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Intangible Capital: Complement or Substitute in the Creation of Public Goods?*

Alexander Schiersch, Martin Gornig

Abstract

This paper tests whether intangible capital is a substitute or, to some degree, a complement to standard inputs in the production process. The analysis is conducted for public sectors in which governmental institutions are directly responsible both for efficiently producing public goods and for investing in new production factors. Knowing the substitutability of inputs is important for achieving the best possible result for the invested money, *inter alia*, when designing stimulus programs. Using three-input two-level nested CES production functions, the results reveal that intangible capital is a relevant input factor in the production of public goods and only weakly substitutable with other inputs. This result implies that any investment plan or any stimulus program should not just focus on tangible assets, but also needs to include investments in intangibles in order to achieve the maximum output and to efficiently use public money.

JEL codes: E22; E23; D20

Keywords: intangible capital; public sector; CES production function; elasticity of substitution

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1 Introduction

Starting with the knowledge production function of Griliches (1979), intangible capital, in the form of R&D in Griliches approach, is increasingly the focus of economic research and policy. Since the millennium, research on intangible capital accelerated with new forms of intangible assets coming into focus. The related economic literature is growing significantly as a result thereof.

Part of that literature is dedicated to evolving the techniques for measuring the different intangible assets, as well as on estimating its importance on firms, industries, and nations. (see *inter alia* Kendrick, 1972; Corrado et al., 2005; Inklaar, 2010; Lipsey, 2010; Nakamura, 2010; Martin-Oliver and Salas-Fumás, 2011; Corrado et al., 2013; Piekkola, 2014; Haan et al., 2010; Görzig and Gornig, 2015; Bacchini et al., 2016). Another strand of the literature focuses on the relationship between intangible capital and productivity growth, finding a mixed picture. While most find an acceleration of labour productivity growth if intangibles are included in the growth accounting framework (see *inter alia* Marrano et al., 2009; van Ark et al., 2009; Fukao et al., 2009; Corrado et al., 2009; Goodridge et al., 2013), others find that TFP growth is lower when investments in intangibles are included in growth accounting (see *inter alia* Fukao et al., 2009; Edquist, 2011; Piekkola, ed, 2011). In these latter cases, conventional TFP growth captures the part of output growth that actually has to be assigned to intangible capital deepening. In other words, TFP, which is measured as a residual within growth accounting, captures the effect of intangibles if they are not explicitly included in the production function. But once included, the upward bias of TFP growth is reduced. Finally, a number of studies focus on output elasticity of intangibles within an augmented Cobb-Douglas production framework. These mostly find a positive and significant effect of intangible capital or intangible investments (see *inter alia* Roth and Thum, 2013; Niebel et al., 2013; Corrado et al., 2014a,b; Chen et al., 2016). As a result of the growing research in this field, there is an increasing awareness that these assets are an important component fueling economic growth (OECD, 2013, 2015). Consequently, policy makers are trying to encourage investment in these assets. This is most obvious with respect to R&D investments that are subsidized, directly or indirectly, by all European governments. In addition, policy makers are now aware that training, software, and other intangible assets are also important factors underlying economic success and societal prosperity.

The literature, however, implicitly assumes that tangible capital and intangible capital are substitutable to some degree. This is due to the fact that these studies usually rely on the Cobb-Douglas production function framework. If, instead, intangibles and tangible capital are just weakly substitutable or even complements to each other, applying Cobb-Douglas is inappropriate. One consequence of complementarity would be that spending cuts in one input would have more severe effects than in the case of substitutability between inputs. Accordingly, economic policy would need to consider always both types of capital when creating investment plans or

when imposing austerity measures. The question of substitutability is particularly important for the non-market sector, because the state is the dominant actor in these industries, whether as the main employer, the main investor, or in providing crucial social services. Thus, this study addresses the following research questions:

Is intangible capital a substitute or, to some degree, a complement for other inputs in the non-market sector? Or in other words, what is the elasticity of substitution between intangible capital, tangible capital and labour?

The study contributes to existing literature in two ways. Firstly, we provide insights regarding the output elasticity of intangible capital at the industry level for the public sector in Europe. Secondly, to the best of our knowledge, this study is the first to estimate the elasticity of substitution between intangible capital and other inputs for public sectors in Europe.

The estimations are conducted by means of nested CES production functions. The estimations show that intangible capital is a relevant input factor in the public sectors. The analysis also reveals that intangible capital is just weakly substitutable with other inputs. Because we find the substitution elasticity to be significantly below 1 in many estimations, the study cannot confirm the assumption of the Cobb-Douglas approach regarding the substitutability between inputs.

The remainder of this paper is organized as follows. Section 2 describes the method and the estimation strategy, while Section 3 describes the database. Our findings are presented in Section 4 and discussed in Section 5. Section 6 concludes.

2 Method and Estimation Procedure

The starting point of the analysis is a production function that includes intangible capital as an additional input. This is based on the approach proposed by Griliches (1979), according to which knowledge capital is included as an additional input factor alongside labour and capital. Hence, we include intangible capital as a third input in the subsequent analysis, as Griliches (1979) did with R&D. In fact, all previous studies addressing the effect of intangible capital on growth or productivity growth, use intangibles as an additional input.¹ The first estimation equation is thus

$$Y_{it} = C_{it}^{\alpha} L_{it}^{\beta} I_{it}^{\gamma} e^{\omega_{it}} e^{\epsilon_{it}} \quad (1)$$

where L_{it} is labour input, C_{it} is tangible capital input, I_{it} is intangible capital, Y_{it} is gross value added, and ω_{it} is the Hick-neutral productivity of country i at time t . Nevertheless we

¹ Alternatively, one could assume that intangible capital only affects TFP and must, therefore, be modelled within the law of motion for TFP (for R&D see *inter alia* Aw et al., 2011; Doraszelski and Jaumandreu, 2013). In this case, of course, the question regarding the elasticity of substitution between intangible capital and tangible capital becomes obsolete.

must keep in mind that estimating Eq. (1) goes along with the restrictive assumption of a constant substitution elasticity of 1 between all inputs.² In addition, using OLS requires a set of restrictive assumptions (cf. Akerberg et al., 2007; Katayama et al., 2009; Van Biesebroeck, 2012, 2015), *inter alia* that TFP is unobservable to the firms and that the firms decide about their inputs without taking productivity into consideration. Without this latter assumption, the well-known simultaneity issue comes into play and any estimation of Eq. (1) by mean of OLS is potentially biased (cf. Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Akerberg et al., 2015). However, as we are interested in gaining an initial impression of the relevance of intangible capital in a first step, these limitations seem acceptable.

In the next step, we deviate from the previous literature as we need a production function approach that allows for any substitution elasticities between any two inputs. Consequently, the analysis applies so-called Constant Elasticity of Substitution (CES) functions. The CES production function for labour and capital with Hick-neutral technological change is defined as follows:

$$Y_{it} = \gamma e^{\lambda t} \left(\delta_C C_{it}^{-\rho_{CL}} + (1 - \delta_C) L_{it}^{-\rho_{CL}} \right)^{-\frac{\nu}{\rho_{CL}}} \quad (2)$$

where λ is the rate of Hick-neutral technological change over time, t is the time index, ρ_{CL} is the substitution parameter for labour and capital, δ_C determined the optimal distribution of the two inputs, γ can be understood as a productivity parameter and ν measures the elasticity of scale. The elasticity parameter ρ can take any value between -1 and ∞ . Based on these values, the elasticity of substitution between any two inputs i and j is derived as $\sigma_{ij} = 1/(1 + \rho_{ij})$. Hence, the elasticity of substitution in a CES production function can take any value between (approaching) zero and infinity.

There are three special cases: First, if $\rho \rightarrow 0$, the substitution elasticity approaches 1. This is the special case of the Cobb-Douglas production function. Second, if $\rho \rightarrow -1$, the substitution elasticity approaches infinity. In this case the production function tends to become linear, meaning that it is an additive production function; given that $\nu = 1$. Consequently, all inputs would be perfect substitutes for each other. Finally, in case that $\rho \rightarrow \infty$, the substitution elasticity approaches 0. This is the case if the production process is best described by a Leontief production function. This limitational production function is characterized by the fact that inputs are not substitutable for each other and that there is exactly one efficient input combination for a given level of output. It also follows that any increase of a factor input has no effect on the output as long as the other inputs are not increased accordingly.

Eq. (2) refers to a CES production function with labour and capital. The simple CES function for n -inputs has the disadvantage that it assumes the elasticity of substitution between

² Hence, a one percentage change in the ratio of input i and input j resulting from a one percentage change in the marginal rate of technical substitution at every point of the isoquant.

all inputs to be identical. To solve this issue, [Sato \(1967\)](#) proposes using nested structures when constructing CES functions with more than two inputs. Essentially, a nested CES function incorporates at least one additional CES function within an upper-level CES function. This, however, requires that the scale elasticity of the lower-level CES function and its productivity parameter is normalized to one. Additionally, the assumption that the inputs aggregated within the lower-level CES function share the identical substitution elasticity toward the other lower-level CES function or the third input is imposed. Finally, it must be kept in mind that the parameters of nested CES functions are not invariant to the chosen nesting structure.

Industry and county fixed effects are another issue. As seen in Eq. (2), industry or country dummies cannot be easily included in CES functions. To circumvent the assumption that all industries across all countries work under the same production function, sharing the same distribution parameters and substitution parameters, the estimation is conducted separately for each industry. Unfortunately, given the low number of observations per industry and country, it is not possible to do the estimations separately at the industry-country level. In order to tackle this issue, we follow a recent strand of literature and use geometric means to normalize each variable at country and industry level ([de La Grandville, 1989](#); [Klump and Preissler, 2000](#); [Klump et al., 2007a,b, 2011](#)). Eq. (3) shows the resulting three-input two-level nested CES function, for the combination $LC - I$ with I being intangible capital.

$$\tilde{Y}_t = \gamma_{CL-I} e^{\lambda_{CL-I} t} \left[\delta_{CL-I} \left(\delta_{CL} \tilde{C}_t^{-\rho_{CL}} + (1 - \delta_{CL}) \tilde{L}_t^{-\rho_{CL}} \right)^{\frac{\rho_{CL-I}}{\rho_{CL}}} + (1 - \delta_{CL-I}) \tilde{I}_t^{-\rho_{CL-I}} \right]^{\frac{\nu_{CL-I}}{\rho_{CL-I}}} \quad (3)$$

with $\tilde{Y}_t = Y_t/\bar{Y}$, $\tilde{C}_t = C_t/\bar{C}$, $\tilde{L}_t = L_t/\bar{L}$ and $\tilde{I}_t = I_t/\bar{I}$. From this equation we will obtain the substitution elasticities for intangible capital with the CES function for labour and capital (σ_{CL-I}). Additional nesting structures that will be estimated are $CI - L$ and $LI - C$. The nesting structure $CI - L$ will reveal the substitution elasticity between tangible capital and intangible capital (σ_{CI}), while the nesting structure $LI - C$ provides the substitution elasticity between labour and intangible capital (σ_{LI}). Estimating all possible nesting structures also serves as a robustness check. Similar results would demonstrate that our findings are not driven by the chosen nesting structure.

Due to the fact that the CES functions are non-linear in parameters, the parameters cannot be obtained by applying linear estimation techniques. Until recently, the so-called Kmenta approximation was used to linearise CES functions and estimate its parameters. But this method is not without drawbacks. Therefore, we make use of recent developments and estimate the parameters of the CES function directly by using different optimization algorithms.³ These

³The optimization routines used by the *micEconCES* package and applied within our analysis are *Levenberg-Marquardt*, *PORT*, *BFGS*, and *L-BFGS-B*. For details see [Henningesen and Henningesen \(2014\)](#) and [Henningesen](#)

routines aim at reducing the sum of squared residuals. Given that all parameters are estimated within one step, there are a multitude of possible solutions to the optimization problem. Depending on the starting point of the calculation, which is defined by a set of starting values – either the default starting values of the routines, or by self-defined starting values – the routines potentially stop at local minimums. Consequently, we apply a grid search. Within a grid search, the routines runs across a set of predefined substitution parameters – i.e. ρ_{ij} and ρ_{ij-k} for a CES function with three inputs – estimating the remaining parameters such that the sum of squared residuals is minimized.

But even the grid search cannot overcome the problem that a certain combination of parameter values might result in a minimal sum of squared residuals, but that the obtained parameters are economically unreasonable. E.g. the optimal parameter combination might imply that the output is produced without using any labour input. This is clearly implausible. The estimation strategy therefore contains an additional step, in which a set of upper and lower values is defined for each parameter. These values are partly derived from the results of the OLS estimation.⁴

3 Data

3.1 Intangible Capital

The study uses data for intangible capital from the *SPINTAN* project. The project aims at providing a data set for intangible investment and intangible capital in public sectors. This comprises the industries *scientific research and development (ISIC4 code M72)*; *public administration and defence, compulsory social security (ISIC4 code O)*; *education (ISIC4 code P)*; *human health and social work activities (ISIC4 code Q)*; *human health activities (ISIC4 code Q86)*; *residential care activities plus social work activities without accommodation (ISIC4 code Q87-Q88)*; *creative, arts and entertainment activities plus libraries, archives, museums and other cultural activities plus gambling and betting activities (ISIC4 code R90-R92)*; and *arts, entertainment and recreation (ISIC4 code R)*. The data set contains information on the intangible assets *organizational capital, design, advertising, market research, training, R&D, and software*. R&D and software are available only at the one-digit industry level. The remaining intangible assets are available only at the two-digit industry level (except for industries *O* and *P*). The data set covers the 1995-2011 period. For a detailed description of the data collection, data production,

and Henningsen (2011). Other available routines are *Conjugate Gradients*, *Newton*, *Nelder-Mead*, *Simulated Annealing* and *Differential Evolution*. However, we run several tests showing that these methods do not perform as well as the methods mentioned above. Moreover, only *PORT* and *L-BFGS-B* allow setting upper and lower limits for parameters when conducting grid searches.

⁴Such an example is shown in Figure 1, where the algorithm finds that the substitution elasticity between two inputs is 0.5, given that the minimal sum of squared residuals is found for a set of parameters that include a ρ of 1. However, $\rho = 1$ rather looks like an outlier. As the figure shows, the robust CES production function has a substitution parameter of approximately -0.4 .

measurement issues, and other issues see [Bacchini et al. \(2016\)](#) and [Mas \(2015\)](#).⁵

As we aim to analyze the substitution elasticity between intangible capital and other independent variables by means of a two-level nested CES function, we construct an aggregated intangible capital variable per industry and country in the first stage. However, because a considerable number of cells are not filled, a simple aggregation is not an option. Instead, we proceed industry by industry, excluding those observations for which one or more of the intangible assets is missing. In most cases, observations are dropped due to lack of observations for R&D. The aggregation is conducted at the one-digit industry level using the deflated capital stocks.

3.2 Labour, Tangible Capital and Gross Value Added

The SPINTAN database, so far, does not contain data on labour, tangible capital, or output. We construct these variables using gross value added (GVA), gross fixed capital formation (GFCF), and the number of persons employed (EMP) at the one-digit industry level from Eurostat.⁶ These data need to be modified for three reasons: First, R&D and software is included in both GFCF and intangible capital; thus the GFCF data must be adjusted. Second, the calculation of CES production functions requires a tangible capital stock, not just the GFCF. We approximate the capital stocks using the adjusted GFCF and applying the Perpetual Inventory Method (PIM). Third, the output needs to be adjusted for investments in those intangible assets that are not included in national accounts.

In a first step, we reduce the GFCF by investments in R&D and software. The data on R&D and software investments are taken from the SPINTAN database. Subsequently, we follow [Berlemann and Wesselhöft \(2014\)](#) and [Görzig and Gornig \(2015\)](#) and use the investment level in t_0 for the calculation of the initial tangible capital stock by means of PIM.⁷ The initial capital stocks, the industry depreciation rates obtained, and the adjusted GFCF are then used to calculate the capital stock for the years following 1995.

< place Table 1 about here >

Eventually, output needs to be adjusted upward if some of the expenditures are considered as intangible investments. This comes from the fact that the respective expenditures are no longer intermediates but capital expenditures. In this case, "they are not subtracted from gross output to obtain value added and they lead to the creation of new capital input. Moreover the own-account production leads to new output and newly owned capital with a (possibly implicit)

⁵ The data is downloadable at <http://http://www.spintan.net/>.

⁶ Because the number of observations for hours worked (HEMP) is considerably smaller than for number of persons employed, we refrain from using HEMP.

⁷ Industry specific depreciation rates and growth rates are taken from the EU KLEMS database. (see <http://www.euklems.net/>) For those countries not included in the latest EU KLEMS database, the industry mean of growth rates from all available countries in the EU KLEMS database is applied.

rental payment. Thus the nominal value added has risen both because intermediate inputs are lower and because gross output is higher. The overall increase in nominal value added of industry j is equal to the additional nominal investment." (Corrado et al., 2014b, pp. 4) We follow Corrado et al. (2014b) and add investment in intangibles, other than R&D and software, to gross value added.^{8,9}

The final data set with all required variables, i.e. intangible capital stock, labour, tangible capital stock and gross value added, contain 700 observations for 14 countries and four public industries. However, it is not a balanced panel and does not contain observations for all industries and years as shown in Table A.5. The descriptive statistics for each industry and variable are shown in Table 1.

4 Estimation Results

Following the procedure outlined in Section 2, we start the analysis by estimating Eq. (1) in logs by means of OLS. The results in Table 2 are in line with expectations. Column (1) contains the output elasticities without controlling for year, country or industry effects. In this specification, the coefficient for labour is 0.71, that of capital is 0.18, and the coefficient of intangible capital is 0.14. All coefficients are significant. This significance persists if we include year and industry dummies (2), although the output elasticities of tangible and intangible capital increases while that of labour decreases. Apart from this deviation, the coefficients of tangible and intangible capital continuously decrease as we include year and country dummies (3), industry and country dummies (4), and all dummies (5). However, the coefficients remain significant in all specifications. This result is in line with previous findings in the literature on market sectors. However, this study is the first to confirm a positive elasticity for intangible capital in public sectors.

< place Table 2 about here >

Eq. (3) with different nesting structures is estimated in the next step of the analysis. Although we do not impose restrictions on the main production function parameters, such as the δ 's, we restrict the range of possible substitution parameters from -0.9 to 2 with interval steps of 0.1 . Consequently, the substitution elasticities can range from 10 , indicating strong substitutability between two inputs, and $0.\bar{3}$, indicating weak substitutability; almost complementarity. This procedure is applied in order to limit computational time.

⁸ $P_V V_j = P_G G_j + P_N N_j^{OA} - (P_M M_j - P_N N_j^{PURCH})$, with $P_V V_j$ as value added of industry j , $P_G G_j$ as the value of gross output, $P_N N_j^{OA}$ as the value of own account intangible assets, $P_M M_j$ as value of intermediate input as reported by national accounts and $P_N N_j^{PURCH}$ as value of purchased intangible assets (Corrado et al., 2014b, pp. 4). Due to a lack of data, we must ignore $P_N N_j^{OA}$ in the adjustment of value added in this study.

⁹ Due to the changes in national accounts following the implementation of SNA2008 and ESA2010, R&D and software are accounted for as investments. Consequently, national accounts gross value added does not need to be adjusted for these two intangible assets.

The results are shown in Table 3. Labour and tangible capital are found to be strong substitutes for each other (σ_{CL}) in industry P (est. no 2), but weak substitutes in industries O (est. no 1) and R (est. no 4). The results are mixed when considering the substitutability between intangible capital and the CES function for labour and capital (σ_{CL-I}), as well as between intangible capital and tangible capital (σ_{CI}), and between intangible capital and labour (σ_{LI}). We find a substitution elasticity close to 1 between intangible capital and the CES function for labour and capital in industry R (est. no 4) as well as between tangible capital and intangible capital in industries Q and R (est. no 7, 8). In the remaining 9 out of the 12 estimations, however, the substitution elasticities between intangible capital and the respective other inputs are below 1, indicating weak substitutability. Or in other words, the substitution elasticities deviate in most estimations from the Cobb-Douglas assumption of a substitution elasticity of 1, whereby it deviates such that intangibles and the other respective inputs are weak substitutes for each other. This is a hint that the assumption of the Cobb-Douglas approach does not apply. However, it must be noted that only 6 of the total 24 substitution elasticities are significantly different from 1. In the remaining cases, we cannot rule out with statistical certainty that the elasticity of substitution is actually 1.

< place Table 3 about here >

Unfortunately, some of the results in Table 3 lack economic credibility. This is apparent looking over the δ 's: It would follow from $\delta_{CL} = 0$ in industries Q and R (est. no 3, 4) that the output is generated without any contribution of tangible capital. Similarly implausible coefficients can be found for δ_{CI} (est. no 7, 8), δ_{CI-L} (est. no 8), and for δ_{LI-C} (est. no 11, 12). In addition, the standard deviation for many substitution elasticities, e.g. for tangible capital and labour in industries Q and R (est. no 3, 4), are outside normal ranges.

Because of these unsatisfying results, we define upper and lower boundaries for all coefficients. These boundaries are partly derived from the OLS results. *Inter alia*, the minimal coefficient for tangible capital in Table 2 is 0.066. Although the OLS results are potentially downward biased, we expect the coefficient for capital to not be below 0.05.¹⁰ Consequently, the maximum coefficient for labour should not exceed 0.95. Likewise, the maximal sum of the coefficients of intangible and tangible capital in Table 2 is 0.44 (column 2). Again, the coefficients might be potentially biased, but we do not expect them to exceed 0.5, thus defining the upper limit of δ_{CI} as being 0.5. We further proceed along this line of reasoning in defining upper and lower boundaries. The full set of boundaries is provided in Table A.6. Using these boundaries, the different nested CES production functions are again estimated using grid search.

¹⁰ As discussed in De Loecker and Goldberg (2014) and De Loecker et al. (2016), the coefficients in parametric production function estimations are most likely downward biased as a result of the *input price bias* or the *output price bias*. An additional source of bias in our simple OLS estimations is the simultaneity issue, which, however, might work the opposite way (Olley and Pakes, 1996; Akerberg et al., 2007)

< place Table 4 about here >

Applying boundaries for all parameters improves the estimation considerably, as shown in Table 4. Not only are the δ 's within economically reasonable boundaries, but the number of significant δ 's also increases to 20. The effect on the substitution elasticities is also favourable. We can state that intangible capital is just weakly substitutable with the CES function for labour and capital in three of the four non-market industries (est. no 1 - 3), whereas the substitution elasticity is significantly different from 1 in two of these estimations. In other words, the substitution elasticity is significantly different from the assumptions of the Cobb-Douglas function. If we consider the nesting structure $CI - L$, in which we combine tangible and intangible capital into one capital variable within the lower level CES function, we find that intangible capital is only weakly substitutable with tangible capital in three industries (est. no 5 - 6), again being significantly different from 1 in two estimations. Finally, intangible capital is only weakly substitutable with labour in three of four industries (est. no 9 - 10). In these estimation the substitution elasticity is significantly different from 1 in all three estimations. Summing up, our findings indicate weak substitutability between intangible capital and other inputs.

5 Some remarks

The rather similar results across the different industries and across the different nesting structures provide strong support regarding the conclusion that intangible capital is only weakly substitutable with other inputs. However, the estimation is not without weaknesses. Firstly, the number of significant substitution elasticities is still rather low. The main reason for this might be the overall data quality, which is clearly affected by the need to merge multiple data sets. This is also reflected in the high standard errors. Thus, other tests, like for $H0 = 0$, i.e. implying a Leontief production function, would also fail. This weakness might be overcome in the future if the SPINTAN data set is further developed into a full data set that contains other inputs and an output.

Another issue is the question of whether our results are subject to the *input price bias*, the *output price bias*. (De Loecker and Warzynski, 2012; De Loecker and Goldberg, 2014; De Loecker et al., 2016). The first issue results from the fact that identical input prices are an implicit assumption in an overwhelming number of production function estimations, not at least because input prices are usually not available. If this assumption is violated, the error term contains input price information. As the input choice of firms will be affected by the different prices the firms face, the inputs will be most likely correlated with the error term. Consequently, the estimated coefficients are potentially biased. Different output prices between firms will have the same effect. Potential sources for different output prices are markups, regional price differences,

as well as price differences between new entrants and incumbents, among others. In other words, imperfect competition is a major source of differences in output prices.

We argue that these two types of biases will most likely not affect our estimations. Firstly, the analysis is conducted at the industry level. As such, differences in prices will only affect our results if a considerable share of decision making units (DMU) is affected in a similar way, such that it transmits into the aggregated numbers. If, instead, some DMU face higher than average input prices and others lower than average input prices, these differences average out. The second reason, which is also related to the question of significant differences in prices between DMU, is the fact that the analysis focuses on the non-market sector. As the term indicates, competition in inputs and outputs is limited. Indeed, input and output prices are often set or strongly regulated by public authorities. This reduces the room for differences in input and output prices. Admittedly, the level of private activities differs across countries and industries. Therefore, we cannot claim that price differences are completely eliminated. However, due to the particularities of the non-market sector, we believe that the price issue has little relevance for our estimates.

Another source for biased results might be the output measurement. As it is difficult to determine real output in public services, national statistical offices are forced to estimate real production (Griliches, 1992; Phelps et al., 2010). In cases where there is no turnover available, say in case of public schooling, output is calculated by approximating the different incomes, e.g. for labour, capital consumption etc. and aggregating these costs. This approach is justified by the identity between the *final expenditures compilation* approach and the *output compilation* approach. Hence, value added in national accounting, even in market sectors, needs to be identical regardless of whether it is estimated using expenditures or by adjusting the observed output. Consequently, value added for the non-market industries is driven by the assumptions for capital consumption made by national statistical offices, and by the observed labour income. This might indeed affect our estimation. However, we only consider it to be a weak assumption that the national statistical offices apply the appropriate depreciation rates, life times, implicit returns etc. . . .

In addition, private DMU are also active in these industries. For these DMU, such as private hospitals, private universities etc., output can be observed. Consequently, part of the value added in these industries is observed and does not need to be approximated. To some extent, this relaxes the previously highlighted issue that we must rely on approximated output from the national statistical offices. Admittedly, the share of private activities differs across industries and countries. But because we find intangible capital being only weakly substitutable with other inputs across the different industries, it seems that neither the approximation of output nor the deviating shares of private activities across industries is driving our results. We therefore conclude that output measurement issues do not affect our estimations such that the general

finding is in question.

6 Conclusions

Stimulus programs were heavily used in response to the economic crisis of 2009. Policymakers are also discussing stimulation programs as a part of both the *Growth Pact* and the *Investment Plan for Europe*. It is important to understand the mechanisms of stimulus programs, but it is equally important to rethink the composition of such programs. This study tries to evaluate whether investments in intangible capital should be considered in any public investment program. To do so, we have to answer the following research questions: Is intangible capital a substitute or, to some degree, a complement for other inputs?

In order to answer this question, we create a data set of inputs and outputs in public sectors. For this purpose, the newly developed SPINTAN database is used as it contains various types of intangible assets at the one-digit and two-digit industry levels. As the study makes use of nested CES production functions, the data are aggregated to create a single intangible capital variable per industry, which later can be applied in a three-input two-level nested CES function. The complete database is built with these SPINTAN data and data on value added, labour and gross fixed capital formation that are obtained from Eurostat.

The analysis reveals that intangible capital is just weakly substitutable with tangible capital, labour, or the nested CES function for capital and labour. In other words, the substitution elasticity is noticeably below 1. This rejects the assumption of the Cobb-Douglas approach. This result is found in 9 of the 12 different estimations. The respective elasticities are significantly different from the assumed substitution elasticity of 1 in 7 of the 12 estimations. Thus, we can conclude that intangible capital is just weakly substitutable with other inputs, *inter alia*, with tangible capital.

The implication of this finding for economic policy is straightforward. Public investment in the public sectors should not focus only on classical tangible assets, but part of the investment should go into intangible capital. That not only increases the output through the positive effect of intangible capital, but it is also required because intangibles and tangibles are weakly substitutable. An excessive focus on one input category will not lead to the expected results because the other inputs are also required, such as intangibles, in order to achieve the maximum output possible. From this finding it also follows that investment programs for tangible assets should not be undermined by austerity programs for intangible assets.

Table 1: Descriptive Statistics

Industry	Variable	N	Mean	Std. Dev.	Min	Max
O	Value added (Mio)	191	47,970.57	50,037.68	1,171.64	151,237.40
	Capital (Mio)	191	283,740.80	280,339.00	13,948.35	1,007,276.00
	Intangible capital (Mio)	191	12,141.88	15,029.33	138.44	55,322.82
	No. of employees (thousand)	191	849.48	925.03	35.25	3,109.00
P	Value added (Mio)	191	35,847.19	35,919.32	3,783.15	111,163.20
	Capital (Mio)	191	75,625.90	84,922.83	6,758.27	307,540.90
	Intangible capital (Mio)	191	6,587.53	7,391.15	516.69	41,497.20
	No. of employees (thousand)	191	730.61	682.51	136.10	2,292.00
Q	Value added (Mio)	159	54,400.03	47,519.78	6,961.59	164,169.50
	Capital (Mio)	159	108,353.20	128,964.80	13,073.00	528,802.10
	Intangible capital (Mio)	159	3,315.42	3,123.73	454.12	12,892.22
	No. of employees (thousand)	159	1,333.58	1,296.11	248.37	4,882.00
R	Value added (Mio)	159	8,457.21	9,047.60	934.07	30,800.09
	Capital (Mio)	159	27,455.76	30,027.18	2,858.21	109,553.60
	Intangible capital (Mio)	159	739.71	675.30	9.77	2,047.55
	No. of employees (thousand)	159	172.82	179.97	27.14	621.00

Source: SPINTAN, EUROSTAT, EU KLEMS; own calculations.

Table 2: OLS Estimation Results using number of employees

Variable	(1)	(2)	(3)	(4)	(5)
C	0.177*** (0.0129)	0.242*** (0.0179)	0.114*** (0.00833)	0.0783*** (0.0125)	0.0660*** (0.0130)
L	0.713*** (0.0131)	0.617*** (0.0180)	0.780*** (0.00961)	0.595*** (0.0236)	0.567*** (0.0249)
I	0.143*** (0.00992)	0.197*** (0.0109)	0.0745*** (0.00661)	0.0384*** (0.00815)	0.0373*** (0.00817)
Year	-	yes	yes	-	yes
Industry	-	yes	-	yes	yes
Country	-	-	yes	yes	yes
Constant	2.534*** (0.0779)	1.830*** (0.116)	3.422*** (0.0639)	5.161*** (0.183)	5.428*** (0.199)
N	700	700	700	700	700
R ²	0.966	0.972	0.990	0.992	0.992

Source: SPINTAN, EUROSTAT, EU KLEMS; own calculations.

Table 3: CES function parameter, estimated without boundaries

industry	λ_{CL-I}	γ_{CL-I}	δ_{CL}	δ_{CL-I}	ν_{CL-I}	σ_{CL}	σ_{CL-I}	N	est. no.
O	-0.004*** (0.001)	1.032*** (0.007)	0.447*** (0.025)	0.918*** (0.007)	1.57*** (0.039)	0.833 (0.696)	0.4*** (0.163)	191	(1)
P	-0.003*** (0.001)	1.023*** (0.009)	0.373*** (0.037)	1*** (0.016)	0.889*** (0.067)	10 (148.04)	0.667 (6.0E+12)	191	(2)
Q	0.009*** (0.002)	0.94*** (0.013)	0 (0.124)	0.862*** (0.041)	0.6*** (0.06)	1.429 (1.7E+13)	0.333*** (0.15)	159	(3)
R	-0.005 (0.004)	1.04*** (0.032)	0 (0.099)	1*** (0.024)	0.901*** (0.149)	0.476 (3.1E+13)	1.25 (6.2E+12)	159	(4)
industry	λ_{CI-L}	γ_{CI-L}	δ_{CI}	δ_{CI-L}	ν_{CI-L}	σ_{CI}	σ_{CI-L}	N	
O	-0.004*** (0.001)	1.031*** (0.007)	0.833*** (0.013)	0.492*** (0.024)	1.568*** (0.039)	0.455*** (0.171)	0.769 (0.55)	191	(5)
P	-0.003*** (0.001)	1.023*** (0.009)	1*** (0.042)	0.373*** (0.038)	0.889*** (0.067)	0.385 (5.2E+13)	10 (147.563)	191	(6)
Q	0.009*** (0.002)	0.94*** (0.013)	0 (0.692)	0.138 (0.089)	0.6*** (0.062)	1.111 (7.7E+12)	0.333** (0.3)	159	(7)
R	-0.003 (0.003)	1.019*** (0.023)	23.348 (798.663)	0 (0.017)	0.836*** (0.113)	1 (0.138)	1.25 (11.72)	159	(8)
industry	λ_{LI-C}	γ_{LI-C}	δ_{LI}	δ_{LI-C}	ν_{LI-C}	σ_{LI}	σ_{LI-C}	N	
O	-0.004*** (0.001)	1.031*** (0.007)	0.861*** (0.013)	0.592*** (0.022)	1.567*** (0.039)	0.455** (0.254)	0.667 (0.463)	191	(9)
P	-0.003*** (0.001)	1.023*** (0.009)	1*** (0.025)	0.627*** (0.038)	0.889*** (0.067)	0.476 (2.5E+13)	10 (147.751)	191	(10)
Q	0.009*** (0.002)	0.94*** (0.013)	0.862*** (0.035)	1*** (0.114)	0.6*** (0.061)	0.333*** (0.149)	0.625 (1.2E+13)	159	(11)
R	-0.005 (0.004)	1.04*** (0.031)	1*** (0.017)	1*** (0.096)	0.901*** (0.147)	0.476 (3.1E+13)	1.25 (6.2E+12)	159	(12)

Source: SPINTAN, EUROSTAT, EU KLEMS; own calculations.

$H_0=1$ for σ_k with $k = \{CL, CI, LI, CL - I, CI - L, LI - C\}$
all other point estimates: $H_0=0$; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4: CES function parameter, estimated with lower and upper boundaries

industry	λ_{CL-I}	γ_{CL-I}	δ_{CL}	δ_{CL-I}	ν_{CL-I}	σ_{CL}	σ_{CL-I}	N	est. no.
O	-0.004*** (0.001)	1.032*** (0.007)	0.447*** (0.025)	0.918*** (0.007)	1.57*** (0.039)	0.833 (0.696)	0.400*** (0.163)	191	(1)
P	-0.002 (0.001)	1.015*** (0.009)	0.355*** (0.047)	0.95*** (0.023)	0.768*** (0.07)	10 (191.961)	0.455 (0.371)	191	(2)
Q	0.008*** (0.002)	0.942*** (0.014)	0.05 (0.152)	0.866*** (0.041)	0.599*** (0.065)	10 (2950.261)	0.333*** (0.153)	159	(3)
R	-0.003 (0.004)	1.022*** (0.033)	0.05 (0.12)	0.95*** (0.033)	0.811*** (0.156)	0.455 (5.027)	2.5 (11.091)	159	(4)
industry	λ_{CI-L}	γ_{CI-L}	δ_{CI}	δ_{CI-L}	ν_{CI-L}	σ_{CI}	σ_{CI-L}	N	
O	-0.004*** (0.001)	1.031*** (0.007)	0.833*** (0.013)	0.492*** (0.024)	1.568*** (0.039)	0.455*** (0.171)	0.769 (0.55)	191	(5)
P	-0.003** (0.001)	1.019*** (0.009)	0.95*** (0.05)	0.371*** (0.04)	0.844*** (0.068)	0.4 (0.89)	10 (176.338)	191	(6)
Q	0.007*** (0.002)	0.95*** (0.014)	0.5 (0.319)	0.219** (0.103)	0.628*** (0.064)	0.333** (0.315)	0.333* (0.381)	159	(7)
R	-0.006 (0.004)	1.052*** (0.033)	0.95** (0.416)	0.06 (0.081)	0.953*** (0.148)	10 (3294.7)	0.526 (3.927)	159	(8)
industry	λ_{LI-C}	γ_{LI-C}	δ_{LI}	δ_{LI-C}	ν_{LI-C}	σ_{LI}	σ_{LI-C}	N	
O	-0.004*** (0.001)	1.031*** (0.007)	0.861*** (0.013)	0.592*** (0.022)	1.567*** (0.039)	0.455** (0.254)	0.667 (0.463)	191	(9)
P	-0.002** (0.001)	1.02*** (0.009)	0.95*** (0.032)	0.637*** (0.042)	0.816*** (0.069)	0.385* (0.34)	10 (170.259)	191	(10)
Q	0.008*** (0.002)	0.942*** (0.014)	0.86*** (0.037)	0.95*** (0.13)	0.602*** (0.062)	0.333*** (0.211)	10 (3668.819)	159	(11)
R	-0.003 (0.004)	1.025*** (0.033)	0.95*** (0.03)	0.95*** (0.115)	0.823*** (0.156)	2.5 (10.481)	0.333 (2.675)	159	(12)

Source: SPINTAN, EUROSTAT, EU KLEMS; own calculations.
 $H_0=1$ for σ_k with $k = \{CL, CI, LI, CL - I, CI - L, LI - C\}$
all other point estimates: $H_0=0$; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

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Appendix

Figure 1: Estimation with and without boundaries

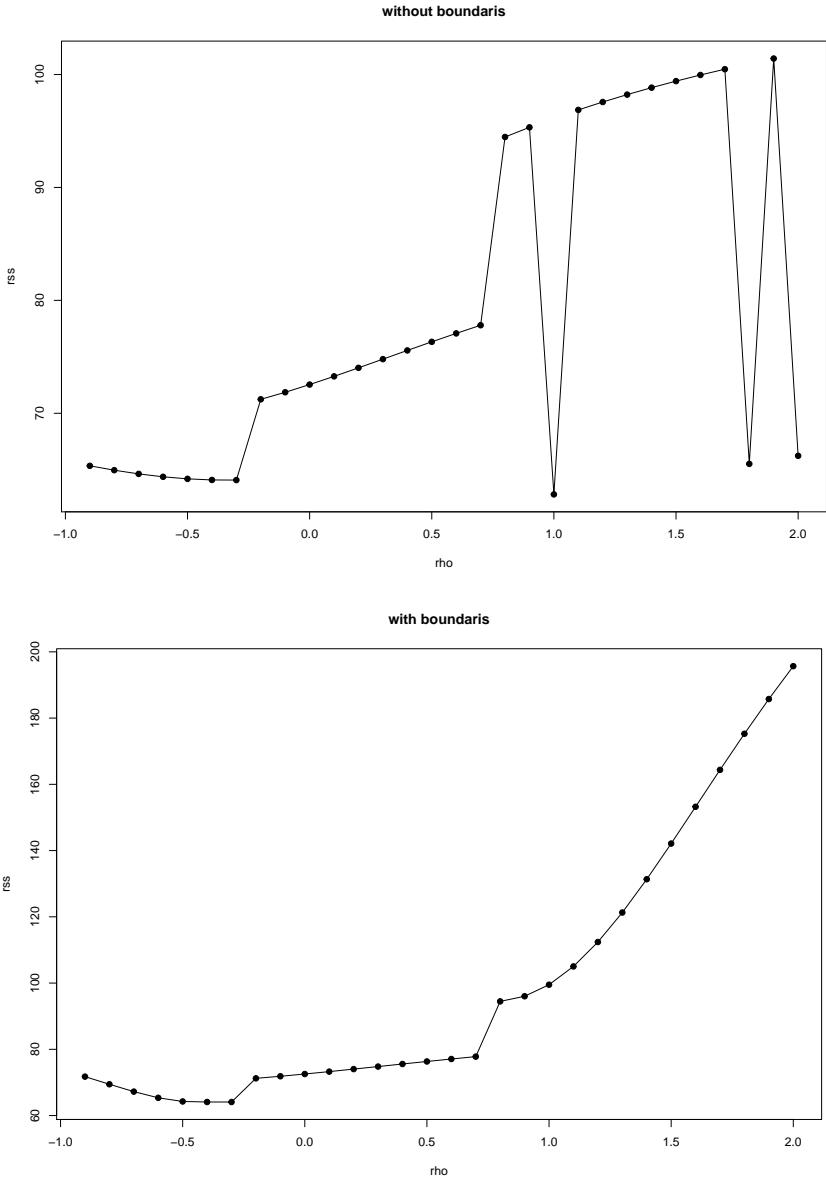


Table A.5: Data availability per country, industry and years

Country	Industry			
	O	P	Q	R
AT	1995-2010	1995-2010	1995-2010	1995-2010
BE	1995-2010	1995-2010	-	-
CZ	-	1995-2010	-	1995-2010
DE	1995-2010	1995-2010	1995-2010	1995-2010
DK	1995-2010	1995-2010	1995-2010	1995-2010
ES	1995-2010	1995-2010	1995-2010	-
FI	1995-2010	1995-2010	1995-2010	1995-2010
FR	1995-2010	1995-2010	1995-2010	1995-2010
HU	-	1995-2010	-	-
IT	1995-2010	1995-2010	1995-2010	1995-2010
NL	1995-2010	1995-2010	1995-2010	1995-2010
PT	1996-2010	1996-2010	1996-2010	1996-2010
SE	1995-2010	-	1995-2010	1995-2010
SI	1995-2010	-	-	-

Source: SPINTAN, EUROSTAT, EU KLEMS; own calculations.

Table A.6: Boundaries of parameters in GRID SEARCH

variables	lower bound	upper bound
γ_k	-100	100
λ_k	-100	100
δ_{CL}	0.05	0.5
δ_{CI}	0.5	0.95
δ_{LI}	0.5	0.95
δ_{CL-I}	0.5	0.95
δ_{CI-L}	0.06	0.5
δ_{LI-C}	0.5	0.95
ν_k	0.5	1.5

with $k = \{CL - I, CI - L, LI - C\}$