Spillovers from Public Intangibles

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This paper sets out a framework for the analysis of spillovers to public investments, tangible and intangible. We exploit a new cross-country industry-level growth accounting database that includes data on intangible investment for the total economy, i.e., covering both market and nonmarket activity at the industry level for 9 EU countries and the United States from 1995 through 2013. Using R&D investment time series newly developed for national accounts, we find support for earlier findings in the literature (e.g., Guellec and Van Pottelsberghe de la Potterie 2002, 2004) that there are spillovers from public sector R&D to market sector productivity. We also find that market sector investments in nonR&D intangible capital generate spillovers to productivity, raising new possibilities for the analysis of policies that might boost economic growth.

JEL: O47, E22, E01
Keywords: productivity growth, intangibles, spillovers, R&D, public sector

I. Introduction

The global productivity slowdown has generated renewed interest in policies that might boost economic growth. One area of interest is spillovers from public sector investments. The public sector is a major investor in intangible assets, especially human and scientific knowledge capital via its public investments in education and R&D. The public sector also is a major investor in tangible assets such as transportation and telecommunications infrastructures. Investments in these assets, both tangible and intangible, are believed to exert positive macroeconomic effects in the long run.

Regarding intangibles, the analysis of public sector spillovers in OECD countries typically looks (in isolation) at R&D and education. Spillovers from publicly performed R&D to market sector productivity were studied by, e.g., Guellec and Van Pottelsberghe de la Potterie (2002, 2004), who found strongly positive effects in their cross-country work. The authors

also investigated interrelationships among sector funding, performance, and research purpose of the R&D. The literature on the positive effects of R&D is extensive but largely pertains to R&D that is privately performed (yet possibly publicly funded).[1] Some of the nuances in this literature discussed in more detail when setting out the models and empirics used to study R&D spillovers in this paper, which we believe to be the first re-examination of these issues using national accounts R&D data.

Spillovers from education to economic growth have also been studied extensively, and a recent study found strong evidence of growth spillovers from human capital accumulation measured as increases in the skill composition of a country's labor force using a growth accounting dataset of 10 major European countries from 1998 to 2007 (Corrado, Haskel, and Jona-Lasinio, 2013). Moretti (2004b,a) also finds spillovers to education using plant and state-level data for the United States. Previous work on this topic concluded that, after accounting accounting for private returns by different worker types, there were no spillovers to human capital (Inklaar, Timmer, and van Ark, 2008) or argued that spillovers to human capital accumulation could not be found in cross-country growth regressions because they were obscured by measurement error (Krueger and Lindahl, 2001). Results are thus highly variable and therefore revisited in this paper using a richer database than available in previous work.

Regarding the scope the work in this paper there are a number of points. First, spillovers from public sector R&D are of course but one dimension of possible spillovers from investments in knowledge/intangible assets. For example, O'Mahony and Riley (2012) examine whether employer-provided training may facilitate the generation of spillovers from education. Their results support the assumption that spillovers from education within broad sectors are stronger when employers engage in training and suggest the need to examine the possibility of multiple channels and also interactive mechanisms whereby intangible assets might impact growth. Complementarities between private ICT investment and private intangible investment (even when software is included in ICT) have been demonstrated in prior work (Brynjolfsson, Hitt, and Yang, 2002; Corrado, Haskel, and Jona-Lasinio, 2016a).

Second, besides the well documented spillovers from the conduct of corporate R&D, there might be pure spillovers from business investments in nonR&D intangibles; these forms of investments have grown dramatically in relative importance in the United States since the late 1970s (Corrado and Hulten, 2010). The empirical analysis of spillovers from nonR&D intangibles is a relatively new, largely unexplored territory. Previous work (Corrado et al., 2013) found evidence of productivity spillovers to increases in intangible capital excluding software by market sector industries, again in 10 major European economies over the years

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[1]See Hall, Mairesse, and Mohnen (2009) and Eberhardt, Helmers, and Strauss (2013) for reviews.

1998 to 2007. The findings were robust to whether R&D was included or excluded intangibles and thus consistent with an underlying mechanism producing a growth dividend to private investment in nonR&D intangibles. This finding is revisited in this paper using additional controls and additional data.

To examine the possible spillovers between public sector intangibles and business sector productivity performance, this paper looks at the correlation between TFP growth and different measures of public sector knowledge creation using a new cross-country industry-level database that includes data on both market and nonmarket intangible investment at the industry level. Nonmarket intangible investment refers to intangible investments by governments and nonprofit institutions as estimated by the SPINTAN FP7.[2] Market sector intangibles are from an imminent update to INTAN-Invest, which includes national accounts estimates of intangible investment for R&D and other intellectual property products capitalized in national accounts (software and databases, mineral exploration, and artistic and entertainment originals), as well as investments in intangible assets not covered in national accounts.[3] Non-national accounts intangibles include design, brand, and organizational capital, including firm capital generated by employer-provided training.

Growth accounts extended to include non-national accounts intangibles are estimated for 11 EU economies and the United States at the two-digit NACE industry level (with certain industries further disaggregated according to institution sector, i.e., market and nonmarket) from 1995 to 2013. For these accounts, capital stocks are built from raw investment data; ICT deflators are harmonised to U.S. official ICT deflators; and non-market rates of return are imputed. For further information and analysis of the implications of this dataset, see Corrado, Haskel, Jona-Lasinio, Iommi, and Mahony (2016).

To preview our results, on this new dataset, we find evidence of spillovers from public sector R&D to productivity in the market sector. The current version of the dataset does not include disaggregate information on labor input yet, so our results are incomplete in this regard. Our earlier finding of spillovers to private nonR&D intangible capital holds in the extended dataset, i.e., it is robust to the inclusion of the United States in the countries studied, extension of the time period to cover the financial crises, and inclusion of public R&D as an additional control.

The rest of the paper sets out a framework (section 2), shows some data (section 3) and some econometric results (section 4). A final section concludes.

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[2] Corrado, Haskel, and Jona-Lasinio (2016b) set out the framework for defining and analyzing public intangibles and Bacchini et al. (2016) set out the methods used to measure investment in the assets included in the dataset used in this paper; for further information and other working papers, see `www.spintan.net`.

[3] INTAN-Invest is an unfunded research initiative that periodically provides intangible investment estimates for 22 EU countries, the United States, and Norway see `www.intan-invest.net` for further details. The forthcoming INTAN-Invest update is previewed in Iommi, Corrado, Haskel, and Jona-Lasinio (2016).

II. Framework and existing literature

A. Definitions

Suppose that industry value added in country c, industry i and time t, $Q_{c,i,t}$ can be written as:

$$(1) \qquad Q_{c,i,t} = A_{c,i,t} F_{c,i}(L_{c,i,t}, K_{c,i,t}, R_{c,i,t})$$

On the right-hand side, L and K are labour and tangible capital services; likewise R is the flow of intangible capital services and A is a shift term that allows for changes in the efficiency with which L, K and R are transformed into output. L, K and R are represented as services aggregates because in fact many types of each factor are used in production. We will introduce some key distinctions among factor types in a moment. Log differentiating equation (1) per Solow (1957) gives:

$$(2) \qquad \Delta ln Q_{c,i,t} = \epsilon^{L}_{c,i,t} \Delta ln L_{c,i,t} + \epsilon^{K}_{c,i,t} \Delta ln K_{c,i,t} + \epsilon^{R}_{c,i,t} \Delta ln R_{c,i,t} + \Delta ln A_{c,i,t}$$

where ϵ^{X} denotes the output elasticity of an input X, which in principle varies by input, country, industry and time.

To empirically investigate the role of intangibles as drivers of growth starting from the existing literature, we take two steps. First, consider the ϵ terms. For a cost-minimizing firm we may write

$$(3) \qquad \epsilon^{X}_{c,i,t} = s^{X}_{c,i,t}, \ \ X = L, K, R$$

where s^{X} is the share of factor X's payments in value added. The substitution of $s^{X}_{c,i,t}$ for $\epsilon^{X}_{c,i,t}$ in (2) then expresses the first-order condition of a firm in terms of factor shares and assumes firms have no market power over and above their ability to earn a competitive return from investments in intangible capital.

Now suppose a firm can benefit from the L, K or R in other firms, industries, or countries. Then, as Griliches (1979, 1992) notes the industry elasticity of $\Delta ln R$ on $\Delta ln Q$ is a mix of both internal and external elasticities so that we can write following Stiroh (2002)

$$(4) \qquad \epsilon^{X}_{c,i,t} = s^{X}_{c,i,t} + d^{X}_{c,i,t}, \ \ X = L, K, R$$

which says that output elasticities equal factor shares plus d, where d is any deviation of elasticities from factor shares due to e.g., spillovers.

To examine spillovers, that is $d > 0$, we note that following Caves, Christensen, and Diewert (1982) a Divisia $\Delta lnTFP$ index can be constructed that is robust to an underlying translog production function such that we can write (2) as

$$(5) \qquad \Delta lnTFP^Q_{c,i,t} = d^L_{c,i,t}\Delta lnL_{c,i,t} + d^K_{c,i,t}\Delta lnK_{c,i,t} + d^R_{c,i,t}\Delta lnR_{c,i,t} + \Delta lnA_{c,i,t}$$

where $\Delta lnTFP^Q_{c,i,t}$ is calculated as

$$(6) \qquad \Delta lnTFP^Q_{c,i,t} = \Delta lnQ_{c,i,t} - s^L_{c,i,t}\Delta lnL_{c,i,t} - s^K_{c,i,t}\Delta lnK_{c,i,t} - s^R_{c,i,t}\Delta lnR_{c,i,t}$$

From (5) therefore, a regression of $\Delta lnTFP^Q$ on the inputs recovers the spillover terms. Note that such terms might arise due to imperfect competition/increasing returns not fully accounted for by the inclusion of intangible capital or translog approximation, and we will also not be able to distinguish between pecuniary and non-pecuniary returns (Griliches, 1992) and thus use the term "spillovers" for convenience.

B. Existing literature

Some existing papers work with economy-wide data and rather few capitalise R&D. Thus they use an aggregate value added output term, V, without R&D capitalized and write down

$$\Delta \ln (V/H)_{c,t} = s^{V,L}_{c,t}\Delta \ln L/H_{c,t} + s^{V,K}_{c,t}\Delta \ln(K/H)_{c,t} + \varepsilon^R_{c,t}\Delta \ln R_{c,t} + \Delta lnA_{c,t}$$

If R does not depreciate this may be simplified to

$$(7) \quad \Delta \ln (V/H)_{c,t} = s^{V,L}_{c,t}\Delta \ln(L/H)_{c,t} + s^{V,K}_{c,t}\Delta \ln(K/H)_{c,t} + \rho^R_{c,t}(N/V)_{c,t} + \Delta lnA_{c,t}$$

where N is the rate of investment in R&D (public or private) and ρ^R is a social (i.e., private plus public) rate of return on the investment—because R&D is not capitalised. Using cross-country aggregate data, Guellec and Van Pottelsberghe de la Potterie (2004) find elasticities of total factor productivity to publicly (privately) funded research of 0.17 (0.13) for 16 OECD countries (including Japan and the United States), Haskel2013b finds a similar public elasticity, but smaller private elasticity using UK time series data.

III.   The Data

Data from multiple sources are merged to generate a database for productivity analysis of (a) the total economy with (b) a complete accounting of intangibles.

A. Coverage

The database covers the following dimensions: countries, industries, institutional sectors and time. Data on tangible assets are gathered from national accounts. Market sector intangibles are from INTAN-Invest with data newly extended through 2013. These estimates include detail at the A21 NACE industry level and cover intangible assets capitalized in national accounts as well as those that are not, as previously indicated. Further breaks by institutional sector (market and nonmarket) for industry sectors M72, P, Q, and R (R&D services, Education, Health, and Arts and Recreation industries) and on nonmarket sector intangibles are preliminary estimates from SPINTAN. The country coverage includes: the United States (US), big Northern European economies (DE, FR and UK), Scandinavian (DK FI, SE), Small European (AT, CZ, NL) and the Mediterranean economies (IT, ES).

B. Market and non-market sectors

Because our data is by country, industry and year, and key industries are further broken down into market and non-market sectors where the latter refers to activities of general governments and non-profit organizations in selected industries, below we shall look at variables according to whether they are "market" and "non-market" in the country-year-industry dimension. These are variables that are weighted sums for that country-year over industry-sectors either market or non-market. So for example, a country-year market sector $DlnX$ would be a value-added weighted sum of $DlnX$ for the market sector in each of the relevant 21 industries for that country-year. A nominal variable would be a simple sum.

C. Rental values

To construct factor shares we require rental values. For the market sector these are calculated via the ex post (i.e., Jorgenson and Griliches) method so that the rate of return is such that the rental values of capital times capital stocks equal gross operating surplus in the market sector for the country-year-industry. For the non-market sector, a rate of return equal to the social rate of time preference is assigned; these estimates are from the SPINTAN project (Corrado and Jäger, 2015).

Assigning a return to public capital is a practice followed most conspicuously in the many productivity studies by Jorgenson and co-authors, e.g., Jorgenson and Landefeld (2006), and also adopted for the official total economy productivity accounts for the United States (Harper et al., 2009). Although it is common to use a government bond rate for this purpose, from a public economics point of view (taken in the SPINTAN project), following Feldstein (1964), Corrado and Jäger argue the Ramsey social rate of time preference is a more logical choice.

D. Scope

The scope of nonmarket intangibles as measured by the SPINTAN project requires clarification. From a theoretical point of view, the project set out to expand the existing national accounts asset boundary to include intangible investments by governments and nonprofit institutions while keeping the traditional production boundary of GDP essentially the same, i.e., that nonmarket production by households remains outside the scope of analysis. The project measured investments in asset types as set out in Corrado et al. (2016b), who adapted the framework of Corrado, Hulten, and Sichel (2005, 2009) to the nonmarket setting. National accounts measures of software and R&D investments are included, as are purchases of services for training of own employees (e.g., these are sizable for elementary and secondary school teachers), promotion of brands (a significant aspect of nonprofit fund raising, e.g., by museums), and organizational efficiencies (e.g., in some countries, governments are significant purchasers of management consulting services).

Although encompassed by the framework as set out and discussed in Corrado et al. (2016b), as a practical matter, the SPINTAN measures of nonmarket intangibles do *not* at this point include government expenditures/subsidies for training; however, as discussed in section I, this paper examines spillovers to education and skills via the labor composition term in growth accounts. Other considerations when employing the SPINTAN measures include, e.g., that expenditures by governments to promote their country "brand" are not included and that national accounts measures of software and artistic originals do not necessarily reflect the information and cultural assets provided to societies by their governments. The SPINTAN project carried out work exploring these topics, but results were limited to a single country (or just a few countries).

IV. Descriptive evidence

This section provides an overview of the correlations between labor productivity growth, TFP and market and non market intangibles. For this purpose, as well as the econometric work reported below, we do not include activity in industries A, L, T, and U (agriculture, real estate, private households, extraterritorial organizations). The time coverage of analysis is 1998–2013.

Figure 1 shows data on $\Delta lnTFP$ for the whole economy against capital growth of NonICT, ICT, intangibles and R&D. As the figure shows, there is a somewhat positive correlation.

Figure 2 shows the same variables, but in double differences, which is how we shall estimate the relation and obtains a similar pattern.
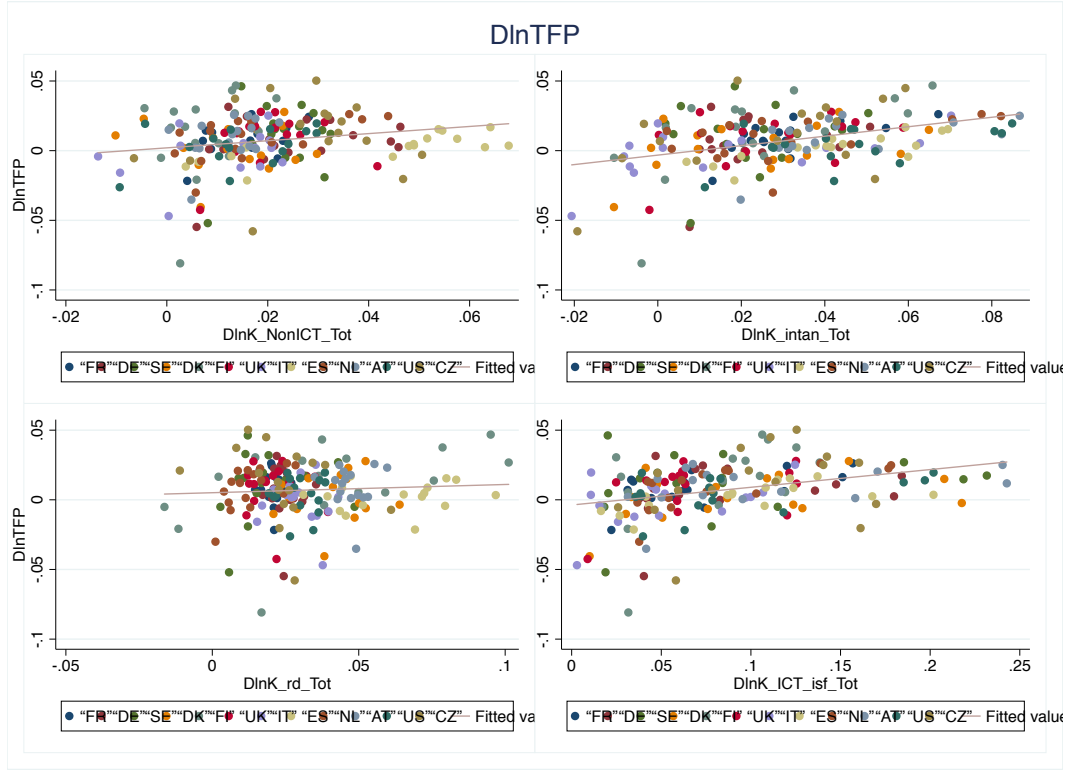
FIGURE 1. LABOR PRODUCTIVITY GROWTH, WHOLE ECONOMY AND CAPITAL INPUTS

Figure 3 shows not $\Delta lnTFP$ for the whole economy, but $\Delta lnTFP$ for the market sector. This is constructed, as above, as a value added weighted sum of $\Delta lnTFP$ for each country-year, summing over the market sector in each of the industries in each country-year. We have plotted this against (growth in log) nonICT capital in the market sector, intangible capital excluding R&D, R&D capital, and, in the bottom panel, the (lagged) level of non-market R&D investment as a proportion of market value added. The final correlation is an indication of spillovers from the public to the private sector.

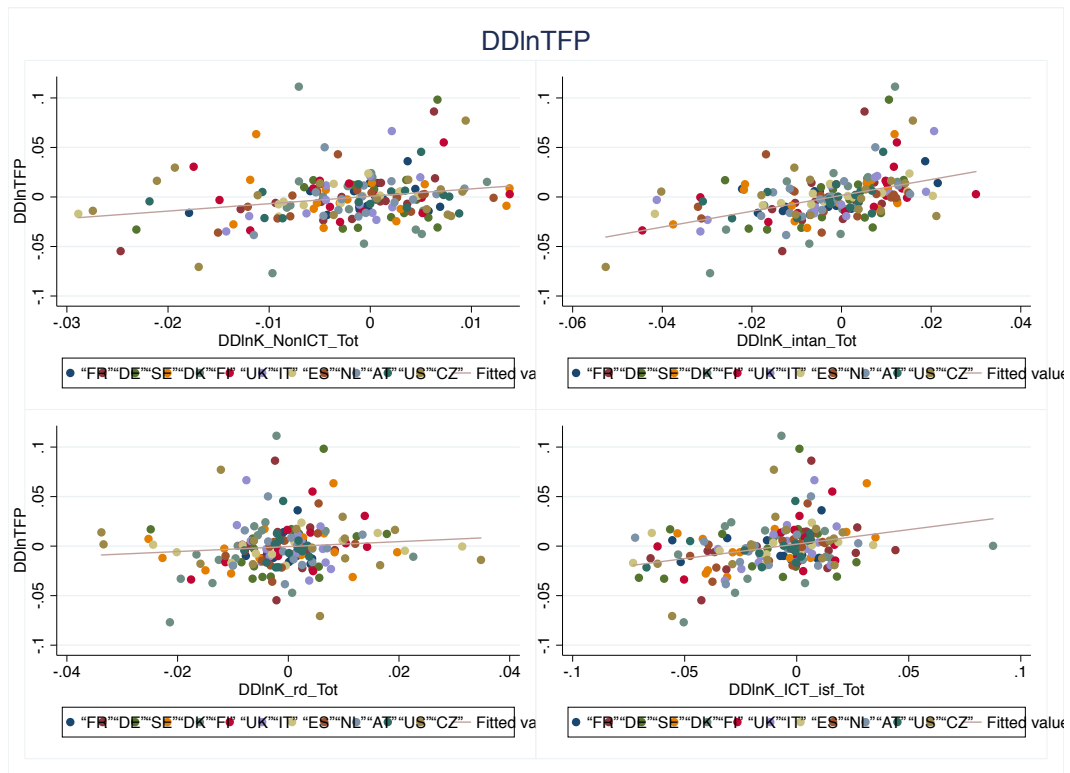Finally, Figure 4 shows the above figure, but in double differences.
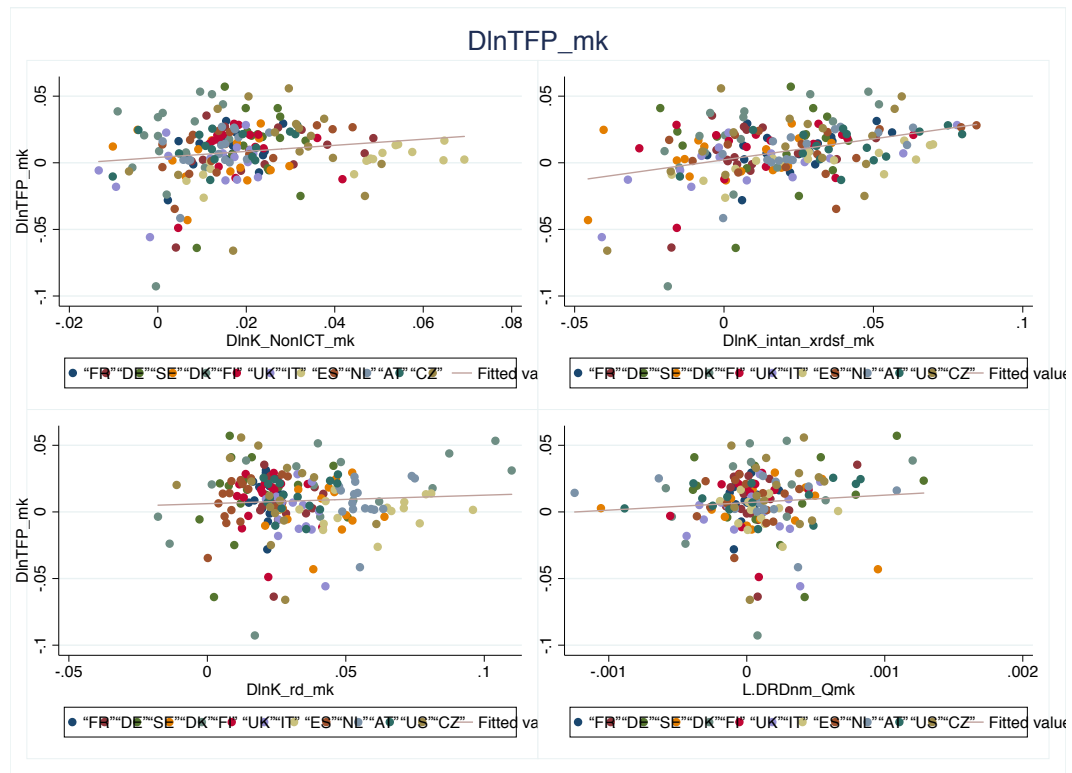
Figure 2. Market and Nonmarket Intangibles

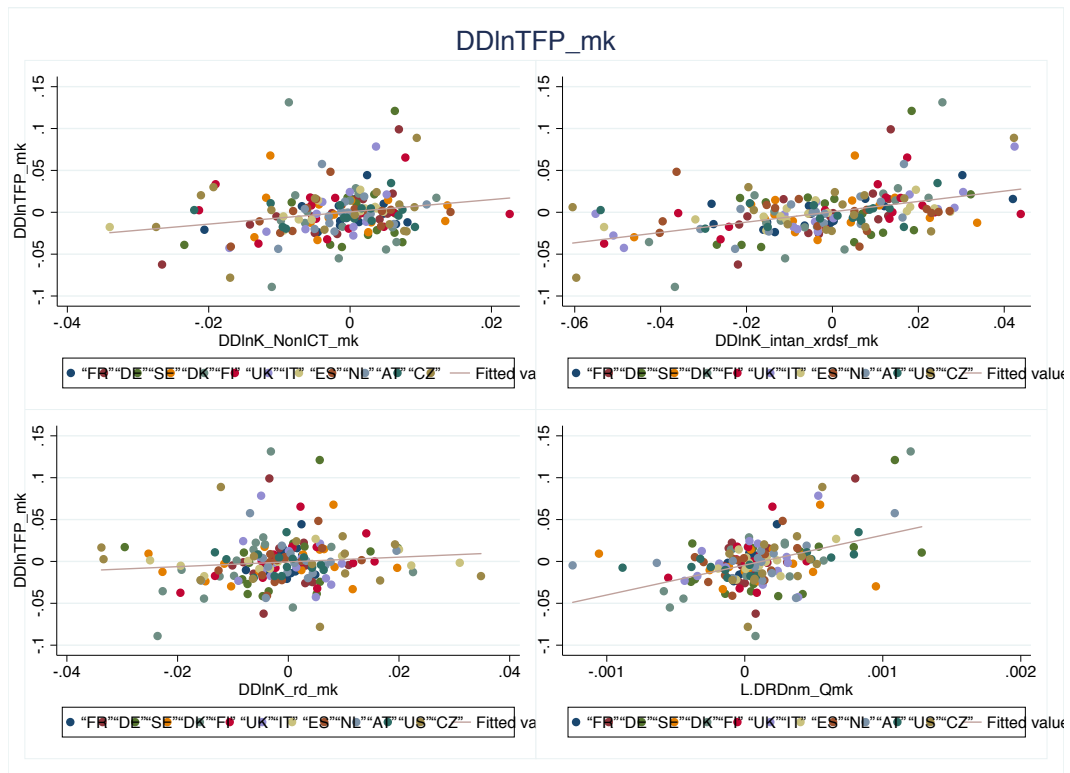FIGURE 3. TFP AND MARKET AND NONMARKET INTANGIBLES

Figure 4. TFP and Market and Nonmarket R&D and ICT

V. The transition to econometric work

To estimate (5) we must take a number of steps. Recall that our raw data is institutional sector-industry-country-year, where by institutional sector we mean market or non-market. Consider then the following model for $\Delta lnTFP$ in industry i

$$
\begin{aligned}
(8) \qquad \Delta lnTFP_{i,c,t}^{Q} \;=\; & d_{i,c,t}^{L}\Delta lnL_{i,c,t} + d_{i,c,t}^{K}\Delta lnK_{i,c,t} + d_{i,c,t}^{R}\Delta lnR_{i,c,t} \\
& + \gamma_{i,c,t}\Delta lnR_{-i,c,t}
\end{aligned}
$$

which assumes that industry i can obtain spillovers potentially from L, K and R in it's own industry, but the only outside-industry spillovers are via R outside the industry, denoted R_{-i} (that is, tangible capital outside a firm's industry conveys no spillovers, but intangible capital does).

Now, as set out by e.g., Griliches, knowledge outside the industry is of potentially very many dimensions. To reduce it to something estimable is typically done by devising a measure that weights the various $\Delta \ln R_i$ in some way e.g., by technological distance, input/output relations etc. Assume this amounts to a weighted sum over industries with weights $\omega_{i,j\neq i}$, i.e., industry i has a vector of weights on other industries j, we can write

$$
\begin{aligned}
(9) \qquad \Delta lnTFP_{i,c,t}^{Q} = & \, d_{i,c,t}^{L}\Delta lnL_{i,c,t} + d_{i,c,t}^{K}\Delta lnK_{i,c,t} + d_{i,c,t}^{R}\Delta lnR_{i,c,t} \\
& + \gamma_{i,c,t}(\Sigma\omega_{i,j\neq i}\Delta lnR_{i,c,t}) \ .
\end{aligned}
$$

A. Aggregated data

At the time of writing we do not have detailed data by industry that would allow us to model ω as industry links with the public sector (i.e., as inter-industry purchases weights, as previously done in the literature for private R&D). We are in the process of collecting these data. So for the time being we work with two data sets. The first is a country-year or "total economy" dataset (it not quite a total economy dataset because we have dropped agriculture, real estate and some other small industries, see above), where we take all our industries and institutional sectors and for each country-year compute, as above, value-added weighted average of changes in the log of each variable. We then estimate for country c in time t

$$(10) \qquad \Delta \ln TFP_{c,t}^Q = a_c + a_t + d^L \Delta lnL_{c,t} + d^{ICT} \Delta lnK_{c,t}^{ICT} + d^{NonICT} \Delta lnK_{c,t}^{NonICT}$$
$$+ d^R \Delta lnR_{c,t} + v_{c,t}$$

where the inter-industry effects collapse into a single effect of R and we have added country and time effects to control for this element of unobserved heterogeneity and $v_{c,t}$ is an *iid* error term.

The interpretation of this equation depends upon what is included in TFP. Recall that R is capitalised into $\Delta \ln TFP^Q$ via value added and via inputs that are given a rate of return when calculating factor shares (with market sector given an ex-post rate of return and non-market sector a rate of return equal to the social rate of time preference, as previously mentioned). Thus the d^R is an "excess" output elasticity in the sense of excess over that elasticity implied by the private and social time preference-based rates of return.

Our second approach is to collapse the output and input data into a "market sector" and "non-market sector." The "market sector" is an aggregation into more or less a non-farm business sector, that is, all sectors excluding agriculture, public administration, public health and public education. In most countries, this aggregation is close to entirely market/for profit i.e. there are very few non-market manufacturing firms for example. But it does of course miss out for-profit education and health. We then construct $\Delta lnTFP$ growth for what we shall call the "market" sector. We look for knowledge spillovers by looking at correlations with market sector and non-market knowledge as follows

$$(11) \qquad \Delta lnTFP_{c,t}^{Q,MKT} = a_c + a_t + d^L \Delta lnL_{c,t}^{MKT} + d^K \Delta lnK_{c,t}^{MKT} + d^R \Delta lnR_{c,t}^{MKT}$$
$$+ \rho(N^{NonMKT}/Q^{MKT})_{c,t} + v_{c,t}$$

Here we have written the elasticity times the log change in the non-market stock of R in terms of its flow i.e. $\gamma_c \Delta lnR_{c,t}^{NonMKT} = \rho(N^{NonMKT}/Q^{MKT})_{c,t}$ where N^{NonMKT} is the flow of investment by the non-market sector in R.[4]

The interpretation of d^R is an "excess over market" returns because output includes R&D and inputs include market R&D at its ex post user cost. The interpretation of ρ is a spillover from non-market to market. Thus the use of market aggregation does not give a full account of inter-industry spillovers but is a first-pass at a summary of spillovers from non-market knowledge creation to the market sector.

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[4] Assume that public R&D does not depreciate (to the extent it is "basic" then is likely to at least become less obsolete than private R&D; the ONS report using a depreciation rate of 5% for government R&D for example.) From the perpetual inventory model, $\Delta lnR_t^{NonMKT} = N^{NonMKT}/R_{t-1}^{NonMKT}$ when $\delta^{NonMKT} = 0$. Thus the elasticity of market output $(\partial Q/\partial R^{NonMKT})(R^{NonMKT}/Q)$ times this term can be written $= (\rho_{it})(R^{PUB}/Q)$ where $\rho_{it} = (\partial Q/\partial R^{NonMKT})$.

B.   Estimates

Equations (10) and (11) may be estimated in second differences which eliminates the country fixed effect and accounts for serial correlation in a consistent framework. We discuss the identifying variation in the data this induces below.

Estimates 1: Total Economy

The first set of results is shown in Table 1, where the regressand is $\Delta \ln TFP_{c,t}^{Q}$, that is, aggregated $\Delta \ln TFP$ by country-year. All the regressors are measured at the same level, denoted "te" for total economy. Column 1 displays conventional regressors i.e., capital and labour inputs, ($\Delta ln K_{te,c,t}^{nonICT}$), ($\Delta ln K_{te,c,t}^{ICT}$), and ($\Delta ln L_{te,c,t}$). The estimated spillover coefficients on nonICT and ICT capital and on labor are not significant. (Note that our measure of L here is person hours; composition-adjusted person hours will be used in the next version of this paper.)

Column 2 adds intangibles, $\Delta ln R_{te,c,t}$, which is found to be statistically significant. This result supports previous findings of positive spillovers from intangible capital (Corrado et al., 2013) that used market sector data only, up to 2007. Column 3 experiments with lags for $\Delta ln L$, but finds no significant effects. Column 4 disaggregates intangibles into two components, R&D and nonR&D intangibles; recall, software is included with ICT, and thus nonR&D intangibles consists of non-scientific innovative property and economic competencies such as brand, organizational structure, and firm-specific human capital (i.e., training). The spillover coefficient on $\Delta ln R_{te,c,t}^{nonR\&D}$ is significant with a value very similar to estimates in previous work. The $\Delta ln R_{te,c,t}^{R\&D}$ coefficient is instead not significant. In column 5 we experiment with lagging the $R\&D$ term and the coefficient becomes negative (but only borderline significant).

Column 6 restricts the sample to 1998–2007. The $\Delta ln R_{te,c,t}^{nonR\&D}$ term remains significant with a similar coefficient but the $\Delta ln R_{te,c,t}^{R\&D}$ coefficient becomes more well-determined but remains negative, which deserves more exploration.

Estimates 2: Market Sector

Table 2 shows estimates of equation (11) for market sector TFP, i.e., the dependent variable is $\Delta ln TFP_{c,t}^{Q,MKT}$. In columns 1 and 2, all the independent variables are also for the market sector and column 2 shows, again, a relation between $\Delta ln TFP_{c,t}^{Q,MKT}$ and own-sector $\Delta ln R_{c,t}^{Q,MKT}$.

	(1)	(2)	(3)	(4)	(5)	(6)
	DDlnTFP(Q)					
VARIABLES	**1998-2013**					**1998-2007**
D.DlnK_NonICT_te	-0.111	-0.110	-0.125	-0.155	-0.155	-0.283*
	(0.138)	(0.133)	(0.129)	(0.130)	(0.129)	(0.153)
D.DlnK_ICT_te	0.053	-0.007	-0.007	0.028	0.033	0.038
	(0.041)	(0.043)	(0.043)	(0.039)	(0.039)	(0.035)
D.DlnK_intan_te		**0.248*****	**0.245*****			
		(0.073)	**(0.073)**			
D.DlnK_intan_xrdsf_te				**0.163*****	**0.162*****	**0.176*****
				(0.044)	**(0.044)**	**(0.047)**
D.DlnK_rd_te				0.101		
				(0.090)		
D.DlnL_te	0.005	-0.016				
	(0.064)	(0.063)				
D.DlnL_te$_{(t-1)}$			0.008	0.009	0.008	0.010
			(0.018)	(0.018)	(0.018)	(0.014)
D.DlnK_rd_te$_{(t-1)}$					-0.168*	-0.190**
					(0.091)	(0.077)
Observations	192	192	192	192	192	120
Number of ctrycode	12	12	12	12	12	12

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

TABLE 1—SPILLOVER REGRESSIONS, 1998 TO 2013

Notes to table: 1. Table shows GLS estimation of equation 10. Estimation is in second differences with year dummies.

2. Data are for total economy for Austria, Germany, Finland, Czech Republic, Denmark, France, Italy Netherlands, Spain, UK, Sweden and US. The final column omits CZ.

Column 3 introduces non-market intangibles, in the form of non-market sector R&D, and column 4 its lag. The lag is statistically significant. Column 5 lags the market sector R&D term as well, and while nonmarket R&D remains significant, lagged market sector R&D does not. When the regression shown in column 4 is run with the sample restricted to 1998–2007, the pattern of signs and significance for nonmarket R&D and market nonR&D intangibles holds up, whereas the market R&D term loses significance. Overall, we have then a robust effects for market non-R&D intangibles and non-market R&D, consistent with spillovers to productivity from investments in these assets.

A number of points are worth making regarding these results. First, the coefficient on N^{NonMKT}/Q^{MKT} indicates a rate of return, in column 4 say, of 403 percent, which is clearly too high. We investigate this in the following section.

Second, this table uses R&D for non-market sector intangibles. To see if there are any possible spillovers from other non-market sector intangibles we entered all the measured

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
				DlnTFPmk		
	1998-2013					1998-2007
DlnK_NonICT_mk	-0.333***	-0.348***	-0.347***	-0.373***	-0.367***	-0.492***
	(0.109)	(0.108)	(0.108)	(0.108)	(0.109)	(0.128)
DlnK_ICT_isf_mk	0.036	0.027	0.032	0.041	0.043	0.027
	(0.033)	(0.032)	(0.033)	(0.034)	(0.035)	(0.033)
DlnK_rd_mk		0.105*	0.108*	0.109*		0.001
		(0.060)	(0.061)	(0.060)		(0.057)
RD_Q_nm			1.316			
			(1.488)			
DlnK_intan_xrdsf_mk		0.073*	0.081*	0.101**	0.104**	0.112**
		(0.041)	(0.041)	(0.041)	(0.042)	(0.045)
RD_Q_nm$_{(t-1)}$				4.032***	3.851**	7.092***
				(1.534)	(1.547)	(1.896)
DlnK_rd_mk$_{(t-1)}$					0.025	
					(0.061)	
Observations	192	192	192	192	192	120
Number of ctrycode	12	12	12	12	12	12

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

TABLE 2—EXPLORING SPILLOVERS FROM NONMARKET INTANGIBLES, 1998 TO 2013

Notes to table: 1. Table shows GLS estimation of equation (11): equation includes time and year effects.
2. Data are for market sector for the following countries: Austria, Czech Republic, Germany, Finland, France, Italy Netherlands, Spain, UK, Sweden and US. CZ ommited in column 7.

non-market non-R&D intangibles (including software). We entered them lagged, adding them to Table 2, column 5, in the form of investment in non-market non-R&D intangibles as a proportion of market sector output. The coefficient was 0.57, with t=0.45. This suggests that any spillovers are from non-market sector R&D and not from other non-market intangibles as measured by the SPINTAN project.

Third, this dataset yields mixed results on spillovers to the conduct of R&D in the market sector, especially the results shown in table 2, column 6 compared with column 4. The results in column 6 for R&D are also at variance with results reported in our earlier work (Corrado et al., 2013) that did not consider public R&D. Our earlier work yielded an elasticity of .2 on market sector R&D capital (significant at the 10 percent level)—similar to findings based on firm-level data.[5] The findings reported here thus deserve further investigation. As a step in that direction, note that the data used in this paper exploit measures of R&D newly developed for inclusion as capital in national accounts. The source data for these estimates are surveys of business expenditures on R&D (BERD surveys),

[5]This occurred when the R&D capital term was lagged in spillover regressions similar to those reported in table 2. The results shown in column 6 are unchanged with the R&D term is lagged and when the public R&D term is dropped.

and, as compiled by the OECD, such data were the (literal) basis of the earlier study. For some countries, the OECD's BERD data are somewhat at variance with the path of R&D investment in national accounts, where adjustments for net trade and other accounting conventions are made. Simple charts of the BERD and national accounts R&D data for the market sector (industry sectors B-M, excluding L and M72) and for manufacturing (industry sector B) are shown in the appendix to this paper.

C.   Rates of return to public sector R&D

We now investigate the very high estimated rates of return to non-market R&D in Table 2. Figure 5 shows $\Delta lnTFP^{MKT}$ for the market sector plotted against N^{NonMKT}/Q^{MKT}, shown as averages for three time periods: before, during and after the financial crisis. Before the financial crisis countries like the US and Sweden were spending a lot on non-market R&D, with Spain rather little, and there appears to be somewhat of a relation between public sector spending on R&D and productivity growth $\Delta lnTFP^{MKT}$. During the depths of the financial crisis, the US and Sweden maintained their lead and there was some reshuffling of other countries. But in all countries productivity growth $\Delta lnTFP^{MKT}$ fell very substantially. During 2010–13 the pre-crisis relation apparently resumed, and possibly strengthened.

This suggests that most of the variation in N^{NonMKT}/Q^{MKT} is cross-country. Indeed, the horizontal axis, which is the same in each panel, shows very slight change over this period, with the US, for example, hovering consistently at just below 0.015. By contrast, changes in $\Delta lnTFP^{MKT}$ have been seismic within countries (see the vertical axis) and have some between country variation. Now, the regresssions above are in differences i.e. $\Delta(\Delta lnTFP^{MKT})$ and $\Delta(N^{NonMKT}/Q^{MKT})$. Thus most of the country variation in N^{NonMKT}/Q^{MKT} is differenced out, leaving the identifying variation being time series changes in N^{NonMKT}/Q^{MKT} within a country. $\Delta lnTFP^{MKT}$ is pro-cyclical (in this period at least). If N^{NonMKT} is pro-cyclical, for political economy or measurement reasons, that would induce a positive correlation between N^{NonMKT} and $\Delta lnTFP$ overstating the coefficient, but procyclical changes in Q would induce a negative correlation with (N^{NonMKT}/Q^{MKT}) so the direction of the bias is unclear. If the marginal publically-funded project within a country has falling rates of return, then the $\Delta(N^{NonMKT}/Q^{MKT})$ specification would give a low ρ, whereas if projects in higher (N^{NonMKT}/Q^{MKT}) countries have higher spillover returns, then a (N^{NonMKT}/Q^{MKT}) would give a high ρ.

In view of the difficulty of a priori signing the bias to ρ we carried out some checks using the pooled data graphed in Figure 5. With limited regression points (12 countries, 3 cross-sections) we estimated equation (11) but excluding the labour and tangible capital terms, that is, we estimated
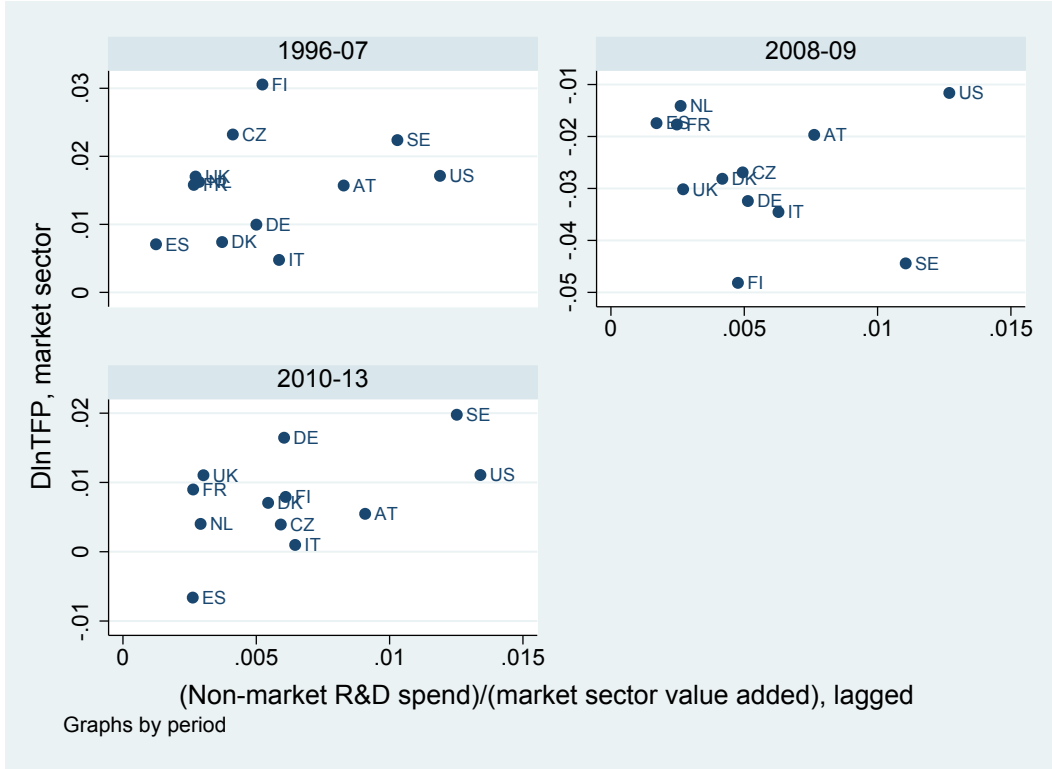
FIGURE 5. DLNTFP, MARKET SECTOR AND NONMARKET R&D

$$(12) \qquad \Delta lnTFP_{c,t}^{Q,MKT} = a_c + a_t + d^K \Delta lnK_{intan,c,t}^{MKT} + d^R \Delta lnR_{c,t}^{MKT}$$
$$+ \rho (N^{NonMKT}/Q^{MKT})_{c,t} + v_{c,t}$$

Table 3 shows estimates of equation (12).

Column 1 shows a simple pooled regression corresponding to Figure 5, and suggests a public rate of return of 53 percent. Column 2 adds period dummies and the return drops: note too the rise in the R^2 showing the considerable common time variation in $\Delta lnTFP_{c,t}^{Q,MKT}$. Column 3 adds market intangibles, with the nonR&D and R&D as separate regressors. $\Delta lnK_{intan\_xrd,c,t}^{MKT}$ is significant whereas $\Delta lnK_{R\&D,c,t}^{MKT}$ is insignificant. The coefficient on $(N^{NonMKT}/Q^{MKT})_{c,t-1}$ has fallen further to a return of 32 percent, where it would appear that some of the cross-country variation in public R&D spending is taken up by these regressors. Column 4 lags $\Delta lnK_{R\&D,c,t}^{MKT}$, which remains insignificant, and column 5 drops it altogether. Finally, column 6 enters fixed effects. The coefficient on $(N^{NonMKT}/Q^{MKT})_{c,t-1}$ rises to 534 percent, echoing the high numbers found above, and

VARIABLES	(1) DlnTFP_mk	(2) DlnTFP_mk	(3) DlnTFP_mk	(4) DlnTFP_mk	(5) DlnTFP_mk	(6)[1] DlnTFP_mk
LRDnm_Qmk	0.526*	0.412	0.323	0.321	0.323	5.345
	(0.283)	(0.325)	(0.256)	(0.254)	(0.252)	(4.710)
DlnK_intan_xrdsf_mk			0.167***	0.166***	0.167***	0.148
			(0.055)	(0.055)	(0.057)	(0.176)
DlnK_rd_mk			-0.000			
			(0.074)			
LDlnK_rd_mk				-0.006		
				(0.062)		
Dummy for 2008-09		-0.043***	-0.039***	-0.039***	-0.039***	-0.041***
		(0.005)	(0.005)	(0.006)	(0.006)	(0.007)
Dummy for 2010-13		-0.009***	-0.006**	-0.006**	-0.006**	-0.011*
		(0.002)	(0.002)	(0.002)	(0.003)	(0.006)
Constant	-0.004**	0.013***	0.010***	0.010***	0.010***	-0.017
	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)	(0.027)
Observations	36	36	36	36	36	36
R-squared	0.00743	0.829	0.843	0.843	0.843	0.498
Number of countries	12	12	12	12	12	12

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

1. Fixed effects. All other columns are random effects.

TABLE 3—REGRESSION ESTIMATES OF (12), DEPENDENT VARIABLE: $\Delta lnTFP_{c,t}^{Q,MKT}$

Notes to table: 1. Table shows robust random effects estimation of equation (12). t statistics in brackets.
2. Column 1 has a constant and no time dummies. Data are for 12 countries and three periods: 1996-07, 2008-09 and 2010-13, the latter two are periodcode2 and periodcode3 in the table.
3. The regression variables are $(N^{NonMKT}/Q^{MKT})_{c,t-1}$, $\Delta lnK_{intan,c,t}^{MKT}$, $\Delta lnK_{R\&D,c,t}^{MKT}$ and $\Delta lnK_{R\&D,c,t-1}^{MKT}$.

the coefficient on $\Delta lnK_{intan\_xrd,c,t}^{MKT}$, whilst insignificant, again is similar to the numbers in previous columns.

All this suggests the following. First, the rate of return on non-market R&D is highly dependent on the variation used to estimate it. The very high within-country estimates of returns seem implausible, suggesting they are contaminated by endogeneity bias or outlier observations which could be measurement error. The between country estimates, based on long differences, despite being potentially biased by country unobservables that might affect $\Delta lnTFP$, seem much more reasonable, at around 30%. Second, we do seem to get a robust correlation between $\Delta lnTFP$ and intangible capital growth, $\Delta lnK_{intan\_xrd,c,t}$, robust to time period and long and short differencing. Third, the spillover effects of market R&D do seem to depend somewhat on method, time period, and data used.

Finally, as is well known, there was a substantial pervasive downward shift in $\Delta lnTFP$ in 2008–9 and weak performance since then, i.e., 2010–13. The time dummies in the regression shown in table 3 (column 5) estimate the downshift shift in TFP growth in 2010–13 relative

to 1999–2003 to be 1.6 percentage points, which is substantial.[6] Thus on this model we have a quite substantial unexplained common decline in $\Delta lnTFP$ after the Great Recession. This much discussed slowdown in productivity growth, as reflected in the data used in this study, is relative to a rather exceptional period, however. While TFP growth for the countries in our sample averaged 1.6 percent during 1999–2007 (and .8 percentage points during 2010–13), average TFP growth from 1999 to 2003 masks substantial heterogeneity in the sample, with US TFP growth relatively strong from 1999 to 2003 and EU growth relatively strong from 2004 to 2007. In subsequent work, we plan to experiment with weighted pooled regressions and look at these periods separately.

VI.   Conclusions

We have used a new cross-country sector-industry-level (i.e. data for industries and market/non-market within industries) growth accounting database that includes data on intangible investment for 11 EU countries (Austria, Czech Republic, Germany, Finland, France, Italy Netherlands, UK, Sweden) and the United States from 1995 through 2013. We build tangible and intangible captial stocks from investment data, use harmonised ICT prices and account for public sector rates of return using the approach of Jorgenson and Scheyrer. Using R&D investment time series newly developed for national accounts, we find support for earlier findings in the literature (e.g., Guellec and Van Pottelsberghe de la Potterie 2002, 2004) that there are spillovers from public sector R&D to market sector productivity. Our findings suggest a rate of return of around 30% to public sector R&D spend. We also find that market sector investments in nonR&D intangible capital generate spillovers to productivity. Finally, we do not find evidence that non-market non-R&D intangible investment has spillover benefits to the market sector.

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[6]The dummies estimated in table 3 are similar to the shifts in the (unreported) coefficients on time dummies for the regressions shown in table 2.

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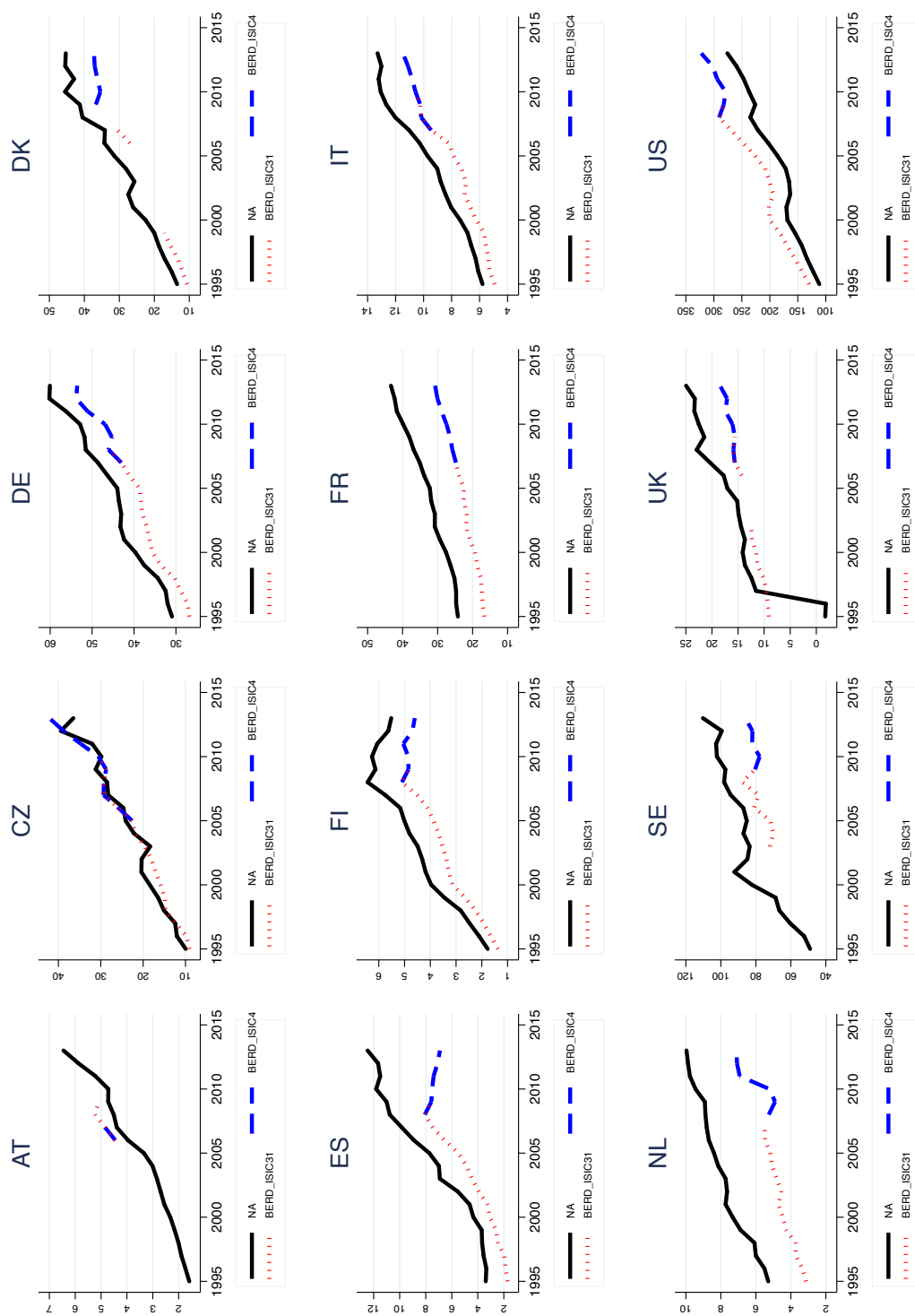Stiroh, K. J. (2002). Are ICT spillovers driving the new economy? *Review of Income and Wealth 48*(1), 33–57.

FIGURE 1. BERD AND NATIONAL ACCOUNTS R&D DATA

Note. BERD data downloaded from OECD website July 14, 2016. National accounts data are sourced from EURO-
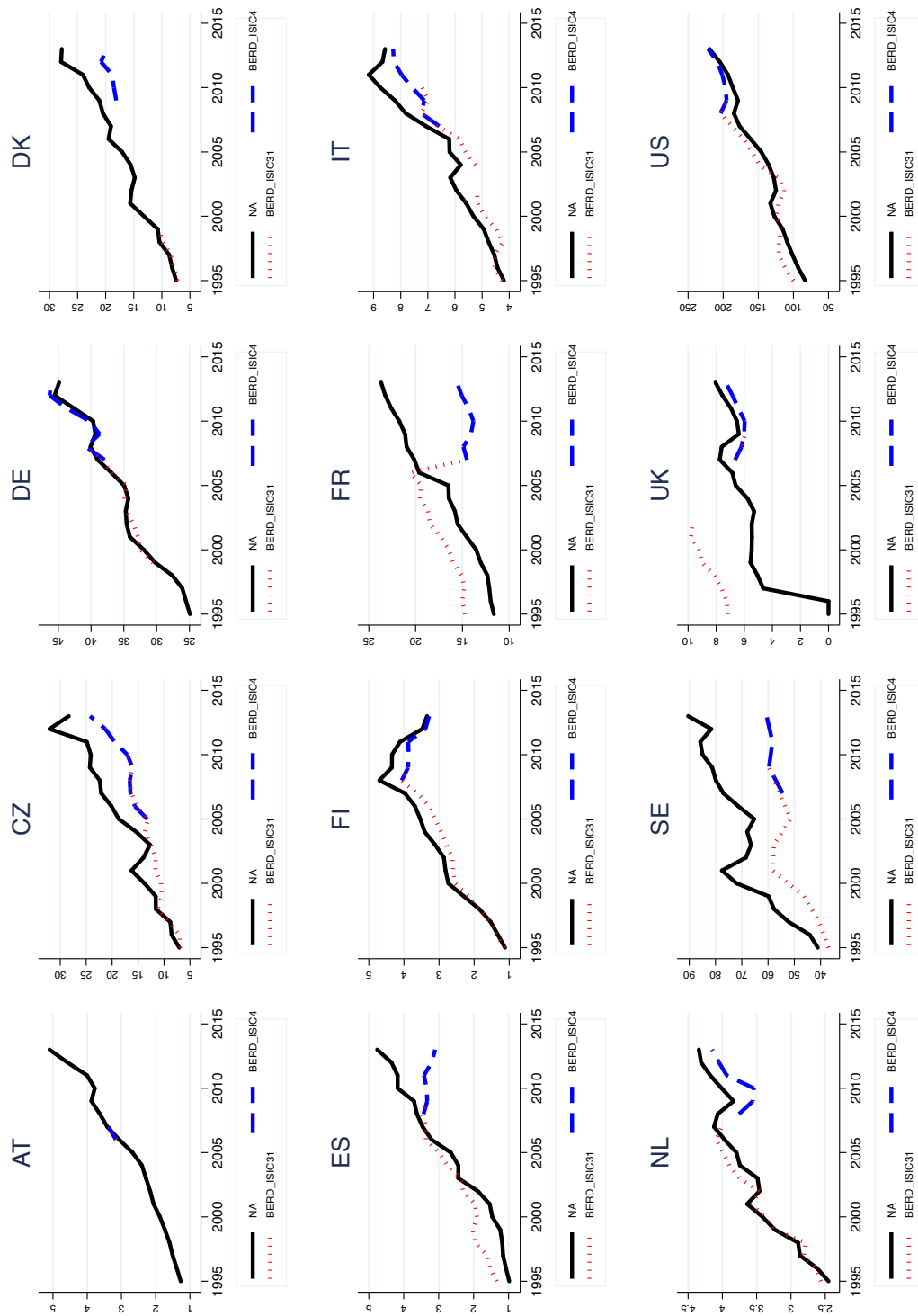STAT; processed into SPINTAN database July 18, 2016.

FIGURE 2. BERD AND NATIONAL ACCOUNTS MANUFACTURING R&D DATA

Note. BERD data downloaded from OECD website July 14, 2016. National accounts data are sourced from EURO-STAT; processed into SPINTAN database July 18, 2016.