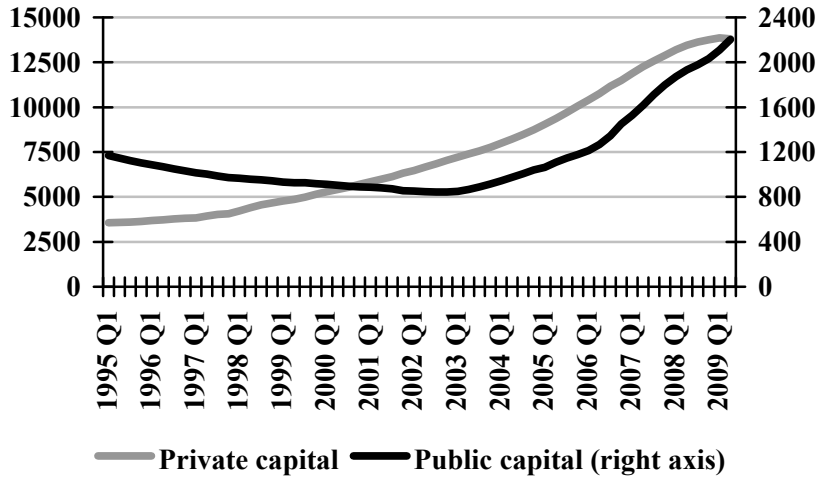
2. Public investment in real terms was calculated by multiplying public investment share obtained in the first step by total real investments.

3. Initial public capital share was set at 18% based on national accounts data. It should be mentioned that both national accounts public capital stock and public

investment data exclude state enterprises such as Latvenergo (energy), Latvijas Gaze (natural gas distribution), Lattelecom (communication), therefore in this paper capital stock of state enterprises is treated as private investment. Capital depreciation rate was set at 2.5% per quarter both for private and public capital. Private and public capital estimated time series are shown in figure 3.

Figure 3

Private and Public Capital Stock in Latvia 1995-2009 (seasonally adjusted, million lats)



Source: author's calculations.

Figure 3 shows that until 2002 public capital level gradually decreased: investment share in government spending was low and it could not compensate public capital stock depreciation. However, from 2003 both buoyant economic growth and access to EU funds (pre-structural and than to structural) contributed to public capital stock increase. At the end of Q2 2009 public capital stock was 2.3 times larger than initially. Private capital stock grew even faster and during the last 14 years increased 3.5 times.

3. Production Function Estimation Results

This section presents the main results of the production function estimation in the forms (1) – (8). Equation (1.2) shows production function estimation in the unrestricted form for the whole sample. Capital stock is not significant and Durbin-Watson statistics points to a positive autocorrelation and spurious regression leading to a conclusion of incorrect specification. This result appeared owing to a large economic contraction as from 2008 which resulted in a sharp unemployment upswing, and correspondingly, a fall in the production factors use intensity as evidenced by Fadejeva and Melihovs [5, 2009].

Therefore economic contraction built a wedge between capital stock accumulated and capital stock used, that is why production function estimates give correct results only when supply factors are binding economic growth, which is not the case for Latvia as from 2008. This could be shown limiting the sample to 1995 – 2007 (equation (1.1) in the table 1): capital stock is highly significant and regression statistics do not point to incorrect specification. Nevertheless, equation (1.3) shows that production function could be estimated for the whole sample as well by augmenting it with additional variables that feature cyclical conditions. First variable is a measure of cyclical unemployment defined as a difference between registered unemployment rate and previous 24-month average registered unemployment rate. Alternative measures of a cycle (proxies of unemployment) were used as well - they were statistically significant but less powerful in explaining GDP variation. Nevertheless, cyclical unemployment did not represent the cycle fully, possibly to the labour hoarding behavior of the firms (negative residuals at the end of the sample became smaller but nevertheless statistically significant), therefore two dummies were added – for 2008 and 2009, respectively (Chow breakpoint test showed maximum F-statistic for 2008 Q1, moreover, splitting this dummy for 2008 and 2009 further increase the adjusted determination coefficient). In this case, residuals at the end of the sample fall down within 2 standard deviation bounds.

Table 1

GDP elasticity to capital and labour

	(1.1)	(1.2)	(1.3)	(2)
Sample:	1995-2007	1995-2009		
Functional form:	unrestricted			restricted
$\hat{\beta}_0$	3.999***	6.522***	3.363***	4.326***
$\hat{\alpha}_K$	0.342***	-0.197	0.296***	0.295***
$\hat{\alpha}_L$	0.647***	1.478***	0.697***	<u>0.705</u>
$\hat{\beta}_1$	0.0083***	0.0175***	0.0089***	0.0089***
[dummy for 2008]			-0.106***	-0.107***
[dummy for 2009]			-0.213***	-0.213***
[cyclical unemployment]			-0.010***	-0.010***
Standard error of regression	0.0192	0.0480	0.0186	0.0184
Adjusted coefficient of determination	0.9950	0.9715	0.9957	0.9958
Durbin – Watson statistics	1.49	0.48	1.80	1.81
Akaike information criterion	-4.99	-3.17	-5.02	-5.06
Schwarz criterion	-4.84	-3.03	-4.77	-4.84

*, **, *** significant at 90, 95 and 99% respectively.
Coefficients that has not estimated directly but derived from other coefficients are underlined.
Source: author's calculations.

Equations (1.3) and (2) in the table 1 compares unrestricted and restricted production function estimation results for the whole sample. Wald coefficient test results (not shown here) implied that assumption about constant returns to scale is not binding in the case of Latvia. In this case, as argued by Holtz-Eakin [7, 1994], constant returns to scale form is desirable. Equation (2) in the table 1 states that GDP elasticity in respect to capital is equal to 0.295, in other words, if capital grows by 1%, GDP increase by 0.295% on average. The result is broadly similar to other authors. While Stikuts [12, 2003] estimates it at lower level (0.225), it could be due to the fact that he used 1995-2004 time period (if we repeat estimation in this sample, without three additional variables, GDP elasticity in respect to capital diminishes to 0.248). Melihovs and Davidsons [10, 2006], using more recent data (1995-2006) estimated GDP elasticity in respect to capital to be 0.303.

Table (2) presents production function estimates in the forms (3) – (8), thus, dividing accumulated physical capital stock by private and public components. Like before, Wald coefficient test does not reject the null hypothesis about constant returns to scale both for (4) and (5), but gives preference to (the larger probability that null hypothesis is true) $\left(\hat{\alpha}_{KP} + \hat{\alpha}_{KG} + \hat{\alpha}_{L}\right) = 1$ contrary to $\left(\hat{\alpha}_{KP} + \hat{\alpha}_{L}\right) = 1$. Therefore functional form (4) appears to be superior than (3) and (5; not shown here). According to equation (4), both private and public capital is highly significant. GDP elasticity in respect to private capital appeared to be almost four times higher than that of public capital (0.231 and 0.047 respectively). However, regarding that private capital stock was on average 7.8 times higher than public capital, each lat of public capital is 1.6 times more productive than that of private capital. Moreover, all three additional variables that reflect the recent cyclical downturn are highly significant and residuals at the end of the sample in all specifications presented in table 2 are within 2 standard deviation bounds.

Comparing equations (4) and (6) we can see that total factor productivity is highly correlated with private capital, therefore including exogenous technical progress in equation (4) does not lead to undervaluation of public capital productivity. Regarding the role of private and public capital in affecting labour productivity, equation (7) and (8) in table 2 show that at least a part of technological progress could be regarded as "doing by learning" externality from the private capital accumulation, but this hypothesis does not hold for public capital. Nevertheless, equation (8) shows that both private and public capital raise labour productivity significantly and again, public capital is much more productive (1.7 times) than private capital. Regarding α_L term inclusion of which tests for variable returns to scale, it appeared to be significant in the equation (7; not shown here), but insignificant in equation (8): labour positively correlates with technological progress but there is no indication that constant returns to scale do not hold in respect to labour input (which represents the size of the economy).

Multiplying estimated elasticities from equation (4) in the table 2, by average growth rate of the respective production factor, we obtain this factor average contribution to economic growth in Latvia. Figure 4 shows that during the last 14 years the driving forces of economic growth in Latvia were total factor productivity (69.8%) and

private capital (26.2%), moreover, also labour and public capital contribution was positive.

Table 2

GDP elasticity to private capital, public capital and labour

	(3)	(4)	(6)	(7)	(8)
Dependent variable:	ln (real GDP)			ln (real productivity per employed)	
$\hat{\beta}_0$	6.314***	4.596***	1.325***	1.321***	4.630***
$\hat{\alpha}_{KP}$	0.139	0.231**	0.661***	0.662***	0.226**
$\hat{\alpha}_{KG}$	0.079**	0.047**	0.009	0.009*	0.048**
$\hat{\alpha}_L$	0.611***	0.722	0.330		
$\hat{\beta}_1$	0.0116***	0.0094***			0.0095***
[dummy for 2008]	-0.117***	-0.112***	-0.093***	-0.093***	-0.113***
[dummy for 2009]	-0.238***	-0.220***	-0.218***	-0.220***	-0.222***
[cyclical unemployment]	-0.011***	-0.010***	-0.009**	-0.009**	-0.010***
Standard error of regression	0.0184	0.0184	0.0220	0.0221	0.0184
Adjusted coefficient of determination	0.9958	0.9958	0.9940	0.9916	0.9941
Durbin – Watson statistics	1.88	1.88	1.14	1.25	1.91
Akaike information criterion	-5.03	-5.04	-4.70	-4.69	-5.04
Schwarz criterion	-4.75	-4.79	-4.49	-4.48	-4.79

*, **, *** significant at 90, 95 and 99% respectively.
Coefficients that has not estimated directly but derived from other coefficients are underlined.
Source: author's calculations.

Figure 5 shows that during 2001-2007 production inputs as well as total factor productivity contributed positively to economic growth in Latvia in each subsequent year. Moreover, an economic downturn in 2008 is mainly attributed to total factor productivity (here it includes the cyclical impact, which was excluded in regressions by three additional variables).

Figure 4
Private capital, public capital, labour and total factor productivity contribution to economic growth in Latvia 1995-2009, %. Source: author's calculations

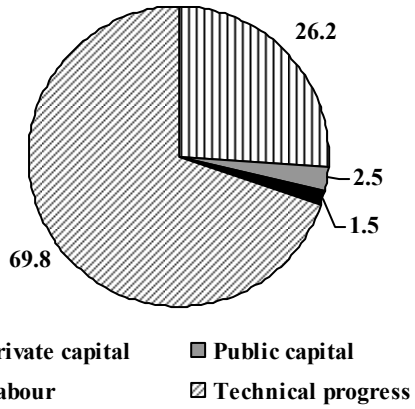
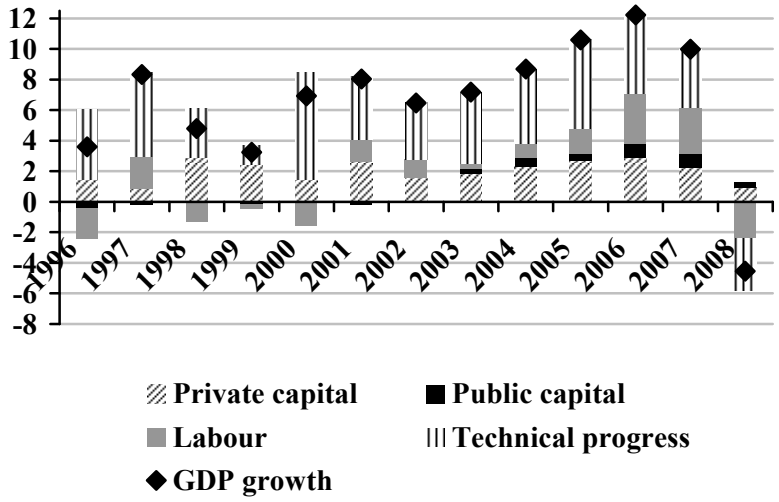


Figure 5
Private capital, public capital, labour and total factor productivity contribution to economic growth in Latvia, annually 2001-2008, percentage points



Source: author's calculations.

Conclusion

The paper estimates private and public capital contribution to economic growth in Latvia 1995-2009 using production function approach. Due to lack of capital formation data, both private and public capital levels were estimated, the initial

share of public capital stock came from national accounts; for subsequent quarters, public and private investment and previously accumulated capital stock depreciation were used to construct capital stock tome series. On average, private capital stock was 7.8 times higher than public capital stock and increased gradually whereas public capital stock decreased until 2002 and raised rapidly afterwards. It was found that both private and public capital has positive and statistically significant impact on economic growth and labour productivity, public capital is 1.6 times more productive than private capital; nevertheless, private capital accumulation affects technological progress through "learning by doing" externality. It was shown that the main driving forces of economic growth in Latvia 1995 - 2009 were total factor productivity and private capital formation, moreover, labour and public capital contribution was also positive. It was pointed out that if economic growth is constrained by demand factors, which is the case of Latvia at the end of the sample, production function estimates do not fit the data well and autocorrelation problem arises. Therefore the production function should be augmented with additional variables that feature the cycle.

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