Bank i Kredyt 49(2), 2018, 93-114

BANK I KREDYT
BANK & CREDIT

Intangible capital and the economic growth in Poland

Robert Pater*, Łukasz Cywiński#, Ruslan Harasym#, Kazimierz Tarchalski#

Submitted: 14 September 2016. Accepted: 6 June 2017.

Abstract

The influence of intangible capital on the economic growth in Poland has never been thoroughly analysed. This article contains estimates of the production function with intangible capital and provides growth accounting extended to the intangible capital. We present the estimates of intangible capital formation for 1995–2013 in Poland. We supply previous studies with the analysis of changes in real intangible capital formation and the effects of accumulated intangible capital on GDP. Since most of the intangible capital components have not been accounted for in the national accounts, we suggest possible improvements in economic growth measurement. We show that intangible capital had a significant impact on economic growth in Poland during 1995–2013, accounting for at least one third of the economic growth. The most probable output elasticity with respect to intangible capital is 0.2 to 0.3.

Keywords: intangible capital, national accounts, growth factors, knowledge-intensive economy

JEL: O30, O40, P24, P26

* University of Information Technology and Management in Rzeszów, Department of Economics; e-mail: rpater@wsiz.rzeszow.pl.
# University of Information Technology and Management in Rzeszów, Department of Economics.

1 Introduction

Classical growth factors are gradually less important, while the intangible capital becomes a crucial determinant of the economic growth (see Cywiński et al. 2017). The role of intangible capital in the economic growth in Poland has never been analysed. The main intention of this article is to present Polish growth accounting with intangible capital. It will provide insights into the scale and effects of intangible capital in Poland in relation to traditional growth factors. Intangible capital includes Research and Development (R&D), intellectual property and managerial know-how, in other words, the new growth factors induced by knowledge-intensive accomplishments, typical for an innovation--driven economy. An analysis of the abovementioned type of capital provides more than just a rough assessment of innovativeness; it shows structural determinants of economic growth.

Innovative enterprises deliberately increase their economic competencies and produce specialized software and other 'intangibles' to maintain growth. Available data allow for GDP decomposition into labour input, (classical, physical or tangible) capital input and total factor productivity (TFP). The latter includes intangible capital (IC), with all its creative components. The main idea behind measurement of intangible capital corresponds with Schumpeter's (1934) definition of innovative growth generated by creative destruction. Such growth includes product and process development, organizational, as well as, managerial and financial change. Understanding the pillars of intangible capital thus defined contributes to knowledge on the long-run drivers of economic growth, as well as deviations from its path. In the early stages of economic growth, technical advancements bring major job destruction. Intangible capital contributes to the gradual transformation of the workforce from industry to services, enabling economies to advance to the next stage of development.

There is a reason to conjecture that intangible capital might also be a driver of the business cycle. The implementation of new advancements, e.g. computerized information or new software, has a stimulating effect on companies' productivity. New software stimulates technology development, hence can be interpreted as a positive and permanent productivity shock within the real business cycle model. Monitoring the level of intangible capital and its components might therefore contribute to a better understanding of structural changes in cyclical fluctuations (see Pater 2015).

This article contributes to the discussion on the sources of economic growth in Poland (see e.g. Próchniak, Witkowski 2012; Konopczak 2013; Growiec et al. 2015; Witajewski-Baltvilks 2016). It provides new data on the sources of growth: investment in intangible capital. The article presents the results of the estimation of the intangible capital in Poland over the period 1995–2013. Hitherto, intangible capital estimates for Poland have been available only up until 2005. This research fills the existing gap and provides the estimates for all components of intangible capital over 2006–2013. To make this estimation we used methodology based on the work by Corrado, Hulten and Sichel (2005, 2009). This allowed us to conduct a comparative analysis for Poland and other selected countries. The results provided by this study have significant implications for economic policy. The evidence demonstrates that intangible capital has been an important factor behind economic growth in Poland. This was not evident before because most of the knowledge-intensive factors of growth have not been included in the Polish national accounts.

The remainder of this paper is organized as follows. In the next section we provide a definition of intangible capital and its components. Then, we present a review of the literature on intangible capital, as well as the research and caveats behind its estimation. In the fourth section we present and interpret the results of growth accounting extended to intangible capital for Poland as well as compare those results with findings on intangible capital for other countries. The last section concludes and presents general policy implications.

2 Definition of intangible capital

The research on intangible capital is based on the work by Denison (1963), Kendrick (1961), Jorgenson (1963) and Griliches (1984). These pioneering works laid the foundation for the first applied study of the US economy by Corrado, Hulten and Sichel (2006). That study was successfully reproduced and improved by Piekkola et al. (2011) during the project called Innodrive for several European countries. The research conducted during Innodrive became very influential, particularly after the European Commission recognized the major determinants of R&D-induced growth during the Lisbon process. The findings of this project have been reflected within the Horizon 2020 agenda, that later sponsored the accompanying project Intaninvest, dedicated entirely to intangible capital estimation for the EU. Both projects (Intaninvest and Innodrive) produced a series of data for 29 countries. Innodrive provided data starting from 1995 until 2005 and Intaninvest from 2005 until 2010. However, the latter provided estimates only for Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Slovenia, Spain, Sweden, the United Kingdom and the United States, and thus excluded Bulgaria, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Norway. In one case – Cyprus – data were estimated on the basis of the weighted average for the new European Union (EU) member states. During Intaninvest research Cyprus' national accounts did not provide sufficient information about investments in computer software.

In both projects intangible investments have been defined as "expenditures by businesses that are intended to boost output in the future but that are not traditional, tangible, physical capital" (see Sichel 2008). Moreover, in both projects, in accordance to the methodology provided by Corrado, Hultan and Sichel (2005), the intangible capital has been divided into three main categories:

– computerized information,
– innovative property,
– and economic competencies.

Computerized information comprises knowledge in the form of computer programmes (software publishing) and computerised databases. Innovative property consists of scientific knowledge that takes the form of patents, licenses, other know-how measures, and the artistic, as well as, innovative content of commercial licenses, designs and copyrights. This category comprises R&D, including social sciences and humanities, mineral exploration, evaluation and copyright and license cost, development cost in financial industry, and new architectural and engineering designs. Notably, development cost in the financial industry is often associated with positive external effects, because they increase the savings rate and generate better means of processing information about investment, notwithstanding that they help encourage the inflows of foreign capital, as well as optimization of capital allocation (Beck, Demirguc-Kunt, Levine 2000). Economic competencies (as a category of intangibles) are defined as the value of brand names and other knowledge, embedded in firm-specific human capital and structural resources. It comprises expenditures on market research, advertising, firm-specific human capital and organisational change. This category includes the following components: brand equity (which comprises advertising expenditure and market research), firm-specific human capital, including continuing vocational training and apprentice training, and the development of organizational structures. Estimates provided in this article apply the methodology created by Corrado, Hulten and Sichel (2005) to calculate the components of intangible capital.

3 Research method

3.1 Data estimation

The main incentive for this research comes from the observation that only a very narrow range of intangible capital components have been included in the European System of Accounts, and consequently in the Polish national accounts (see Jeznach 2010). Admittedly, in 2013 regulation No. 549/2013 compelled all member states to apply new methodological standards of ESA 2010 as an improvement to ESA 95 methodology. These standards partially changed the way R&D is included in growth accounting. Previously, it was 'used up' within one period. Since 2010 R&D has started to be treated as investment in fixed assets that are used and held in the process for multiple periods (United Nations Statistical Commission 2009). This included the amortization of intangible non-productive assets. Yet, even with the new methodology in place, the range of intangibles included in the national accounts does not cover all knowledge-intensive factors of growth that determine growth of most of the modern innovation-driven economies.

Out of the three main categories of intangible capital – computerized information, innovative property and economic competencies – the first one has been to a large extent included in the Polish national accounts. However, the other two have not been included thoroughly (Corrado et al. 2012). The main component of computerized information – computer software – is derived from intangible fixed assets accounts. It is already included as gross fixed capital formation (GFCF) in national accounts. Computerised databases are not identified as economic assets in the national accounting system, but they are captured by national account software measures (both purchased and own-account). From innovative property, R&D investments have been classified as the costs of acquiring property rights and patents, licenses and trademarks. However, they do not include the development of non-scientific R&D and financial products. Similarly, mineral exploration and evaluation was included in the national accounts, but only partially – they excluded important research costs. Economic competencies have not been included in the Polish national accounts whatsoever.

Our primary source of information on intangible capital was the Eurostat database. The data on intangible capital components can be retrieved from statistics on production in the enterprises sectors. Gross intangible capital formation estimates did not include agriculture and non-market services. The excluded NACE sections consisted of agriculture, fishing, public administration, defence and compulsory social security, education, health, other community, social and personal service activities, and private households (see Jona-Lasinio, Felix, Iommi 2011 for a detailed explanation). The Innodrive project used NACE rev 1.1 structure, while we could use only NACE rev 2. We have integrated the data according to Piekkola's (2011) specifications and harmonized NACE rev 2 components with the NACE rev 1.1. The change in the NACE classification occurred in 2006. Its structure has been extended from

17 sections (and 62 divisions) to 21 sections (with 88 divisions). The extension allowed new concepts to be introduced. For instance, section J – transport, storage and communications has been separated into H – transportation and storage and J – information and communication.

We have used schemes corresponding to Piekkola's (2011) method, developed on the basis of the commonly accepted work by Landes and Rosenfield (1994) and Marrano and Haskel (2006). As a result, the majority of data have been retrieved from the following NACE categories:

– software publishing and other software publishing,

– R&D expenditure in the business enterprise sector and private non-profit sector (this included the following R&D categories: basic research, applied research, experimental development and not specified),

– support activities for petroleum and natural gas extraction,

– support activities for other mining and quarrying,

– motion picture, video and television programme production, sound recording and music publishing activities,

– architectural and engineering activities; technical testing and analysis,

– market research and public opinion polling,

– business and other management consultancy activities.

Unfortunately, we were still missing some data on advertising expenditures, the development cost in the financial industry, firm-specific human capital and organizational structure. According to Piekkola et al. (2011), approximately 60% of advertising can be included in capital formation as advertising expenditures. We followed this estimate. Other missing data comprised development cost in financial industry. In line with the observation of Corrado, Hulten and Sichel (2009), Piekkola (2011, p. 42) assumed that development costs in financial services contain 20% of total intermediate spending by the financial intermediation, excluding insurance and pension funding. Data on pension funding was not available in the Eurostat. In the Innodrive, the missing data were estimated on the basis of 'other financial service activities, except insurance and pension funding'. This category was not available in any commonly available data source. However, using Polish Central Statistical Office data we were able to retrieve the missing data from the F01/I01 forms. Henceforth, this category of intangible capital has been included entirely in our further estimates.

Firm-specific human capital was also estimated on the basis of the methodology provided by Piekkola (2011, p. 48). As for the base of the estimation, we used cost of continuing vocational training, an indicator available in the Eurostat database (Continuing Vocational Training Survey, CVTS). We estimated training expenditures by multiplying the cost of CVT courses as a percent of total labour costs by compensation of employees taken from national accounts. According to the suggestion of Piekkola (2011, p. 48), we have treated 100% of the estimated training expenditures as gross intangible capital formation.

'Organizational structure', which is a subcategory of economic competencies, is split into own account and purchased intangibles. The own account sub-category had to be estimated. The estimation of this component was divided into the following stages. First we collected two sets of data from the Eurostat: the Structure of Earnings Survey (SES) and the Labour Force Survey (LFS). We selected the following variables: mean earnings of managers and mean earnings of all employees (from SES), number of managers and number of all employees (from LFS), and compensation of employees (from national accounts). The next steps of estimation were as follows:

1. Estimating the gross earnings of managers and gross earnings of all employees by multiplying the mean annual earnings (from the SES) by the number of employees (from the LFS). Calculating the share of gross earnings of managers in gross earnings of all employees.

2. Estimating the total expenditure for management compensation, consistent with national accounts data, by multiplying the share of gross earnings of managers by total compensation of employees.

3. Making an assumption about what proportion of spending is to be considered investment. Following Corrado, Hulten and Sichel (2005), we have assumed 20%. Estimating the value of own--account investment in the organizational structure by multiplying the investment share by total manager compensation.

After estimating the specific types of intangible capital we identified some missing data. They were interpolated with unobserved components models (Harvey 1989). It was necessary in the case of software publishing and other software publishing, innovative property, brand equity (purchased and own account) and firm-specific human capital.

To calculate the production function and to perform growth accounting we gathered data for traditional growth factors, that is, tangible capital and labour input. Data on labour was taken from the Central Statistical Office as total employment according to Labour Force Survey (annual means). Data on the stock of real tangible capital was provided by Witajewski-Baltvilks (2016). We assumed 6% capital depreciation, which is considered a 'baseline' by the author. Data on gross fixed capital formation, GDP at market prices and relevant price indices were taken from the Eurostat database. We analysed only annual data, since only annual data on IC formation were available.

Estimates of intangible capital allowed us to expand the GDP identity by the flow of new intangibles and to extend the production function with intangible services. We obtain:

$$P^Q(t)Q(t) = P^C(t)C(t) + P^I(t)I(t) + P^N(t)N(t) = P^L(t)L(t) + P^K(t)K(t) + P^R(t)R(t) \quad (1)$$

where:

P – indicates prices,

Q – output,

C – consumption,

I – physical (tangible) capital investments,

N – intangible capital investments.

GDP is produced according to the function of production with factors: labour input (*L*), tangible capital (*K*) and intangible capital (*R*). The last is accumulated as follows:

$$R(t) = N(t) + (1 - \delta_R)R(t-1) \quad (2)$$

where δ_R is its depreciation rate.

To estimate initial intangible capital stock we used the formula shown by Epstein and Macciarelli (2010):

$$R_{95} = I_{95} / (\delta_R + g_R) \quad (3)$$

where g_R is the mean logarithmic growth of intangible investments in the sample period 1995–2013, and index 95 means year 1995.

Intangible capital depreciation rate was calculated on the basis of Corrado et al. (2012).

3.2 Modelling procedure

With the stock of intangible capital we can estimate the production function in a commonly used Cobb--Douglas form:

$$Q_t = A_t L_t^{\alpha} K_t^{\beta} R_t^{\gamma} \tag{4}$$

where A is a measure of total factor productivity, and α, β and γ are elasticities of output with respect to the production factors.

Given the estimates, the constant returns to scale (CRTS) $\alpha + \beta + \gamma = 1$ hypothesis can be tested with the use of Wald test.

Model (4) can be estimated, after logarithmic transformation by ordinary least squares (OLS). However, we deal with a small sample, so parameter values are very sensitive to outliers. Although we carefully checked for outliers and did not find any, the results still have to be treated with caution. Also, annual data may cause a temporal aggregation problem. Finally, the correlation coefficient between intangible and tangible capital stocks is close to 1. This collinearity may affect the estimates considerably. That is why we made an effort to conduct further analysis of parameters' sensitivity.

The small sample and collinearity between covariates justify the use of partial least squares (PLS) regression. In the least-squares method the vector of structural parameters is obtained by:

$$\hat{\mathbf{B}} = (\mathbf{X}^T \mathbf{X})^{-1} \mathbf{X}^T \mathbf{y} \tag{5}$$

where $\hat{\mathbf{B}} = [\alpha \quad \beta \quad \gamma]'$, $\mathbf{X}$ is a matrix of covariates and $\mathbf{y}$ is a vector of dependent variable observations.

In PLS, matrix **X** can be decomposed into orthogonal scores **T** and loadings **P** such that **X = TP**. As a result, scores and loadings compose maximum k components (latent variables) for each variable in **X**, where k is the number of independent variables. To estimate latent variables and loadings, we used a de Jong's (1993) SIMPLS method, which maximizes the covariance between covariates and the explanatory variable. Choosing the number of latent variables is determined by cross-validation. We used one-sigma heuristic and permutation approaches to choose their number. We used the *pls* R package for this procedure (Mevik, Wehrens 2007).

Another way to deal with correlated covariates and improve interpretability of regression parameters, especially overfitting, is to apply a ridge regression and the least absolute shrinkage and selection operator (lasso). They are examples of generalized linear models with convex penalties (Friedman, Hastie, Tibshirani 2010). Ridge regression shrinks the coefficients of correlated predictors towards each other. Lasso is more indifferent for parameter values, but indicates whether some of them should be dropped. Both methods are special cases of an elastic net method with a mixing parameter $0 \le \phi \le 1$, with $\phi = 0$ in the ridge regression and $\phi = 1$ in the lasso. In our case the latter may be used to find out whether IC is an important production factor. Both methods lead to lower variance of the estimator, but at the cost of its bias. They require setting a λ parameter. The higher it is, the larger the bias is. So, again a cross-validation method must be applied to choose appropriate λ. We used the *glmnet* R package to estimate ridge regression, lasso method and perform cross-validation (Friedman, Hastie, Tibshirani 2010).

With a new growth factor we can perform extended sources of growth accounting. When intangible and tangible capitals are treated symmetrically, economic growth equals:

$$g_Q(t) = s_C(t)g_C(t) + s_i(t)g_i(t) + s_n(t)g_n(t) = s_l(t)g_l(t) + s_k(t)g_k(t) + s_r(t)g_r(t) + g_a(t) \quad (6)$$

where g denotes the growth rate of: $g_Q(t)$ – output, $g_C(t)$ – consumption, $g_i(t)$ – investments in tangibles, $g_n(t)$ – investments in intangibles, $g_l(t)$ – labour, $g_k(t)$ – tangible capital, $g_r(t)$ – intangible capit; $g_a(t)$ means multifactor productivity, while s denotes output shares.

Such an approach enables us to calculate the impact of intangible capital on economic growth.

4 Results

4.1 Intangible capital in Poland

In 1995 intangible capital formation in Poland amounted to EUR 3.3 billion (Figure 1). In relation to GDP it was 3.1%. This share increased until 2001, reaching 5.3%. Then the ratio decreased during the next five years to 4.8% in 2005. This slacking off with knowledge-intensity started during the economic slowdown. The reason for the decrease was related to the institutional framework that was yet unable to support an abrupt assimilation of knowledge from foreign investments (see Cywiński, Harasym 2016), nor created enough confidence to proceed with own innovations. In other words, the institutional nexus was more prone to facilitate traditional growth factors than the brisk knowledge-intensive growth. The potential cause for the slowdown in intangible capital intensity in 2001–2005 should not be associated with the alleged middle-income trap and relative low level of national R&D expenditure (see Cywiński et al. 2017). The level of R&D expenditure in Poland from the beginning of the transformation has been low and stayed low during the period of the slowdown.

The intangible capital formation to GDP ratio increased in 2006. If R&D expenditure was not responsible for growth of intangible capital, then what factor was? In 2004 Poland joined the European Union and was subject to a significant inflow of foreign direct investment (FDI). The literature on foreign direct investment suggests that the knowledge-intensity of FDI increases the productivity of local firms by stimulating the network of suppliers and beyond (Smarzynska-Javorcik, Spatareanu 2005). The spillover effects to local networks of suppliers are nothing less than a cross-border transfer of intangible capital. What therefore determines its absorption? Most of the research indicates that the fundamental determining factors are related to investment climate, political stability and compatibility of the institutional framework (Faeth 2008). This explains why some countries are more successful in turning discoveries into innovations: they have the institutional nexus that creates enough trust in business arrangements to take higher risks. A good investment climate is hard to build, and developing trust is even harder. However, after the transformation new political arrangements have been subsequently moving towards restructuring and modernization of the Polish economy. Yet only after the accession to the EU, the institutional configuration was good enough to allow for greater own intangible capital formation and assimilation of knowledge via foreign direct investments.

Improving investment climate was achieved by enforcing better quality of institutions. This is why from 2006 to 2009 intangible capital grew again, reaching its highest value of 6.3% GDP. New technologies imported from the West have been enhancing competitiveness and knowledge-intensity of goods produced in Poland. Governmental strategy enforced by institutions such as the Polish Information and Foreign Investment Agency included a wide-range of investment programmes, for example the regional investor service centres. They convinced Polish firms to cooperate with foreign investors and use up-to-date human resource management methods. This had positive micro- and macroeconomic effects in the long-run (Ancyparowicz 2009).

The general dynamics of intangible capital formation during 1995–2013 was similar to that of GDP, including the trend and cycle. Among the main components, economic competencies and innovative property also changed similarly. However, innovative property was more responsive to the business cycle, showing steeper expansions and more profound recessions. The recession during 2007–2009 and its consequences in the following years had the largest effect on computerized information. The value added of computerized information grew until 2008. Since then it has decreased. The latter changes contributed to a decrease in IC formation to GDP ratio during 2010–2013. In 2013 IC formation amounted to EUR 21.4 billion, and accounted for 5.5% of GDP.

During 1995–2013 real intangible capital formation in Poland grew annually by 7.6% on average. The average annual growth of real GDP at that time was 4.1% and the figure for gross fixed capital formation was 6.7%. This favourable (for intangibles) difference occurred mainly in 2001, 2006 and 2008 (Figure 2). Fast intangible capital growth in 2001 may have resulted from the initially low IC level and, hence, the 'base' effect. Poland was 'catching up' to other countries (see Section 4.3). That period might also be associated with assimilation of simpler technologies, pulled in thanks to the arrangements related to liberalization of trade. Later economic expansion increased IC formation dynamically. There were also periods of visibly slower intangible capital growth, especially in 1999, 2002–2004 and after 2008. This might have been caused by lower trust of investors in the investment climate in Poland, measured by the World Economic Forum Global Competitiveness Index and responsive reaction to global downturns.

Median IC formation growth in the whole analysed period was 3.8%, which was lower than both GFCF and GDP growth. It means that intangible capital growth was very uneven. It also seems that IC formation lags, especially after recessions. Figure 2 shows that its troughs occurred in 2003 and 2012, that is after the business cycle troughs of GDP and GFCF. IC formation was highly correlated with the GFCF. This is not surprising, since many fixed and intangible assets may be connected, i.e. machinery and licenses. Intangible capital formation was more prone to the business cycle fluctuations than GDP and similarly prone as GFCF (coefficient of variation equalled 1.6 for IC formation growth as well as GFCF and 0.5 for GDP). In effect, IC formation to GDP ratio was pro-cyclical. This means that the increase in intangible capital share in the future might induce larger GDP fluctuations. The distribution of IC formation growth was more platykurtic than GDP and GFCF and, in contrast to GFCF, it was negatively skewed.

After a sharp increase in the share of investment in computerized information in 1996 (from 2.9% to 8% of intangible capital), it was stable until 2007 (Table 1). Since 2008 both the level and the share of investment in computerized information in Poland have been decreasing and reached 3.1% of intangible capital in 2013. After 2008, investment in computerised information had to slow down, because the stormy phase of universalization of computerization of Eastern European economies came to an end.

The share of investment in innovative property during 1996–1998 increased slightly (from 31.9% to 34.3% of intangible capital). After that, and until 2005, we observe a negative tendency, during which it decreased to 25.5% of intangible capital. During the next period, 2006–2008, it grew sharply, reaching 42.5%. Since then, it has fluctuated around this figure. Out of the elements of innovative property, mineral exploration and evaluation, as well as copyright and license cost exhibited similar tendencies. The main element of innovative property, which is new architectural and engineering designs, also changed similarly until 2009, after which it started to decrease. This decrease has been compensated by sharp growth in the share of R&D expenditure, including social sciences and humanities, and by rising development costs in financial industries.

The end of the first decade of the 2000s was a period of high growth of R&D expenditure in the Polish economy. Internal R&D expenditure grew especially fast during 2009–2012 (mean annual growth of 16.9%) and even higher if we take into account only the enterprise sector. External expenditure on R&D during 2008–2010 grew annually by 101.7% on average. Both R&D expenditure and development costs in financial industries did not reach, however, the high shares in intangible capital observed during 1995–1996 (R&D) and the early 2000s (development costs). Since 2004 the Polish economy has been able to benefit from an improvement in investment climate that would allow for capitalization of the country's own innovations. There are reasons to believe that a lot of the 'innovations' were in fact firm-level upgrades subsidized by the EU. This creates a serious risk that when the subsidies end, the low quality of institutions and limited economic freedoms may cause long-lasting stagnation.

The share of investments in economic competencies in intangible capital formation for the most part of 1995–2005 was over 60%. Afterwards, it decreased and fluctuated between 50% and 55%. The first element of economic competencies, brand equity, rose from 1995 to 2005, then considerably decreased, and in 2010 again started to grow, although slowly. The share of firm-specific human capital did not exhibit a visible trend. Instead, it fluctuated roughly according to the business cycle. Interestingly, its peaks and troughs occurred with a lead in comparison to GDP. The share of organizational structure decreased at the beginning of the analysed period and, since then, it stabilised at the level of 30% of intangible capital formation.

4.2 Growth accounting with intangible capital

To analyse elasticity of output with respect to intangible capital, we estimated an aggregate production function. Production function estimates of a Cobb-Douglas form with (classical) physical capital and labour inputs for Poland were shown in Table 2. GLS estimation gave $\alpha = 0.60$ and $\beta = 0.25$ (model 1). Both coefficients are statistically significant at least at $p = 0.05$. They do not deviate much from a typical $\alpha = 0.66$ and $\beta = 0.34$ encountered in the literature. In comparison to the previous works on the Polish economy, the output elasticity with respect to labour is similar to the one in Gradzewicz and Kolasa

(2005), who reported α = 0.57. Output elasticity with respect to capital is lower in our calculation, as they reported β = 0.43. In turn, Epstein and Macchiarelli (2010) provide estimates: α = 0.49 and β = 0.53. On the basis of the Wald test we do not reject the null hypothesis that there are constant returns to scale in the production process.

The inclusion of intangible capital in the production function specification diminished output elasticity with respect to labour and increased it with respect to tangible capital (model 2). The elasticity of output with respect to intangible capital was statistically significant at the 1% level. It was quite high and amounted to 0.29. In this specification the TFP coefficient was insignificant and returns to scale were constant. On the basis of the LR test, the hypothesis of eliminating intangible capital as a non-significant growth factor was rejected at the 1% level. It confirmed that intangible capital was an important factor behind Polish economic growth during 1995–2013.

To test the robustness of the above results on the role of IC for economic growth, given the small sample and collinearity between covariates, in the next step we used the PLS estimator. There were at most three components of each variable. The cross-validation algorithms suggested one or two--components (see Figure 3 in the Appendix). The root mean squared error of prediction (RMSEP) was the smallest (2.8%) and R^2 was the highest (0.98) in the model with two components. The two--component model was also economically interpretable, as in the case of only one component, the model showed very low output elasticity with respect to labour (α = 0.03). In the two-component model, the estimates for α and β were slightly lower than those attained with the OLS, while the estimate for γ = 0.31 was slightly higher (model 3).

In the further analysis we applied ridge regression and the lasso method. Coefficients from the ridge regression depending on the log (λ) parameter are shown in Figure 4 (Appendix). For λ = 0.024 the cross-validated mean squared error of estimation reached the minimum. In such a case, α = 0.44, β = 0.38 and γ = 0.25 (model 4). If λ increased, the elasticity of output with respect to labour became higher and the one with respect to intangible capital became lower. For an estimation error as high as one standard error from the minimum λ = 0.038 (model 5), both coefficients were similar and γ = 0.24. For λ = 0.17 output elasticity with respect to labour is the highest, reaching 0.52, while both other parameters decreased, to 0.33 in the case of tangible capital input and to 0.18 in the case of intangible capital (model 6). This estimate of the parameter at tangible capital was the closest to the previous studies. After this point, increasing λ resulted in the decrease of all coefficients. The Lasso method gave a slightly higher intangible capital coefficient estimate than the ridge regression (Figure 5), primarily at the cost of labour. It was quite stable with increasing λ. For λ = 0.001, the cross--validated error was at its minimum and γ = 0.29 (model 7). All three production factors remained in such a model. For λ value one standard error higher, the estimates remained similar. Out of the three production factors, the lasso procedure most likely rejected labour as the least significant in the production process. To conclude, for the whole continuum of λ parameters, intangible capital was an important production factor.

Having output elasticities with respect to all production factors, we were able to compute growth accounting. The elasticities informed us about the contribution of a particular production factor to economic growth. We assumed CRTS, since this hypothesis was not rejected. As we showed, the most probable range of output elasticities with respect to intangible capital is 0.2–0.3, so we computed growth accounting for these two extreme cases (Figure 3). The left panel in the figure shows the case where γ = 0.2. In such a case, during 1995–2013 intangible capital growth would have contributed

37% to total real GDP growth, while total factor productivity growth would have contributed 28%. With these assumptions physical capital growth contribution was 31%, while the contribution of labour was 4%. If we assumed $\gamma = 0.3$ with the cost of lower output elasticity with respect to labour, the contribution of intangible capital growth increased to 55% and TFP growth decreased to 11%. The contribution of tangible capital stayed at the level of 28% and the contribution of labour dropped to 3%. In both scenarios the contribution of intangible capital was high, especially during the periods of 1996–2001 and 2006–2008.

4.3 Poland and other countries

Cywiński et al. (2017) show the level of intangible capital investments related to GDP in selected Eastern European countries. From the eight Eastern European economies, the Czech Republic had been the leader in boosting economic growth by intangible capital from 1995 to 2005. Hungary and Slovenia followed. This changed during the consecutive years, when Slovenia noted the highest pace of intangible capital formation. The calculations show that Poland increased relative intangible capital formation, although still being behind Slovenia and the Czech Republic.

Eastern European leaders of intangible capital formation were in the bottom of the top ten European countries (Cywiński et al. 2017). Sweden, the United Kingdom and Belgium proved to use intangible capital to the largest extent, even though in the former two, the relative level of intangible capital investment fell slightly at the end of the first decade of 2000s. Poland belongs to the countries with close trade integration with Germany. If we compare the structural composition of intangible capital in Poland and in Germany over time, we observe several engaging contingencies. The share of computerized information in total intangible capital formation was generally higher in Germany, similarly to the share of innovative property. However, the share of economic competencies was higher in Poland. After 2005 we observe a swift increase in the share of innovative property in both countries and a corresponding decrease in the share of economic competencies. Yet, in the case of computerized information we do not see the abovementioned relationship.

One of the prominent components of intangible capital is the development costs in the financial industry. These costs were increasing in Poland until 2001. However, a year later we observed a relatively sharp decline (by 9.7%) followed by another 4% decline a year later. The intangible investments in the financial industry returned to the level from 2001 only after 2004, that is after the accession to the EU. In 2005 these investments were 10.3% higher than in 2001. The intensity of financial innovations is related both to the global financial nexus and country-specific institutional configurations. That is why in 2009 development costs in financial industry decreased by 22.3%, reacting to emerging financial constraints and uncertainty. Their level dropped to the one observed before the 2000s. In 2010 they increased again, but only for one year. Their significant increase occurred in 2013, when they rose to levels surpassing previous highs.

In terms of an institutional nexus that creates an investment climate apt for the development of financial products, one of the global leaders was the United States, where in 1998–2010 financial products comprised 0.2% of GDP. Among European countries, only Luxembourg had a higher development cost in financial industry intensity – 0.3%. In Poland this relation oscillated around 0.07% of GDP during 1995–2013. A similar scale could be found in the Czech Republic, Finland, Germany and

Italy. There were also European countries that produced more financial products relative to their GDP, for instance Spain (0.1% of GDP), the Netherlands (0.1% of GDP), Ireland (0.15% of GDP) and Cyprus (0.2% of GDP).

5 Conclusions

Intangible capital proved to be an important factor of growth in the Western European countries. The highest developed Eastern European economies benefited from these non-classical assets as well. In this study we addressed a question: What is the level of intangible capital in Poland and how does it affect economic growth? Intangible capital estimates from the Innodrive and Intaninvest project for Poland end in 2005 and indicate a rather modest knowledge-intensity of the economy. We followed the methodology proposed within these projects and calculated the values of intangible capital investments in Poland up to 2013, as well as its structure. On the basis of these data, we evaluated intangible capital stock in Poland, then estimated a production function for Poland, extending it with intangible capital and performed growth accounting. We performed an analysis of the sensitivity of production function parameters with partial least squares and two shrinkage methods.

Our results indicate that intangible capital was an important factor of growth in Poland. It grew faster than GDP and its meaning for economic growth gradually increased during the analysed period. It accounted for 3.1% of GDP in 1995, and for 5.5% in 2015. 'Economic competencies' were the most prominent component of intangible capital, accounting for 54% of its whole value. The second most significant IC component was innovative property (43% of intangible capital), and the third was computerized information (3% of intangible capital). In the subcategory of economic competencies growth was visible in 1995–2001 and 2004–2008. The skyrocketing boom in innovative property investments took place especially in 2006–2008. Within the latter, the highest growth occurred in investments in mineral exploration, licenses and copyrights. The investments in computerised information was gradually rising during 1995–2008, but it has been falling ever since the post-crisis period of 2009–2013.

The econometric exercise for Poland for the period 1995–2013 indicates that:

– intangible capital was a statistically significant production factor,

– the most probable output elasticity with respect to intangible capital is between 0.2 and 0.3,

– constant returns to scale hypothesis with intangible capital was not rejected.

With the above estimate, intangible capital contributed to at least one third of economic growth in Poland during 1995–2013, explaining a high portion of the Solow residual. The intangible capital effects were especially visible in 1995–2001 and 2006–2008.

Our findings supply additional arguments for the intensification of policies that support the build-up of many forms of intangible capital. At present Poland can still benefit from industrial manufacturing as a factor of growth. However, compared to Western European economies, the level of intangible capital is modest. It is therefore of crucial necessity to improve investment climate in Poland, by improving higher education and training institutions, fostering improvements in the financial market and in areas affecting technological readiness.

References

Ancyparowicz G. (2009), *Wpływ bezpośrednich inwestycji zagranicznych na wzrost polskiej gospodarki w okresie poakcesyjnym*, Główny Urząd Statystyczny, http://stat.gov.pl/cps/rde/xbcr/gus/ pgw_wplyw_bezp_inwest_zagr_na_wzrost_pol_gosp.pdf.

Beck T., Demirguc-Kunt A., Levine R. (2000), A new database on the structure and development of the financial sector, *World Bank Economic Review,* 14(3), 597–604.

Corrado C., Haskel J., Jona-Lasinio C., Iommi M. (2012), *Intangible capital and growth in advanced economies: measurement methods and comparative results*, IZA Discussion Paper, 6733.

Corrado C., Hulten C., Sichel D. (2005), Measuring capital and technology: an expanded framework, in: C. Corrado, J. Haltiwanger, D. Sichel (eds), *Measuring Capital in the New Economy. Studies in Income and Wealth*, The University of Chicago Press.

Corrado C., Hulten C., Sichel D. (2006), *Intangible capital and economic growth,* NBER Working Paper, W11948, National Bureau of Economic Research.

Corrado C., Hulten C., Sichel D. (2009), Intangible capital and U.S. economic growth, *Review of Income and Wealth*, 55(3), 661–685.

Cywiński Ł., Harasym R. (2016), Inwestycje w kapitał niematerialny w gospodarkach na średnim poziomie rozwoju, *Ekonomia XXI w.*, 10(2), 89–102.

Cywiński Ł., Harasym R., Pater R., Tarchalski K. (2016), Intangible capital, level of economic development, and middle income trap, *Studia Ekonomiczne*, 90(3), 439–461.

De Jong S. (1993), SIMPLS: an alternative approach to partial least squares regression, *Chemometrics and Intelligent Laboratory Systems*, 18, 251–263.

Denison E.F. (1963), The sources of economic growth in the United States and the alternatives before US, *Journal of the American Statistical Association*, 58(304), 1168–1171.

Epstein N., Macchiarelli C. (2010), *Estimating Poland's potential output: a production function approach*, IMF Working Paper, 10/15.

Faeth I. (2008), Determinants of foreign direct investment – a tale of nine theoretical models, *Journal of Economic Surveys*, 23(1), 165–196.

Friedman J., Hastie T., Tibshirani R. (2010), Regularization paths for generalized linear models via coordinate descent, *Journal of Statistical Software*, 33(1), 1–22.

Gradzewicz M., Kolasa M. (2005), *Estimating the output gap in the Polish economy: VECM approach*, IFC Bulletin, 20.

Griliches Z., ed. (1984), *R&D, Patents, and Productivity*, University of Chicago Press.

Growiec J., Pajor A., Górniak D., Prędki A. (2015), The shape of aggregate production functions: evidence from estimates of the World Technology Frontier, *Bank i Kredyt*, 46(4), 299–326.

Harvey A.C. (1989), *Forecasting Structural Time Series Models and the Kalman Filter,* Cambridge University Press.

Jeznach M., ed. (2010), *Rachunki kwartalne Produktu Krajowego Brutto. Zasady metodologiczne*, Główny Urząd Statystyczny.

Jona-Lasinio C., Felix R., Iommi M. (2011), National measures of intangible capital in the EU27 and Norway, in: H. Piekkola (ed.), *Intangible capital – driver of growth in Europe*, Proceedings of the University of Vaasa Research Report, 167, 20–62.

Jorgenson D.W. (1963), Capital theory and investment behaviour, *American Economic Review*, 53(2), 247–259.

Kendrick J. (1961), *Productivity trends in the United States*, Princeton University Press.
Konopczak K. (2013), Konwergencja gospodarek państw Europy Środkowo-Wschodniej względem strefy euro – test wspólnego trendu i wspólnego cyklu, *Bank i Kredyt*, 44(4), 353–374.
Landes E., Rosenfield A. (1994), The durability of advertising revisited, *Journal of Industrial Economics*, 42(3), 263–276.
Marrano G., Haskel J. (2006), *How much does the UK invest in intangible assets?*, Working Paper, 578, Queen Mary University of London, School of Economics and Finance.
Mevik B.H., Wehrens R. (2007), The pls package: principal component and partial least squares regression in R, *Journal of Statistical Software*, 18(2), 1–24.
Pater R. (2015), *The UK business cycle and the structure of the economy*, Prace i Materiały Instytutu Rozwoju Gospodarczego IRG-SGH, 97, 67–93.
Piekkola H., ed. (2011), *Intangible capital – driver of growth in Europe*, Proceedings of the University of Vaasa Research Reports, 167.
Próchniak M., Witkowski B. (2012), Konwergencja gospodarcza typu β w świetle bayesowskiego uśredniania oszacowań, *Bank i Kredyt*, 43(2), 25–58.
Schumpeter J.A. (1934), *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle*, Transaction Publishers.
Sichel D.E. (2008), Intangible capital, in: N.S. Durlauf, L.E. Blume (eds), *The New Palgrave Dictionary of Economics*, Palgrave Macmillan.
Smarzynska-Javorcik B., Spatarenau M. (2005), Disentangling FDI spillover effects: What do firm perceptions tell us? in: T. Morgan, E. Graham, M. Blomstrom (eds) *Does Foreign Direct Investment Promote Development*?, Institute of International Economics.
United Nations Statistical Commission (2009), *System of National Accounts 2008*, World Bank.
Witajewski-Baltvilks J. (2016), Catching up in Czech Republic, Hungary and Poland, *Bank i Kredyt*, 47(4), 319–340.

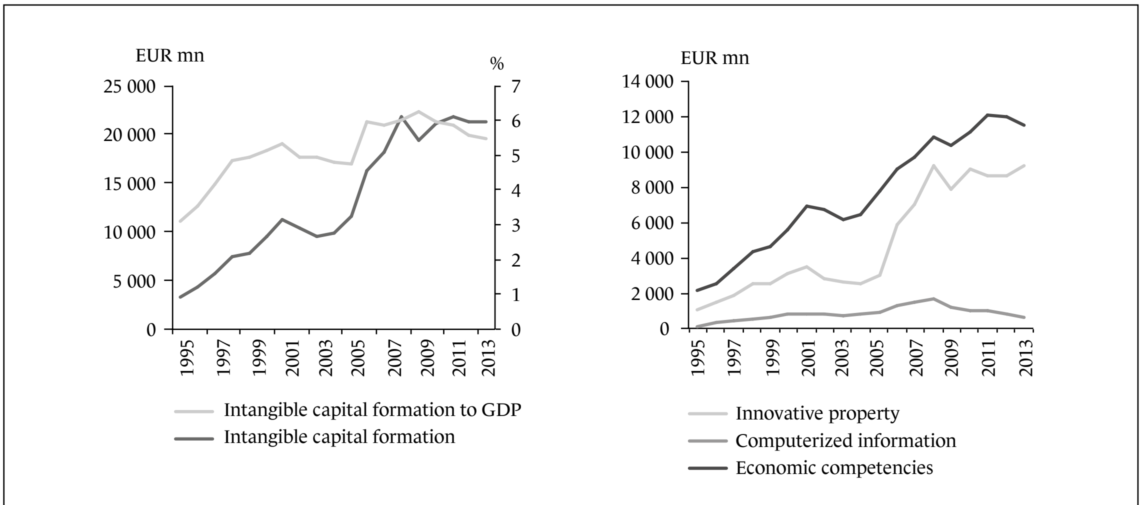
Acknowledgements

We would like to thank Jan Witajewski-Baltvilks for providing us with the data on physical capital stock.

Appendix

Figure 1

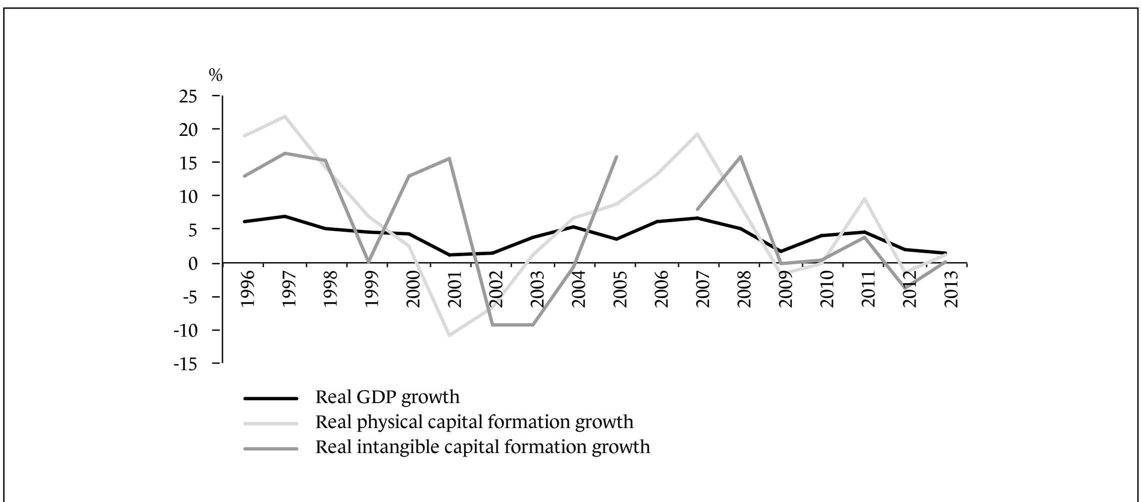
Intangible capital formation in Poland and its main components



Source: 1995–2005 – Innodrive project data, 2006–2013 – own calculations.

Figure 2

Annual growth rates of real intangible capital formation, fixed capital formation and GDP in Poland

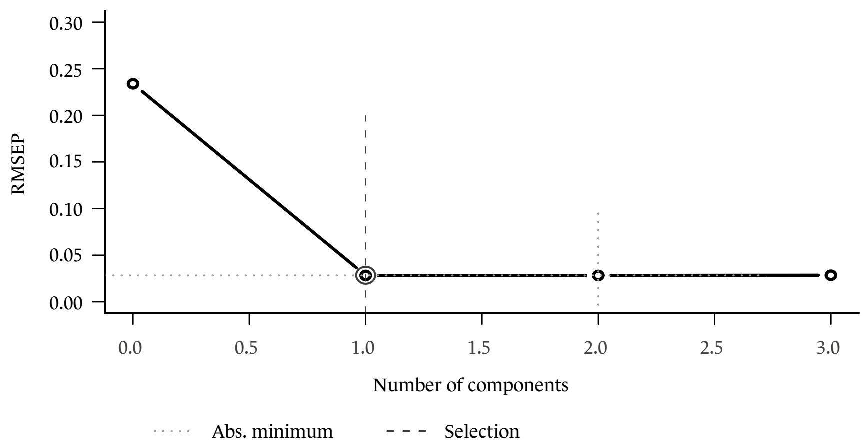


Notes:

The 2006 gap is the result of change in the national accounts methodology. Price index, 2005 = 100. Price index for intangible capital formation was estimated on the basis of Corrado et al. (2012) and Innodrive project data.

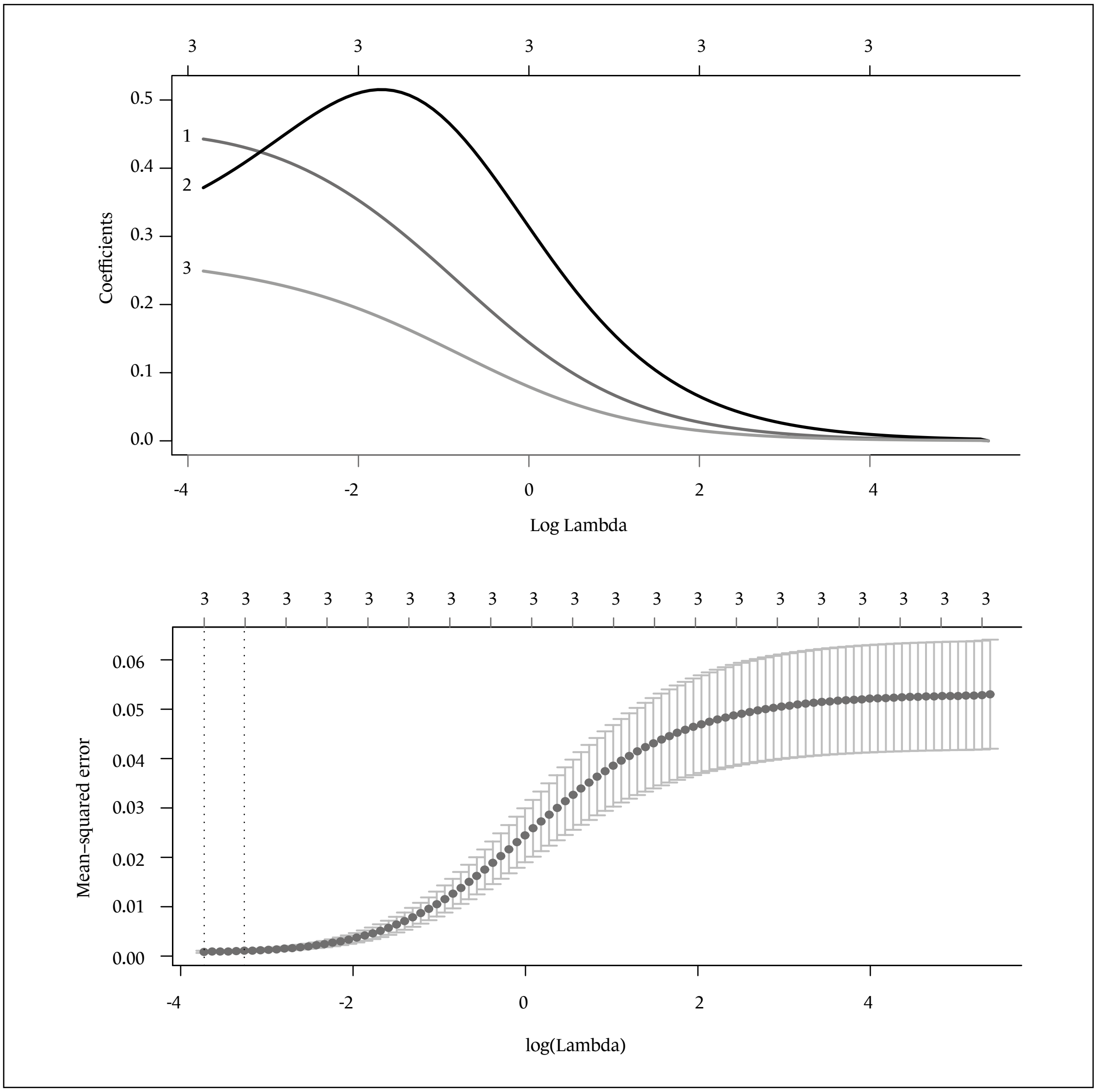
Source: 1995–2005 – Innodrive project data, 2006–2013 – own calculations.

Figure 3
Number of components in PLS regression according to root mean squared error of prediction (RMSEP)



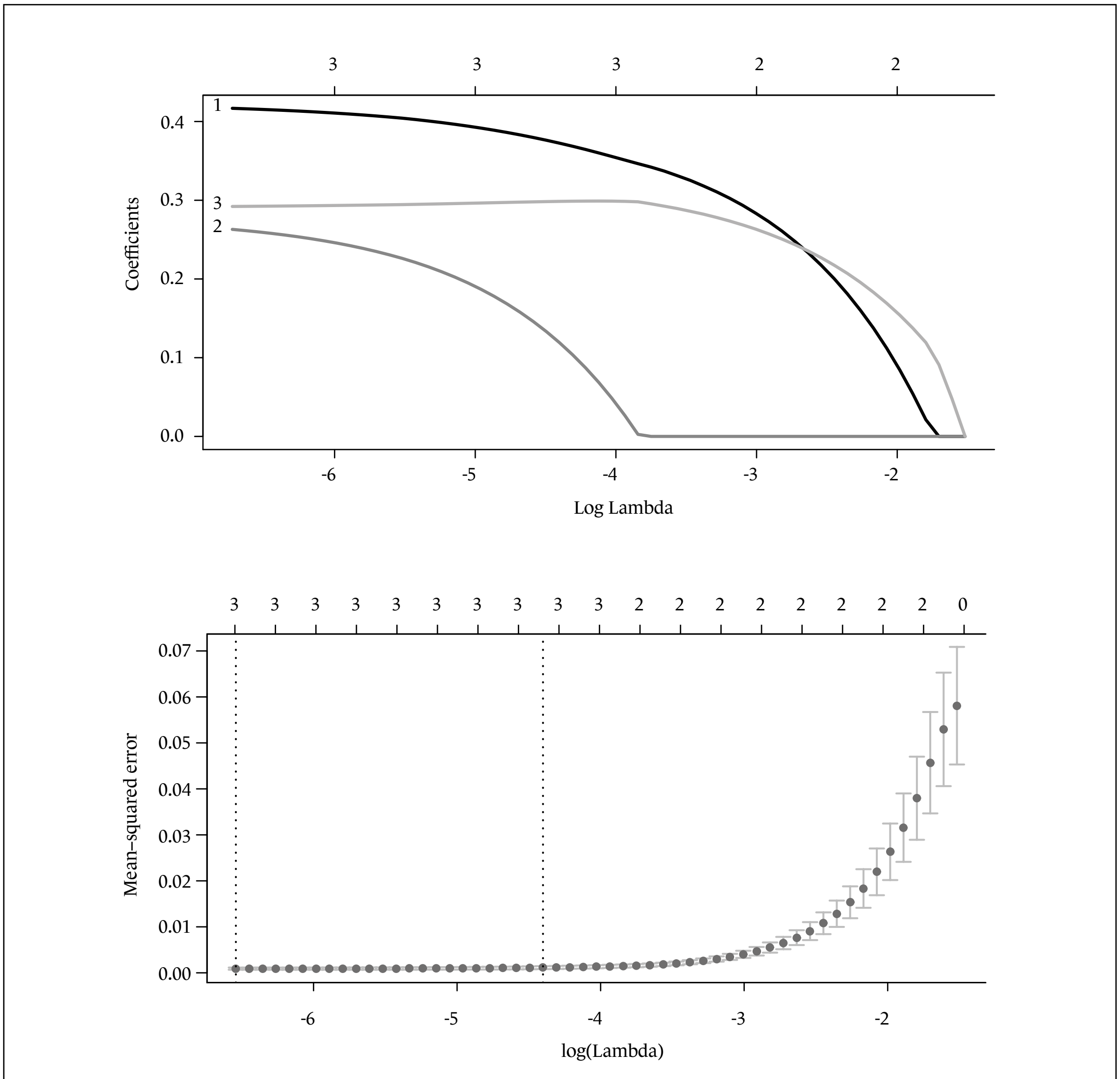
Notes:
Abs. minimum means the lowest RMSEP. Selection means the number of components suggested by one-sigma heuristic and permutation cross-validation techniques.

Figure 4
Results of ridge regression



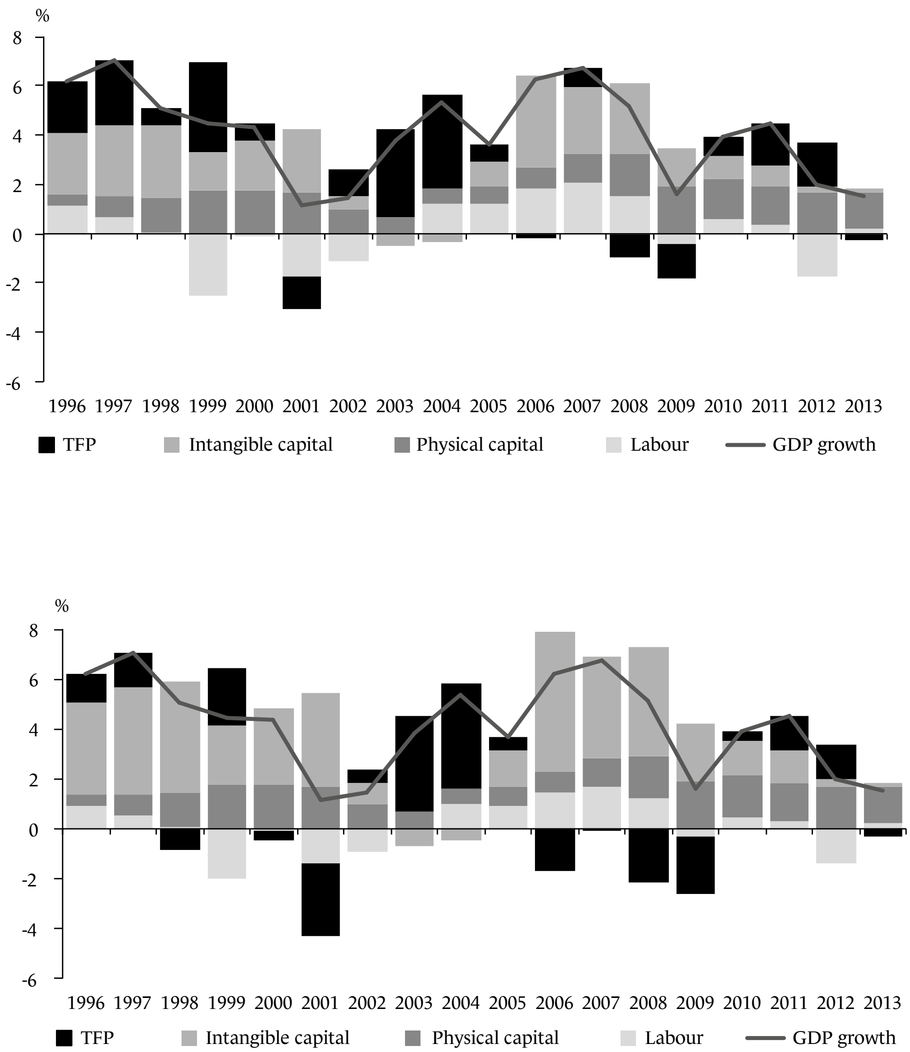
Notes:
The top panel presents estimates as a function of log (λ); 1 = β, 2 = α, 3 = γ. Bottom panel presents the cross-validated mean squared error with one standard deviation error bars as a function of log λ. Numbers at the top of the graphs represent the number of covariates.

Figure 5
Results of lasso method



Notes:
The top panel presents estimates as a function of log λ; 1 = β, 2 = α, 3 = γ. Bottom panel presents the cross-validated mean squared error with one standard deviation error bars as a function of log λ. Numbers at the top of the graphs represent the number of covariates.

Figure 6
The contribution of TFP, labour input, physical and intangible capital growth to total GDP growth



Notes:
Top panel: $\alpha = 0.5, \beta = 0.3, \gamma = 0.2$; bottom panel: $\alpha = 0.4, \beta = 0.3, \gamma = 0.3$.

Table 1
Intangible capital in Poland and its components (EUR mn, current prices)

Type of investment	**1995**	**2000**	**2005**	**2010**	**2013**
1. Computerized information	95.1	845.9	912.6	1,003.9	657.7
a) Software publishing and database	95.1	845.9	912.6	1,003.9	657.7
2. Innovative property	1,049.0	3,064.0	2,963.0	9,023.3	9,175.9
a) R&D including social sciences and humanities	238.9	396.6	380.3	597.3	1,289.9
b) mineral exploration, evaluation and copyright and license cost	72.4	645.3	322.0	1,664.3	1,754.1
c) development cost in financial industry	143.4	701.7	872.6	1,008.0	1,145.8
d) new architectural and engineering designs	594.3	1,320.2	1,388.1	5,753.7	4,986.2
3. Economic competencies	2,142.0	5,609.1	7,727.6	11,092.9	11,523.5
a) brand equity	631.6	2,180.4	3,316.3	3,833.3	4,009.2
– advertising expenditure	363.3	1,541.9	2,682.9	3,364.0	3,536.0
– market research	268.3	638.4	633.4	469.3	473.2
b) firm-specific human capital	251.1	554.9	844.9	1,226.5	1,248.1
– continuing vocational training and apprentice training	251.1	554.9	844.9	1,226.5	1,248.1
c) organizational structure	1,259.3	2,873.8	3,566.5	6,033.2	6,266.3
– purchased	620.3	1,718.9	2,251.2	3,111.3	3,554.1
– own account	639.0	1,154.9	1,315.3	2,921.9	2,712.2
Total intangible capital	3,286.1	9,518.8	11,603.2	21,120.1	21,357.1

Source: 1995–2005 – Innodrive project data, 2006–2013 – own calculations.

Table 2

Aggregate production function estimates for Poland with intangible capital

	Model						
	(1) classical	(2) with IC	(3) 2 comps.	(4) λ = min	(5) λ = 1se	(6) λ = max α	(7) λ = min
	Method						
	GLS	**OLS**	**PLS**	**Ridge**	**Ridge**	**Ridge**	**Lasso**
const	10.339	5.734	–	5.281	5.278	6.574	5.994
st. error	1.530	1.359	–	–	–	–	–
ln (K)	0.254***	0.424***	0.391	0.441	0.428	0.333	0.416
st. error	0.042	0.128	–	–	–	–	–
ln (*L*)	0.602**	0.279*	0.298	0.388	0.414	0.515	0.260
st. error	0.180	0.133	–	–	–	–	–
ln (R)	–	0.290***	0.307	0.247	0.238	0.183	0.292
st. error	–	0.072	–	–	–	–	–
adjusted R^2	0.666	0.987	0.984	–	–	–	–
LR	–	14.04	–	–	–	–	–
p-value	–	< 0.01	–	–	–	–	–
Wald CRTS	0.77	0.002	–	–	–	–	–
p-value	0.39	0.96	–	–	–	–	–

* significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. ln denotes the natural logarithm.