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State Aid, R&D, and the Digital Content of Trade

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Abstract

We test for the role of state aid as a driver of digital competitiveness at the industry level, focusing on the digital factor content of trade. Results show that state aid may increase digital competitiveness, particularly in R&D-intensive industries and in relation to the export of (digital) capital-intensive goods and services. Interestingly, aggregate state aid appears to be more effective than specific R&D funds in explaining the performance of country-industries in foreign markets.

Keywords: Factor content of trade, ICT capital, state aid, sectoral R&D capability

JEL classification: F14, O30

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1. Introduction

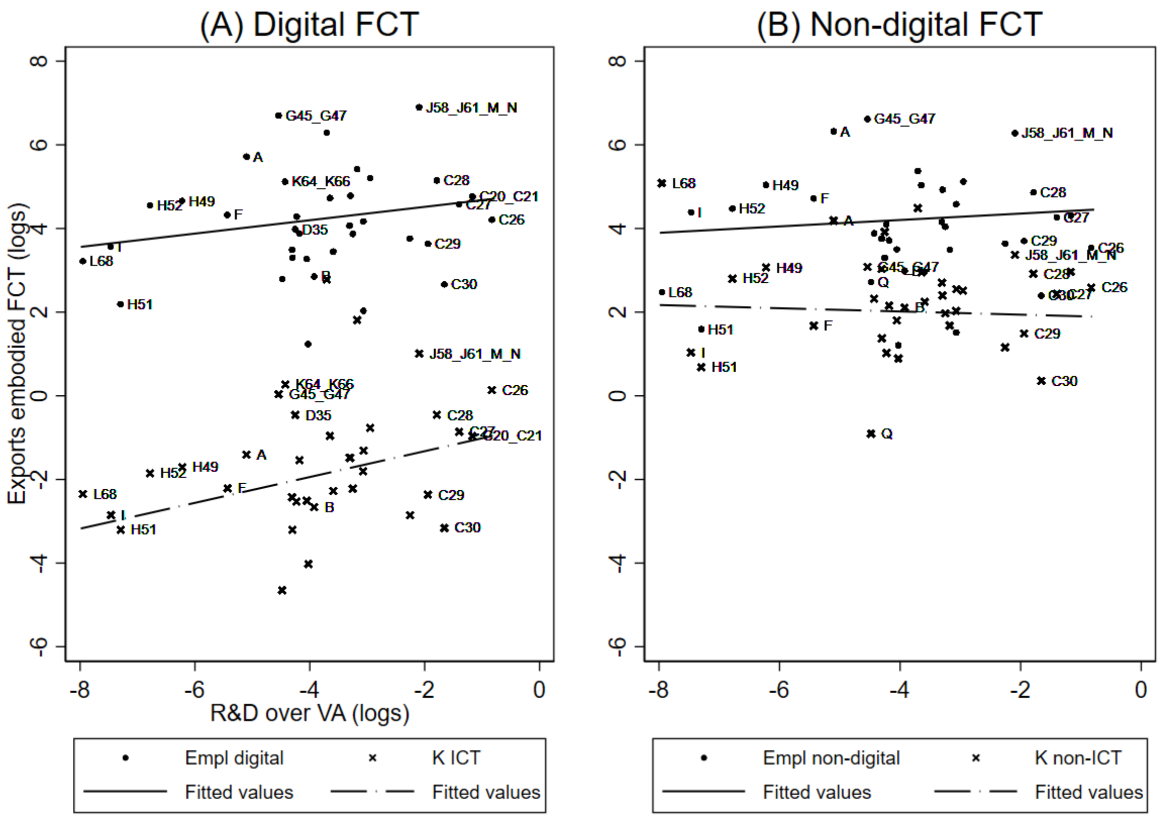
Digitalisation is becoming key to explaining economies' competitive performance. This positive connection between the accumulation of digital endowments and competitive performance suggests that policies and institutions should support the accumulation of digital capital and skills, which should result in comparative (Wang and Li, 2017) or absolute advantages (Dosi et al., 2015). Country and industry-specific technological capabilities, together with institutions supporting knowledge diffusion and technology transfer, are of central importance in explaining countries' competitiveness. This is particularly true in the ICT domain, given the path-dependent, cumulative and intangible asset-intensive nature of digital technologies (Rikap and Lundvall, 2021). In this context, an exploration of the underlying factors that explain cross-country differences in terms of digital competitiveness – measured in this paper by using data indicating the digital factor content of exports (DFCE) – is of central importance. The trade literature argues that comparative advantages are driven by relative factor endowments, focusing on the factors underlying the accumulation of ICT capital and digital skills. However, a more recent stream also evaluates the role of policies and institutions in driving comparative advantages. Examples include financial development (Manova, 2013), the security of contract enforcement (Costinot, 2009) and labour market flexibility (Cuñat and Melitz, 2009). Other contributions go a step further, exploring the interplay between factor endowments and institutions (Chor, 2010; Wang and Li, 2017). Institutions and policies are in fact key to explaining absolute advantage differentials and, consequently, persistent cross-country divergence in terms of technological competitiveness (Dosi and Tranchero, 2021).

However, to the best of our knowledge, the empirical evidence on the role of institutions and industrial specialisation in shaping digital comparative advantages remains scant and inconclusive. Building on Wang and Li (2017), this work adds to the extant literature testing whether industry-level R&D capacities and institutional drivers play a role in determining patterns of DFCE at the country-industry level.[1] In doing so, we deviate from the original framework of Wang and Li (2017) by considering a full interaction model to distinguish the role of individual versus complementary effects of the two drivers. A first simple descriptive analysis shows a positive relationship between DFCE and R&D stock, which is not confirmed for non-digital exports (see Figure 1).[2]

1 For a list of countries and industries, see Appendix, Table A.1.

2 For a detailed description of the numerical variables, see Appendix, Table A.2.

Figure 1 / Relation between digital and non-digital factor content of exports versus aggregate industry R&D stock in 2012



Source: own calculations.

2. Data and methodology

Data on countries' DFCE are based on Guarascio and Stöllinger (2022), available for most EU27 members for the years 2007 and 2012. This procedure starts with information on labour and capital endowments at the country-industry level,[3] expressed as employment content (digital and non-digital) and capital content (ICT and non-ICT), respectively. Data are then combined with the intermediate linkage indicator from the World Input-Output Database (Timmer et al., 2015), which provides information on trade and production relationships between country-industry pairs. [4] Taking export flows as reference for trade, this methodology allows us to derive the bilateral industry-level final content of exports (FCE), differentiating between digital (DFCE) and non-digital (NDFCE) components, for all EU members in 2012.

DFCE and NDFCE are studied with respect to two key elements: state aid, proxying the role of institutions as a driver of digital competitiveness; and R&D stock relative to sectoral value added, proxying industry-level technological capabilities. In particular, state aid, as defined by the European Commission (EC), refers to a wide range of public interventions (e.g. grants, interest and tax concessions, guarantees, etc.) that member states can use to support the development of specific industries and enterprises exposed to market failures, as long as these measures do not undermine the principles of fair competition in the EU's internal market.[5] Accordingly, the EC regulates specific policy objectives for which state aid is considered compatible, such as those related to the promotion of R&D and innovation. In this analysis, we will refer either to the amount of total state aid (AID) or Objective 3 state aid on R&D and innovation (AID03),[6] adjusted for the size of the economy (in terms of value added). Our second main variable of interest is R&D at the industry level, which we express as R&D stocks relative to sectoral value added, based on Eurostat data. We express these monetary variables in 2015 constant terms, using country and industry-specific gross output price indices.[7]

The econometric specification builds on Wang and Li (2017) and Chor (2010), who estimate the relationship between industry-level bilateral exports on a measure for product complexity and R&D intensity at the industry level, interacted with information on ICT endowments at the country level. We build on this approach to investigate whether and to what extent the DFCE of a country-industry pair is supported by the role of innovation-related institutions and policy (proxied by state aid) and industry-specific technological capabilities (proxied by country-industry R&D expenditures). As in Wang and Li

3 Specifically, labour statistics are taken from the European Labour Force Survey (LFS) and the Survey on Italian Occupations (ICP) for digital tasks, whereas capital stocks are retrieved from the EU KLEMS and the Eurostat database for capital stocks.

4 That is, intermediate linkages quantify the amount of direct and indirect intermediate goods required from industry A to obtain one unit of output in industry B. At the same time, the Input-Output method allows quantification of the bilateral trade flows between A and B.

5 These principles include, among others, the prohibition to act in favour of any distortion of the market competition and trade within the EU by favouring certain companies or the production of certain goods (following TFEU, Article 107).

6 According to the EU legislation (2006), R&D and innovation state aid includes funding for personnel, instruments and equipment, patenting and other costs related to R&D projects, which might be relevant boosters of both innovation capital and employment.

7 For further details on the conversion procedure, see Appendix, Table A.2.

(2017), we use the first lag (i.e. 2007) of state aid and R&D to account for potential endogeneity and simultaneity issues. However, we deviate from the original econometric strategy first by focusing on the bilateral factor content of exports and second by using the inverse hyperbolic sine (IHS) transformation to express these flows, owing to the presence of zeros and skewed data.[8] Third, we account for both the direct and indirect role of industry-level R&D and state aid through interaction terms. The final specification runs as follows:

$$\text{arcsinh}(f_{k,2012}^{rs}) = \beta\left(StateAid_{2007}^{r} \times RD_{k,2007}^{r}\right) + StateAid_{2007}^{r} + RD_{k,2007}^{r} + \gamma^{rs} + \varphi_{k}^{s} + \varepsilon_{k}^{rs}$$

where *r* is the exporter, *s* is the importer and *k* denotes the industry.[9] The dependent variable f_k^{rs} measures both digital and non-digital FCE categories. The variable $StateAid$ represents the institutional characteristics of the exporting country and industry-level RD stock proxies country-industry technological capabilities. γ controls for country-pair fixed effects and φ denotes importer-industry fixed effects.

8 For a recent discussion of the use of the IHS transformation in applied economics, see Bellemare and Wichman (2020), which provides guidelines for the application and interpretation on this methodology.

9 For further information on the sample composition, see Appendix, Table A.1.

3. Results

Results are reported distinguishing between total (Table 1) and R&D-specific state aid (Table 2), highlighting the heterogeneous impact of public interventions directly aimed at promoting innovation (AID03) compared with more general ones (AID). Both digital and non-digital content of exports are shown for comparison.[10]

Table 1 / Results for total state aid

	Employment content		Capital content	
	Digital	**Non-digital**	**ICT**	**Non-ICT**
R&D stock × StateAid (AID)	39.13***	55.64***	50.30***	25.11**
	(10.18)	(10.52)	(10.42)	(11.52)
R&D stock	0.00849	-0.302***	0.261***	0.619***
	(0.0997)	(0.105)	(0.0919)	(0.107)
StateAid (AID)	1,123***	1,141***	984.5***	1,242***
	(92.46)	(89.82)	(80.41)	(90.23)
Constant	-1.650***	-2.025***	-4.998***	-5.331***
	(0.522)	(0.512)	(0.490)	(0.570)
Observations	11,550	11,550	11,550	11,550
R-squared	0.881	0.882	0.800	0.852
Adjusted R-squared	0.832	0.832	0.832	0.832
Bilateral FE	Yes	Yes	Yes	Yes
Importer-Industry FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1
Source: own calculations.

The transformation of the dependent variables by the IHS function allows us to obtain a first interpretable indication of the estimated effects simply by looking at the signs and magnitudes of the coefficients. Overall, both the technological and the institutional variables included in the analysis seem to play a key role in explaining comparative advantages in the digital domains, especially with respect to the capital content of exports. R&D intensity shows a strong positive impact on the capital domains for which we can calculate the corresponding elasticities (Bellemare and Wichman, 2020). That is, taking the mean value as a reference, we calculate a positive change of 2.8% and 6.6% in ICT and non-ICT capital exports, respectively, owing to a 1% change in sectoral R&D intensity.[11] These findings support the 'technology push' hypothesis (Peneder, 2010), which suggests that positive spillovers are more likely to occur where R&D capabilities are stronger. However, for the employment content of trade, R&D intensity only shows a positive effect when it interacts with state aid. We can interpret this result as less direct evidence of the promoting role of R&D capabilities for employment-embedded exports, which requires

[10] Additional robustness checks, including standardised coefficients and regressions using non-deflated capital FCE are included in the Appendix, Tables A.3 to A.5.

[11] That is, fixing the value of *x* at its mean value (i.e. 0.1071 for R&D stock), then for large values of *y* we can compute $\widehat{\xi_{yx}} = \hat{\beta}x$ (as derived in Bellemare and Wichman, 2020:3).

the presence of an adequate institutional framework (based on digital skills-enhancing education, private-public synergies in R&D investment, etc.) to materialise. Indeed, the supportive role of state aid is illustrated here by a generally positive impact observed in all specifications, where the bias towards the capital domains is no longer detected.

Further heterogeneities could materialise by switching the focus on innovation-specific institutions, i.e. state aid aimed at promoting R&D. Table 2 confirms the results reported in Table 1 as regards the role of sectoral R&D. However, contrary to what is shown in Table 1, R&D and innovation-specific state aid seem to have a negative impact on exports, irrespective of their digital or non-digital content. Nevertheless, the interaction between our two regressors again turns out to be positive across all specifications. This suggests that policies aimed at supporting country-industry technological competitiveness require a strong knowledge base in order to be successful. As for the negative sign of the coefficient associated with innovative state aid, there are two main likely explanations: first, this may signal a structural weakness of the sector-country, particularly in relation to its technological competitiveness; and second, as it is aimed at strengthening specific technology and product segments, this type of government support is more difficult to implement and less likely to result in a fast and visible increase in exports. However, in relation to R&D industrial specialisation, positive R&D spillovers can emerge even in non-digital exports, as shown by the positive and significant coefficient of non-digital capital factor content of trade (FCT). This may be related to the complementarity between technology-push and demand-pull drivers (Di Stefano et al., 2012), i.e. the competitiveness-enhancing impact of state aid unfolds if firms are equipped with enough competences to rapidly seize innovation and export opportunities.

Table 2 / Results for R&D and innovation state aid

	Employment content		Capital content	
	Digital	**Non-digital**	**ICT**	**Non-ICT**
R&D stock × StateAid (AID03)	250.4***	210.2**	125.7*	339.6***
	(83.19)	(83.96)	(75.93)	(83.55)
R&D stock	0.0931	-0.0740	0.515***	0.541***
	(0.0704)	(0.0772)	(0.0699)	(0.0651)
StateAid (AID03)	-16,592***	-16,901***	-14,567***	-18,328***
	(1,340)	(1,299)	(1,167)	(1,307)
Constant	14.98***	14.90***	9.597***	13.05***
	(0.907)	(0.875)	(0.765)	(0.894)
Observations	11,550	11,550	11,550	11,550
R-squared	0.881	0.882	0.800	0.852
Adjusted R-squared	0.833	0.833	0.833	0.833
Bilateral FE	Yes	Yes	Yes	Yes
Importer-Industry FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1
Source: own calculations.

4. Conclusions

We provide a novel contribution concerning drivers of comparative advantages measured by digital and non-digital FCT. We show that industry-specific R&D as well as institutions aimed at supporting competitiveness and innovation are key in explaining country-industry export performance. The findings confirm the importance of knowledge and innovation-related idiosyncratic capabilities as well as institutions in explaining export performance, going beyond explanations based only on differences in endowments (Dosi and Tranchero, 2021). Remarkably, both R&D intensity and (general) state aid have a stronger effect on ICT capital, while a smaller effect is detected with respect to digital employment endowments. Such heterogeneity may be explained by the complex, cumulative and context-specific nature of digital skills, which require highly specialised institutions and relevant shares of intangible assets in order to significantly consolidate. Meanwhile, state aid and sectoral R&D seem to reinforce each other. For capital content, pronounced R&D stocks appear to be a prerequisite for stronger effects of state aid, confirming the complementarity between technology-push and demand-pull competitiveness drivers (Di Stefano et al., 2012). Finally, our results point to the need for relatively broad state aid, rather than relying exclusively on actions aimed at supporting R&D activities, in order to have a significant impact on a country's performance in digital exports.

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Appendix

Table A.1 / Sample description

Variable	N	Description
Exporter industries (NACE Rev.2)	36	The industry classification follows the NACE Revision 2 at a 2-digit aggregation level, with some exceptions. That is, depending on the availability of export data, a few sectors were considered at the 1-digit level (i.e. A, B, E, F, G, I, K and Q) or combined with other industries (i.e. C10to12, C13to15, C17_18, C20_21, C31to33, J58to61_M_N, J62_63, R_S). Finally, sectors T and U were excluded from the analysis, owing to their negligible economic size.
Exporter countries	19	Austria, Belgium, Bulgaria, Czechia, Germany, Estonia, Finland, France, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Romania, Slovakia, Slovenia and Sweden.
Importer countries	25	Exporter countries plus Denmark, Ireland, Poland, Portugal, Spain and the United Kingdom.

Table A.2 / Descriptive statistics

	N	Mean	SD	Min	p25	Median	p75	Max
2007								
State Aid	11725	0.0056	0.0036	0.0009	0.0037	0.00490	0.0065	0.0196
State Aid03	11725	0.0006	0.0005	0	0.0001	0.0005	0.001	0.0014
RD Stock	11550	0.1071	0.2761	0	0.0018	0.0159	0.0954	3.0205
IHS RD Stock	11550	0.0971	0.2103	0	0.0018	0.0159	0.0953	1.8249
2012								
Digital Emp FCE	11745	5132.5672	66544.3334	0	12.1413	62.8304	327.3162	3003117.3
Non-dig Emp FCE	11745	4413.6242	54743.6971	0	10.3843	54.977	287.1775	2078480.1
ICT cap FCE	11745	25.8152	387.9366	0	0.0212	0.1851	1.464	20048.822
Non-ICT cap FCE	11745	1406.4501	41762.5517	0	1.6921	10.3266	59.0107	3886721.3
IHS Dig Emp FCE	11745	4.9347	2.4811	0	3.1915	4.8336	6.4841	15.6083
IHS Non-dig Emp FCE	11745	4.7949	2.4874	0	3.0358	4.7001	6.3533	15.2403
IHS ICT cap FCE	11745	0.89	1.4369	0	0.0212	0.184	1.1746	10.5991
IHS Non-ICT cap FCE	11745	3.256	2.3593	0	1.2968	3.0302	4.7709	15.8662

Explanatory remarks:

The table is divided into two panels. The upper panel presents information on total and R&D-specific state, and R&D stocks by country-industry for the year 2007. Starting from raw data expressed in current millions of euro, these variables are transformed into constant terms (i.e. chained linked volumes in 2015) and corrected for the corresponding economic dimension (i.e. value added, in millions of euro, taken at country level for state aid and at country-industry level for sectoral R&D). The presence of a left-skewed distribution of R&D stocks justifies an inverse hyperbolic sine (IHS) transformation of the variable, which we include in Table A.4 as a robustness check.

The lower panel shows the 2012 information of the response variables used in the analysis, namely labour and capital FCE differentiated by digital and non-digital components. As before, the capital-related variables have been transformed from current values to constant values (2015, millions of euro) and corrected for the economic size of the corresponding country-industry. The skewness of the distribution of the four variables, as shown here by the notable differences between the third quantile and the median and between the maximum and the third quantile, again motivates the IHS transformation, as shown in the last rows of this table.

The main findings of Tables 1 and 2 are confirmed by the specifications shown in Tables A.3 and A.4, respectively.

Table A.3 / Alternative estimation with IHS transformed dependent variables and R&D stock variable, total state aid

	Employment content		Capital content	
	Digital	**Non-digital**	**Digital**	**Non-digital**
IHS R&D stock × StateAid (AID)	63.75***	76.94***	100.7***	78.88***
	(13.03)	(13.80)	(14.05)	(14.52)
IHS R&D stock	-0.0310	-0.419***	0.123	0.615***
	(0.118)	(0.127)	(0.109)	(0.129)
StateAid (AID)	1,119***	1,140***	977.6***	1,232***
	(92.71)	(89.97)	(80.72)	(90.84)
Constant	-1.634***	-2.016***	-4.968***	-5.289***
	(0.523)	(0.513)	(0.491)	(0.573)
Observations	11,550	11,550	11,550	11,550
R-squared	0.881	0.882	0.799	0.852
Adjusted R-squared	0.833	0.833	0.833	0.833
Bilateral FE	YES	YES	YES	YES
Importer-Industry FE	YES	YES	YES	YES

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1
Source: own calculations.

Table A.4 / Alternative estimation with IHS transformed dependent variables and R&D stock variable, R&D and innovation state aid

	Employment content		Capital content	
	Digital	Non-digital	Digital	Non-digital
IHS R&D stock × StateAid (AID03)	505.7***	494.6***	675.8***	582.6***
	(142.3)	(144.8)	(156.2)	(144.0)
IHS R&D stock	0.0510	-0.232	0.855***	0.985***
	(0.148)	(0.155)	(0.164)	(0.146)
StateAid (AID03)	-16,118***	-16,463***	-21,790***	-18,508***
	(1,727)	(1,675)	(1,701)	(1,733)
Constant	21.57***	21.51***	18.03***	19.67***
	(1.172)	(1.132)	(1.144)	(1.177)
Observations	11,550	11,550	11,550	11,550
R-squared	0.817	0.823	0.816	0.799
Adjusted R-squared	0.772	0.772	0.772	0.772
Bilateral FE	YES	YES	YES	YES
Importer-Industry FE	YES	YES	YES	YES

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1
Source: own calculations.

Table A.5 / Alternative estimation with non-deflated FCT capital elements

	Total state aid factor content		R&D and innovation state aid factor content	
	ICT	Non-ICT	ICT	Non-ICT
R&D stock × StateAid (AID)	0.119***	0.0635***		
	(0.00768)	(0.00683)		
R&D stock × StateAid (AID03)			0.0474***	0.0361***
			(0.00461)	(0.00436)
R&D stock	0.742***	0.362***	0.460***	0.296***
	(0.0443)	(0.0389)	(0.0372)	(0.0352)
StateAid (AID)	11.15***	9.522***		
	(0.499)	(0.492)		
StateAid (AID03)			-10.27***	-8.869***
			(0.467)	(0.467)
Constant	56.92***	51.80***	-77.55***	-63.71***
	(2.599)	(2.574)	(3.500)	(3.480)
Observations	10,013	10,221	10,013	10,221
R-squared	0.890	0.897	0.889	0.897
Adj R-squared	0.881	0.881	0.881	0.881
Importer-Industry FE	YES	YES	YES	YES
Bilateral FE	YES	YES	YES	YES

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

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