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Deliverable 6.5

The combined contribution of intangible capital and global value chain participation to productivity

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Summary

This deliverable investigates the relationship of four types of intangibles (R&D, software and databases, design and economic competencies) and global value chain (GVC) participation and their contribution to productivity. The deliverable uses an industry level panel consisting of 14 countries and 16 industries observed for the period 2000–2014, with data collected from multiple sources, such as the World InputOutput Database (WIOD), the INTAN-Invest database and the World Bank database.

The analysis is conducted proxying GVC participation with network centrality measures calculated using intermediate input exchanges between country-industries and retrieving a total factor productivity (TFP) proxy with production function estimation methods. The impact of intangibles and GVC is evaluated both separately and combinedly, via interaction terms that allow evaluating the role of intangibles in the transmission mechanism between GVC and productivity. Both GVCs and intangibles are found to be significant drivers of productivity, and intangibles are found to moderate the relation between GVC and productivity.

1. Introduction

The increased fragmentation of production chains across countries is a phenomenon that has attracted considerable interest in recent times. The whole set of activities that contribute to the production of a product and that are increasingly "global", in the sense that are managed in different locations all over the world, are commonly referred as Global Value Chains (henceforth, GVCs). The implication for productivity of GVCs are object of analysis by many researchers and policy makers. In practical terms, GVCs translate into exchanges of material, services and information that are used in the production process. All these exchanges can be seen as huge networks that connect firms, industries and countries together. As noted by Porter (1990) the main advantage of this type of production organization is that countries and firms can specialize in specific portion of the production chains, relying on imports for those activities in which they are not specialized, with obvious advantages in terms of efficiency.

In these circumstances, a central role is played by intangible capital. From one side, intangibles are replacing traditional inputs as main drivers of productivity; from the other, they favor the organization of production through GVCs. Most of the value added created in production chains is created in early and later stages, which strongly involve intangible capital. The delocalization of these stages is of course easier, because feasible at a distance, and their increase in importance is one of the factors that explain the rise of GVCs.

In this deliverable, we aim at assessing the impact of intangibles and GVC participation both separately and combinedly. In fact, in the literature, the two factors have been studied mostly separately, with some concentrating on how GVCs improves productivity (Baldwin et al., 2014) and some others on how intangibles encourage participation in GVCs (Jona-Lasinio et al., 2016). Instead, we test the linkage between these two factors in improving productivity efficiency via interaction terms.

In order to proxy for GVC participation, we exploit industry-level data on exchanges of intermediate inputs between industries, extracted from the World Input Output Database (WIOD) and build network centrality indicators. As proxy for productivity, we estimate a measure of total factor productivity (TFP), with production function estimation methods. Using the INTAN-Invest database, four types of intangible capital investment are considered, following the classification in Corrado et al. (2005): R&D, software and databases, design and economic competencies, which includes brand, organizational capital and training. The final panel consists of 14 countries and 16 industries, for the period from 2000 to 2014.

The deliverable is structures as follows. The next section reviews the relevant literature, section 3 describes the data and the econometric framework, section 4 presents the results and section 5 concludes.

2. Intangible capital and Global Value Chain participation

Intangible capital is playing a role of growing importance as driver of productivity in modern economies. There is a wide literature that recognizes this fact (Bounfour, 2003; Corrado et al., 2005; Gu and Lev, 2011; Marrocu et al, 2012; Ståhle et al., 2015). However, measurement issues are still at the center of the intangibles debate, as they are by nature difficult to measure and their lack of recognition in national account creates possible issues when measuring productivity growth. The general consensus is that treating intangibles as investment rather than expenditure (Corrado et al., 2005) can help correct for these issues. This is why some intangible types, such as R&D, have recently started to be included in national accounts. However, the strand of literature on intangibles to which this deliverable is mostly connected is the one that recognizes their role in enhancing productivity (Arrighetti et al., 2014; Corrado et al., 2016; Hall et al.,2005; Oliner et al., 2007; O'Mahony and Vecchi, 2009; Sandner and Block, 2011).

On the other hand, there are less studies that analyze GVCs and intangibles together. Some authors concentrate on specific case studies. Some examples are Chen et al. (2017) and Dedrick (2010). Among macroeconomic studies, we mention Jona-Lasinio et al. (2016) whose work, to our knowledge, is the most similar to ours in the scope, among those present in the literature.

Another issue is related to the ways GVC participation can be proxied. Most of the GVC works emphasized how GVCs help enhancing productivity (Sturgeon and Kawamaki, 2010; OECD, 2013; WIPO, 2017; UNCTAD, 2013; Roos, 2017). In order to build indicators that represent the participation of agents into GVCs, Input-Output (I-O) tables have frequently been employed. These summarize exchanges of inputs between agents (usually countries or industries) in a compact way and allow to build indicators that measure how much each unit makes use of GVCs in its production process. Some examples of I-O tables are provided by Koopman et al. (2014), which provide data on export exchanges; Yamano (2016), on within-countries sales and purchases of goods; Lenzen et al. (2012) and Tukker et al. (2013), in the environmental technologies context. Finally, the World Input-Output Database (WIOD) of Timmer et al. (2015), which provides data on intermediate input exchanges of 56 industries located in 43 different countries, is the database used in this study.

3. Methodology

3.1 Data

We use yearly data for 14 countries[1] and 16 sectors[2] for the period 2000-2014. In particular, GVC indicators are built using data on bilateral trade collected from the World Input-Output Database (WIOD), developed by Timmer et al. (2015). Network centrality measures, that represent the degree of integration of each sector into GVCs, are computed based on this data information (Bloch et al., 2016). Different centrality measures reflect the different roles that nodes can have in a network. In particular, we focus on two indicators: strength

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[1] Austria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Luxembourg, Slovakia, Slovenia, Spain and Sweden.

[2] We follow the Industrial Classification of All Economic Activities (ISIC Rev. 4) classification of industries.

centrality, calculated as the sum of all transactions flowing in and out an industry, and betweenness

centrality, which measures each node's importance in linking other nodes (Brandes, 2001; Freeman, 1978).

Moreover, within strength centrality, we distinguish transactions that flow in and out industries considering

separately backward and forward GVC participation.

Data on intangible investment are collected from the INTAN-Invest database, developed by Corrado et al.

(2016). The intangible categories considered are R&D, software and databases, design, and economic

competencies, which include brand, organizational capital and training.

For the estimation of the production function, we use value added adjusted for intangibles from INTAN-

Invest, labor (hours worked) and non-ICT capital stock3 from EU Klems (Jäger, 2016). Finally, some country

level control variables that are believed to affect productivity in the literature are obtained from the World

development indicators of the World Bank. These variables are: imports, tertiary education attainment as

proxy for human capital, domestic credit to private sector as proxy for financial development and the

corporate income tax as proxy for taxation. Data sources are summarized in Table 1.

Table 1: Data sources

	Database	**Variables**
Global Value Chain	World Input-Output Database (WIOD)	Intermediate inputs, trade flows
Intangibles	INTAN-Invest	Investment (at 2010 prices) in R&D, computers and software, design and economic competencies (including organizational capital, branding and training); value added corrected for intangibles.
Production factors	EU Klems	Labor (hours worked by industry) and non-ICT capital stock (real fixed capital stock at 2010 prices)

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3 Non-ICT capital stock is computed as total capital stock minus Software, Information Technology and Communication Technology capital.

Control variables	World development indicators (World Bank)	Imports, Tertiary education attainment, domestic credit to private sector and corporate income taxation.

3.2 Econometric model

Prior the econometric estimation, a TFP proxy is retrieved by considering a Cobb-Douglas production function in logarithms with labor and capital as productive factors, as in equation (1).

$$\log Y_{c,i,t} = \beta_0 + \beta_1 \log K_{c,i,t} + \beta_2 \log L_{c,i,t} + \epsilon_{c,i,t} \qquad (1)$$

In the equation, Y represents value added, K capital stock and L is labor measured as total hours worked by employees, while the subscripts c, i and t denote country, industry and year.[4] The residual of the equation is our proxy for TFP. In order to correct several typical issues related to production function estimations, such as the endogeneity of capital, we estimate the equation with the Olley and Pakes (1992) method, using capital investment to correct for productivity shocks.

The TFP measure retrieved from equation (1) is later used to assess the impact of the independent variables, namely GVC indicators and intangible investment variables, via fixed effect panel regressions. The estimated model is:

$$TFP_t = \beta_0 + \beta_1 GVC_t^j + \beta_2 int^m_t + \gamma X_t + e_t \qquad (2)$$

where GVC_t^j is one of the above mentioned GVC indicators that are tested separately, int^m_t are intangible investment variables and X_t are control variables. The GVC measures, denoted with the notation j, are strength centrality, forward and backward centrality, and betweenness centrality. The intangible components, denoted with the notation m, are software and databases, R&D and economic competencies.

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[4] In the estimation, lagged values for capital stock, labour and investment are used.

Secondly, we test the hypothesis that intangibles moderate the relation between GVC and TFP, by adding interaction terms between each type of intangible and GVC.

In formulas, we estimate the following model for each GVC-intangible combination:

$$TFP_t = \beta_0 + \beta_1 GVC_{tj} + \beta_2 int_{mt} + \beta_3 int_{mt} GVC_{tj} + \gamma X_t + \mu_t \qquad (3)$$

4. Results

The output from fixed effects estimations[5] are presented in Tables 2 and 3. As mentioned, in every specification, we test a measure of GVC and one type of intangible. We also add interaction terms to test moderation effects. Controls and year dummies are shown at the bottom of the tables.[6] In table 2, strength centrality, our main measure of GVC, is used. The results suggest that both GVC and all the types of intangibles considered are strong and significant drivers of productivity in every specification. In addition, interaction terms are positive and significant in three out of four cases, namely software and databases, R&D and economic competencies, while the design interaction term is not. This means that three of the four types of intangibles considered moderate the relation between GVC and productivity. In other words, for each GVC-intangible type pair, we find that the effect of GVC on TFP is different for different levels of the investment in the intangible considered.

In addition, also the sign of the coefficients of the control variables is as expected, even if often nonsignificant. Imports, financial development and human capital tend to have a positive impact on TFP, while taxation tend to negatively affect productivity.

We are also able to distinguish between two components of strength centrality[7], and capture the distinction between forward and backward integration.[8] Forward integration measures the goods that flow out from a sector, while backward integration indicates the goods flow into that sector. Forward integration happens when industry i provides inputs to sector j (exports along the GVC), while backward integration occurs when

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[5] The choice between random and fixed effects has been taken after running the Hausman test.
[6] Industry and country dummies have been tested but not included as non-significant.
[7] The network literature often refers to these measures as in-strength and out-strength centrality.
[8] The distinction between the two components is recurrent in the GVCs literature. See, for example, Jona-Lasinio et al. (2016) and Koopman et al. (2010).

industry i receives inputs from sector j (imports along the GVC).[9] Our results suggest that both forward and

backward integration matter for productivity. We show the output of these estimations in Tables 3 and 4.

Table 5 uses a second measure of centrality, namely betweenness centrality, which captures the extent

to which a node is important in linking other nodes in the network. Here, betweenness is not significant,

meaning that acting as a bridge for other industries does not have any direct effect on productivity, even

though some moderating effects are detected. This suggests that while having many connections matters for

productivity, being a bridge for other industries does not.

Table 2: GVC strength centrality

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[9] For the purpose of this study, we use the terms imports and exports in a more broad way beyond their conventional understanding, as, in our analysis, transactions also include exchanges between industries within the same country.

Dep. Variable:	(1) TFP	(2) TFP	(3) TFP	(4) TFP	(5) TFP	(6) TFP	(7) TFP	(8) TFP
GVC-strength	0.132***	0.0711***	0.156***	0.141***	0.0364	-0.0474	0.132***	0.151***
	(0.0242)	(0.0261)	(0.0238)	(0.0251)	(0.0280)	(0.0343)	(0.0255)	(0.0282)
Software & databases	0.0243***	-0.123***						
	(0.00922)	(0.0272)						
R&D			0.0204***	-0.0344				
			(0.00515)	(0.0292)				
Economic competencies					0.158***	0.0273		
					(0.0215)	(0.0380)		
Design							0.0277**	0.0740**
							(0.0112)	(0.0304)
Software & databases*GVC		0.0163***						
		(0.00285)						
R&D*GVC				0.00553*				
				(0.00290)				
Economic competencies*GVC						0.0149***		
						(0.00359)		
Design*GVC								-0.00510
								(0.00311)
Imports	0.148**	0.234***	0.172**	0.193***	0.188***	0.260***	0.136*	0.109
	(0.0695)	(0.0703)	(0.0700)	(0.0708)	(0.0699)	(0.0716)	(0.0726)	(0.0744)
Financial development	0.0144**	0.0181***	0.00771	0.00929	0.0117*	0.0145**	0.0161**	0.0158**
	(0.00660)	(0.00656)	(0.00700)	(0.00704)	(0.00662)	(0.00662)	(0.00681)	(0.00681)
Corporate income tax	-0.0825*	-0.104**	-0.118**	-0.125***	-0.0793*	-0.101**	-0.0871*	-0.0790*
	(0.0433)	(0.0430)	(0.0471)	(0.0472)	(0.0431)	(0.0431)	(0.0450)	(0.0452)
Education	0.164***	0.181***	0.246***	0.252***	0.145***	0.153***	0.158***	0.151***
	(0.0383)	(0.0380)	(0.0403)	(0.0404)	(0.0377)	(0.0376)	(0.0390)	(0.0392)
Constant	-3.247***	-3.072***	-3.722***	-3.667***	-3.181***	-2.724***	-3.169***	-3.234***
	(0.380)	(0.377)	(0.404)	(0.404)	(0.378)	(0.391)	(0.393)	(0.395)
Year dummies (joint significance)	25.91***	22.48***	24.09***	22.43***	22.43***	24.14***	24.27***	24.21***
Observations	1559	1559	1390	1390	1567	1567	1521	1521

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Backward GVC integration

Dep. Variable:	(1) TFP	(2) TFP	(3) TFP	(4) TFP	(5) TFP	(6) TFP	(7) TFP	(8) TFP
Backward integration	0.0858***	0.0287	0.113***	0.0941***	-0.0462	-0.118***	0.0779***	0.0927***
	(0.0252)	(0.0271)	(0.0251)	(0.0263)	(0.0292)	(0.0350)	(0.0266)	(0.0294)
Software & databases	0.0288***	-0.0966***						
	(0.00926)	(0.0250)						
R&D			0.0203***	-0.0432				
			(0.00520)	(0.0267)				
Economic competencies					0.192***	0.0890**		
					(0.0216)	(0.0354)		
Design							0.0358***	0.0667**
							(0.0112)	(0.0284)
Software & databases*GVC		0.0151***						
		(0.00280)						
R&D*GVC				0.00696**				
				(0.00287)				
Economic competencies*GVC						0.0129***		
						(0.00351)		
Design*GVC								-0.00371
								(0.00314)
Imports	0.167**	0.246***	0.191***	0.217***	0.213***	0.275***	0.161**	0.141*
	(0.0698)	(0.0707)	(0.0706)	(0.0713)	(0.0696)	(0.0714)	(0.0729)	(0.0748)
Financial development	0.0155**	0.0190***	0.00903	0.0110	0.0117*	0.0142**	0.0176**	0.0173**
	(0.00664)	(0.00661)	(0.00705)	(0.00709)	(0.00662)	(0.00662)	(0.00685)	(0.00685)
Corporate income tax	-0.0805*	-0.104**	-0.121**	-0.132***	-0.0882**	-0.109**	-0.0879*	-0.0813*
	(0.0437)	(0.0435)	(0.0477)	(0.0478)	(0.0432)	(0.0434)	(0.0455)	(0.0458)
Education	0.168***	0.183***	0.248***	0.254***	0.151***	0.158***	0.162***	0.158***
	(0.0386)	(0.0383)	(0.0407)	(0.0407)	(0.0378)	(0.0377)	(0.0394)	(0.0396)
Constant	-2.852***	-2.707***	-3.285***	-3.219***	-2.701***	-2.359***	-2.733***	-2.776***
	(0.382)	(0.379)	(0.406)	(0.406)	(0.377)	(0.387)	(0.395)	(0.397)
Year dummies (joint significance)	27.29***	24.20***	25.55***	23.74***	30.25***	27.27***	25.95***	25.67***
Observations	1559	1559	1390	1390	1567	1567	1521	1521

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Forward GVC integration

Dep. Variable:	(1) TFP	(2) TFP	(3) TFP	(4) TFP	(5) TFP	(6) TFP	(7) TFP	(8) TFP
Forward integration	0.116*** (0.0204)	0.0542** (0.0227)	0.131*** (0.0204)	0.117*** (0.0218)	0.0506** (0.0228)	-0.0421 (0.0304)	0.115*** (0.0215)	0.136*** (0.0244)
Software & databases	0.0250*** (0.00916)	-0.115*** (0.0250)						
R&D			0.0197*** (0.00515)	-0.0268 (0.0261)				
Economic competencies					0.151*** (0.0206)	0.0200 (0.0353)		
Design							0.0280** (0.0111)	0.0748*** (0.0276)
Software & databases*GVC		0.0169*** (0.00282)						
R&D*GVC				0.00504* (0.00277)				
Economic competencies*GVC						0.0163*** (0.00358)		
Design*GVC								-0.00557* (0.00301)
Imports	0.148** (0.0694)	0.239*** (0.0702)	0.175** (0.0700)	0.194*** (0.0707)	0.181*** (0.0697)	0.260*** (0.0713)	0.137* (0.0725)	0.108 (0.0741)
Financial development	0.0141** (0.00660)	0.0179*** (0.00655)	0.00758 (0.00700)	0.00904 (0.00704)	0.0114* (0.00661)	0.0146** (0.00660)	0.0158** (0.00681)	0.0154** (0.00681)
Corporate income tax	-0.0956** (0.0433)	-0.113*** (0.0428)	-0.128*** (0.0471)	-0.133*** (0.0471)	-0.0834* (0.0430)	-0.105** (0.0429)	-0.0999** (0.0449)	-0.0918** (0.0451)
Education	0.166*** (0.0382)	0.183*** (0.0379)	0.250*** (0.0403)	0.257*** (0.0404)	0.144*** (0.0377)	0.153*** (0.0375)	0.161*** (0.0390)	0.154*** (0.0391)
Constant	-2.985*** (0.355)	-2.881*** (0.351)	-3.385*** (0.381)	-3.353*** (0.381)	-3.207*** (0.354)	-2.767*** (0.365)	-2.905*** (0.367)	-2.957*** (0.368)
Year dummies (joint significance)	30.23***	25.13***	28.92***	26.40***	29.43***	25.64***	28.54***	28.28***
Observations	1559	1559	1390	1390	1567	1567	1521	1521

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: GVC betweenness centrality

Dep. Variable:	(1) TFP	(2) TFP	(3) TFP	(4) TFP	(5) TFP	(6) TFP	(7) TFP	(8) TFP
GVC-Betweenness	-0.00185	0.00218	-0.00285	-0.00739	-0.00433	-0.000569	-0.00320	-0.00871
	(0.00391)	(0.00700)	(0.00428)	(0.00626)	(0.00383)	(0.0110)	(0.00405)	(0.00652)
Software & databases	0.0360***	0.0430***						
	(0.00928)	(0.0137)						
R&D			0.0170***	0.00599				
			(0.00538)	(0.0123)				
Economic competencies					0.169***	0.174***		
					(0.0185)	(0.0221)		
Design							0.0445***	0.0355***
							(0.0108)	(0.0136)
Software & databases*GVC		-0.00115						
		(0.00166)						
R&D*GVC				0.00172				
				(0.00173)				
Economic competencies*GVC						-0.000748		
						(0.00205)		
Design*GVC								0.00168
								(0.00156)
Imports	0.180**	0.181**	0.215***	0.211***	0.197***	0.197***	0.184**	0.184**
	(0.0715)	(0.0715)	(0.0724)	(0.0725)	(0.0701)	(0.0701)	(0.0737)	(0.0737)
Financial development	0.0135*	0.0138**	0.00699	0.00687	0.00789	0.00795	0.0149**	0.0150**
	(0.00702)	(0.00704)	(0.00752)	(0.00752)	(0.00690)	(0.00691)	(0.00714)	(0.00714)
Corporate income tax	-0.0680	-0.0659	-0.114**	-0.116**	-0.0605	-0.0596	-0.0822*	-0.0846*
	(0.0455)	(0.0456)	(0.0494)	(0.0494)	(0.0444)	(0.0445)	(0.0468)	(0.0468)
Education	0.183***	0.183***	0.268***	0.271***	0.149***	0.150***	0.180***	0.178***
	(0.0398)	(0.0398)	(0.0420)	(0.0421)	(0.0390)	(0.0390)	(0.0405)	(0.0405)
Constant	-2.251***	-2.283***	-2.421***	-2.387***	-2.974***	-3.000***	-2.219***	-2.178***
	(0.342)	(0.346)	(0.362)	(0.364)	(0.347)	(0.354)	(0.352)	(0.354)
Year dummies (joint significance)	56.35***	56.36***	66.86***	66.67***	40.29***	40.27***	52.82***	52.29***
Observations	1495	1495	1337	1337	1500	1500	1454	1454

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Finally, for robustness purposes, we estimate our model with the GMM estimator of Arellano and Bond (1991). We do this mainly to overcome the possible remaining endogeneity in the intangible inputs considered in our model. The output, presented in Table 6, confirms the results previously obtained, with three out of four intangibles that moderate the relation between GVC and productivity.

Table 6: GMM estimates

Dep. Variable:	(1) TFP	(2) TFP	(3) TFP	(4) TFP	(5) TFP	(6) TFP
GVC-strength	0.538***	0.351***	0.540***	0.420***	0.552***	0.503***
	(0.0585)	(0.0840)	(0.0629)	(0.0787)	(0.0587)	(0.0878)
Software & databases	0.0471*	-0.148**				
	(0.0257)	(0.0724)				
RandD			0.0434**	-0.161**		
			(0.0190)	(0.0801)		
Design					0.0198	0.0141
					(0.0337)	(0.101)
Software & databases*GVC		0.0219***				
		(0.00837)				
RandD*GVC				0.0199**		
				(0.00853)		
Design*GVC						0.00174
						(0.0104)
Education	0.531***	0.477**	0.578***	0.614***	0.457***	0.509***
	(0.161)	(0.192)	(0.177)	(0.157)	(0.127)	(0.150)
Imports	0.0398	0.0501	0.0161	-0.0265	-0.0935	-0.0803
	(0.0549)	(0.0526)	(0.0638)	(0.0592)	(0.0620)	(0.0651)
Financial development	-0.0443**	-0.0133	-0.0479**	-0.0198	-0.0166**	-0.0198**
	(0.0186)	(0.00970)	(0.0198)	(0.0137)	(0.00781)	(0.00825)
Corporate income tax	0.414***	0.337***	0.315**	0.331**	0.319***	0.250**
	(0.118)	(0.106)	(0.156)	(0.139)	(0.0989)	(0.0972)
Observations	1357	1357	1219	1219	1317	1317

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5. Concluding remarks

This deliverable highlighted the combined impact of GVC and intangible capital on productivity. Using industry level data and a panel of 14 countries observed from 2000 to 2014, network-based indicators are constructed to measure GVC participation, while intangible capital effects are evaluated using investment data on four categories of intangibles.

Positive effects are found both for all types of intangibles considered and for GVC measures. Furthermore, the results demonstrated the moderating role of intangibles in the relationship between GVC and productivity. From the GVC side, both backward and forward integration measures are found to be

significantly effective in enhancing productivity, meaning that participating to GVC is beneficial both when receiving and when providing intermediates from and to others. This confirms the theory according to which it is beneficial for industries and countries to specialize on specific portions of the production chain, relying on trade for those portions on which they are not specialized. From the intangibles side, software, R&D, design and economic competencies are all found to positively drive productivity. However, significant differences are found when considering interactions, with design that is found to be the only intangible type whose combined effect is not significant.

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