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Investment dynamics in Europe: Distinct drivers and barriers for investing in intangible versus tangible assets?

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ABSTRACT

In this paper, we look at the determinants of investment in intangible assets in Europe and explore whether their drivers and barriers are the same as for tangible assets. Our assessment suggests that tangible and intangible assets indeed appear to be affected somewhat differently by some of the tested key determinants. For instance, the regulatory framework seems to be more relevant for investment in intangibles while financial conditions, and in particular the availability of external funding, appear to be more relevant for tangible investment. Moreover, some evidence of complementarities between investments across different asset types suggests that a barrier to investment relevant for one asset type may indirectly impede investment in other assets too as there are synergies among different asset types, notably between tangible and intangible assets but also between different types of intangible assets.

1. Introduction

Since the onset of the global economic and financial crisis, the EU has been experiencing relatively low levels of investment. Despite signs of a moderate turnaround since 2014, the investment recovery remains fragile. Accordingly, across Europe, remarkable endeavours are being made to stimulate investment, notably to unlock drivers and to address barriers preventing investment from reaching a socio-economically optimal level (European Commission, 2018).

To the extent that low investment is observed even among some of the most successful sectors and firms, it is difficult to argue that it is mainly driven by a constraint limiting capital accumulation. Instead, it appears that we either struggle to capture investment well - i.e. for some reason underestimate total investment[1] - or faced with pertinent barriers holding back their investment decisions firms may have deliberately chosen a lower level of investment. Resolving these questions is important for policy making. In fact, if the explanation for an overall sluggish investment in Europe arises from a temporary phenomenon, for instance due to credit rationing in times of crisis, the policy implications would be quite different than in case of a systematic change in the capital allocation choices made by firms (Crouzet and Eberly, 2018).

Zooming into investment figures per asset type reveals some interesting patterns (see Graph 1). While investment in tangible assets dropped during the financial crisis and remained flat thereafter (at least in the EU28), evidence points to a rapid expansion of investment in intangible assets.[2] Over the last 20 years, growth in 'intellectual property products' alone (which refers to the intan-

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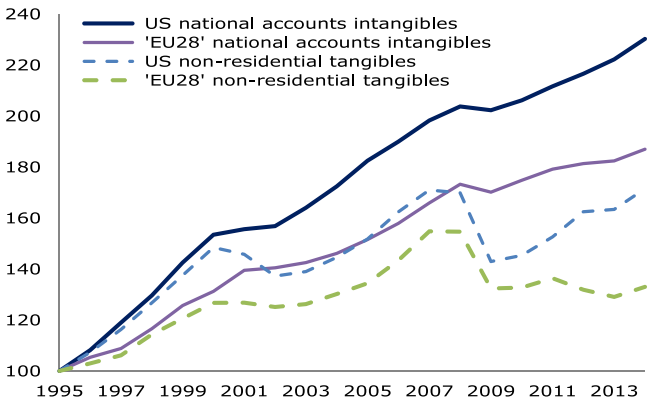
[1] This view relates to a debate on what is perceived to constitute a capital asset (i.e. investment) and what is seen as (intermediate) consumption (i.e. expenditure).
[2] Intangible assets do not have a physical embodiment. In the literature, they are (synonymously) also termed 'intellectual assets', 'knowledge assets', 'knowledge based capital' or 'intellectual capital'.



Graph 1. Non-residential investments in intangible and tangible assets, EU-28 vs. US, 2014, Index: 1995 = 100.
Source: Eurostat, Bureau of Economic Analysis (BEA).

gible assets accounted for as investment in the National Accounts; according to SNA ESA 2010) has outpaced growth in tangible investment in the euro area (ECB, 2018) and, similarly, in OECD countries (OECD, 2018).

While this observation suggests a changing pattern in capital allocation from tangible towards intangible assets, it does not seem to square with the recently observed sluggish investment volumes in aggregated terms. To account for this puzzle, this paper aims at analysing investment dynamics in Europe with a particular emphasis on distinguishing tangible vs. intangible assets and, building on the literature on determinants of investment, the respective drivers and barriers specific for investing in such assets. Based on a dataset providing various measures of intangible assets as defined in Corrado et al. (2005), we re-estimate investment regressions that previous studies had estimated for aggregate investment figures as recorded by the National Accounts. Relevant determinants are tested both jointly and separately in order to unveil systematic differences across asset types. We are especially interested in how to potentially unlock investment in intangible assets, which raise academic attention (see for example Corrado et al., 2012, 2014, 2016, 2017 who suggest that intangible assets are a key component of the production function)[3] and spur the policy debate (Thum-Thysen et al., 2017a, 2017b) due to their potential to foster economic growth and boost productivity (European Commission, 2014). We thus complement the compelling literature looking at investment in general or specifically at tangible assets.

2. What determines investment in intangible assets?

Throughout this paper we consider intangible assets to include the intangible assets captured in the System of National Accounts (labelled 'NA-intangibles') and, by assuming an extended asset boundary according to Corrado et al. (2005, 2009), also further intangibles (labelled 'non-NA-intangibles') (see Table 1). Much of the focus on intangibles has been on R&D and ICT. Nevertheless, the range of intangible assets is indeed considerably broader. According to Corrado et al. (2005, 2009), conceptually, business sector intangibles include investment in training of own staff as well as spending on R&D, spending on market development, organisational and also management efficiency. Taking this broader view and going beyond the SNA2008/ESA2010 standards is in line with the view of many in the business community who attribute fundamental aspects of corporate success to spending on acquired goods or services such as e.g. marketing, design and business process re-organisation. For this paper, we follow this broader view and consider also spending on 'economic competencies', 'new product development' and 'new architectural and engineering designs' as investment in intangible capital. In this paper we are interested in the determinants of intangibles as compared to tangibles; and in the determinants of what is currently considered as investment ('NA-intangibles') compared to what could be considered as investment under a broader view ('non-NA-intangibles').

The remainder of the paper is structured in five sections: Section 2 provides considerations on potential determinants of investing in tangibles and intangibles. An empirical analysis (at macroeconomic level) is described in Section 3 and the corresponding results and related conclusions are presented in Sections 4 and 5, respectively.

There is a vast theoretical and empirical literature on the possible drivers for and barriers to investment, which will be discussed below. To identify the main determinants of investment in Europe, the European Investment Bank (EIB, 2016) brings together lessons from this literature with 'on the ground' evidence from financed investment projects and identifies six categories of determinants: regulation/administrative burdens, market size and structure[4], public-sector constraints,[5] access to finance,[6] institutional environment,[7] and macroeconomic conditions[8] . While those categories are likely to be relevant for investment, we believe that an important category, namely 'human capital', is missing. In fact, the lack of relevant skills is often perceived as a significant barrier to investment as a recent firm-level survey by the EIB (2018) shows. Based on the literature and the EIB's (2016) classification[9] this Section will discuss evidence on potential determinants, with a view at how they could be particularly relevant for investment in intangible assets, along the following categories: (1) **macro-economic conditions**, (2) **the regulatory framework**, (3) **public intervention other than the regulatory framework**, (4) **financial conditions** and (5) **human capital**. Human capital is related to a further determining factor, namely complementarities between different types of capital.

Some of these determinants may be associated in a specific way to intangible assets (see e.g. Andrews and de Serres, 2012; Cassiman and Veugelers, 2006; Haskel and Westlake, 2017 or Thum-Thysen et al., 2017a, 2017b). Haskel and Westlake (2017) for instance group features that could be specific for intangibles under "four S's", namely: 'scalability'[10], 'sunkenness'[11], 'spillovers'[12], and 'synergies'.[13] Some of these characteristics of intangible assets

[3] A large body of literature points in the same direction such as Jorgenson and Stiroh (2000); Oliner and Sichel (2000); Corrado et al. (2009); Roth and Thum (2013); van Ark (2015); Haskel and Westlake (2017).

[4] In particular factors influencing the potential demand for a good or service, including the extent of competition on the market.

[5] Such as the institutional capacity of public-sector promoters to procure and implement a large infrastructure project.

[6] I.e. factors influencing the ability of businesses to obtain financial services, such as credit or insurance.

[7] Such as properties of the legal system, protection of property rights in legislation or prevalence of crime.

[8] Including a country's fiscal and monetary policies and their predictability.

[9] We grouped "regulation" and "institutional environment" under "regulatory framework"; we included "market size and structure" under "macro-economic conditions" – in both cases to reduce overlap; and we renamed "access to finance" to "financial conditions" and "public-sector constraints" to "other forms of public intervention" – in both cases to broaden the scope of the category.

[10] A 'non-rival good' can be used several users at the same time. The authors express this 'non-rivalry' as 'scalability'.

[11] Trying to get back the investment's cost by selling the created asset tends to be harder if the investment is an intangible than and this can be referred to as 'sunk costs' or 'non-separability' (see for instance Webster and Jensen, 2006).

[12] 'Spill-overs' can occur due to an exchange of ideas (see for instance Romer, 1990).

[13] 'Synergies' can occur for instance through complementarities between asset types (see for instance Autor et al., 2000).

Table 1
Types of intangible assets.

Broad category of intangible assets	Type of intangible assets included	Remark	captured in SNA (ESA 2010)
COMPUTERISED INFORMATION	• Software	includes knowledge embedded in computer programmes and computerised databases	√
	• Databases		√
INNOVATIVE PROPERTY	• R&D	scientific knowledge embedded in patents, licenses and general know-how (scientific R&D); artistic content of commercial copyrights, licenses and designs (incl. new motion picture films and other forms of entertainment)	√
	• Mineral explorations		√
	• Copyright and creative assets		√
	• New product development in financial services		–
	• New architectural and engineering designs		–
ECONOMIC COMPETENCIES	• Brand-building advertisement	value of brand names and other knowledge embedded in firm-specific human and structural resources; expenditures on advertising, market research, firm-specific human capital and organisational change	–
	• Market research		–
	• Training of staff		–
	• Management consulting		–
	• Own organisational investment		–

Source: adapted from Corrado et al. (2005)

may imply market failures and consequently under-investment in intangible assets in particular. Beyond market failures, the literature identifies also other failures of systemic nature which could arise from the existence of innovation systems (see for instance Metcalfe, 2005 or Smith, 2000) and be particularly relevant for intangibles. A survey on investment in intangible assets conducted by the European Commission (2013) also provides evidence for investment in intangibles to be driven by particular determinants and finds that relationships with customers and business partners, greater efficiency of internal business processes and larger market shares are the main drivers for investing in intangible assets. Building on this database, Montresor and Vezzani (2016) study the innovative potential of intangibles and conclude that in the services sector the internal development of intangibles is essential (to be fostered e.g. by addressing the lack of internal competences and resources), while in the manufacturing sector the sheer volume of investment in intangibles is crucial (to be stimulated by policy e.g. by creating the right incentives). Moreover, there may also be differences in the role of determinants between investment in 'NA-intangibles' ('computerised information', 'R&D', 'mineral exploration' and 'copyright') and investment in 'non-NA-intangibles' ('economic competencies' and 'new products and designs') (see Table 1).

2.1. Macro-economic conditions

The literature around the accelerator model (Knox, 1970) suggests that changes in economic output lead to changes in a desired capital stock and, hence to investment (see for instance Oliner et al., 1995; Lee and Rabanal, 2010 or IMF, 2015). This relationship between investment and economic output can be explained for instance through the fact that macro-economic characteristics, such as the general level of development (implicitly including the state of technology, but also the degree of digitalisation, relevance of high-tech/knowledge-intensive services, cost-competitiveness etc.) might be a determinant for investment. In addition, macro-economic uncertainty and/or political instability may be detrimental to investment (see for instance Aizenman and Marion, 1993).

As investment in intangible assets is characterised by comparably high inherent risk, they may be particularly affected more by macro-economic (demand) uncertainty. For instance, Bontempi (2016) shows on Italian firm-level data that macro-economic (especially demand) uncertainty may delay investment in R&D. On the other hand, cyclical macro-economic conditions may affect investment in intangible assets less than investment in tangible assets since the observed general upswing in intangible investment tends to result from a structural shift towards knowledge economy rather than from cyclical fluctuations (see Graph 1). The typically rather long lags between kicking off an investment project and associated returns could also imply that short-term cyclical fluctuations matter less.

Another macro-economic condition possibly affecting investment intangibles more strongly than investment in tangibles could be the sectoral composition of an economy. However, evidence on whether a more service-oriented economy tends to be more intangible-intense is mixed. While Corrado et al. (2014) show that investment in intangibles has grown more in the services sector, the OECD (2013) shows that in some countries the share of investment in the manufacturing sector is higher with respect to intangibles than tangibles. One reason for this could be that the manufacturing sector involves an increasing volume of services that could indirectly increase the role of intangibles in the sector. Haskel and Westlake (2017) show that the share of intangibles in value added is actually more important than that of tangibles both in manufacturing and in services, and that in both sectors this trend is on the rise. In the manufacturing sector this was the case for the full sample period (1995–2015); in the services sector since the early 2000s.

Given the mixed evidence in terms of economic output and sectoral composition as drivers for investment in particular in intangible assets, we would not expect a strongly significant difference in terms of these determinants across asset types.

2.2. Regulatory framework

Regulations can act as a driver, but administrative burdens can also act as a barrier to investment. Flexible product market regulations can be a driver for efficient resource allocation (see for instance Arnold et al., 2011). Pro-competitive product market reforms can also foster knowledge diffusion, as recent empirical (firm-level) evidence suggests (OECD, 2016). The growing productivity gap between technological leaders (frontier-setters) and laggard firms in many industrialised countries may be driven by the difficulties being experienced by the latter in transiting to the economy of ideas. This can also be due to the fact that incumbents are sheltered from competition. In this respect, procompetitive product market reforms can be expected to raise incentives for incumbent firms to adopt new technologies due to the entrance of new firms in the market (thus triggering both investments in tangible and intangible assets). Competition on the product markets can also create incentives to improve management, technical and economic efficiency, thus increasing investment in organisational capital (see Andrews and de Serres, 2012).The negative relationship between stringent product market regulations and investment is supported by a large body of macro-, sectoral- and firm-level studies (see for instance Egert, 2017; Kerdrain et al., 2010; Alesina et al., 2005; Araújo, 2011 or Griffith and Harrison, 2004).

With regards to labour market regulation, the picture appears more heterogeneous, with some authors not finding clear effects at macro-economic level (Kerdrain et al., 2010) and mixed evidence at the firm and sectoral level (Autor et al., 2007; Cette et al., 2016; Cingano et al., 2010, 2015). With a view at capital markets, progress towards a European capital market union can facilitate both a swift channelling of resources towards the most productive investment and the scale-up of companies also through freeing up resources to invest cross border in more profitable and riskier projects (Valiante, 2016). Arguably, a fragmented regulation across capital markets can increase the cost of investment by demanding firms to comply with several sets of regulatory requirements across different jurisdictions. Earlier studies examining the effects of financial regulations on investment, without differentiating between tangible and intangible, find positive or weak positive effects of stock market capitalisation and private credit to GDP (Bassanini et al., 2001; Pelgrin et al., 2002, Lim 2014).

The literature also provides evidence that the relationship between flexible regulation and investment may be non-linear: some product market regulations provide innovators with incentives to invest by ensuring high *ex post* rents (see e.g. Aghion et al., 2005, who also provide evidence of an inverted U-shaped relationship between competition and innovation). Similarly, some forms of employment protection may increase investment. In other words, firms have greater incentives to invest in training if workers are less likely to leave subsequently (see e.g. Aghion et al., 2005).

While the regulatory framework is important for all types of investment, it is arguably more so for intangibles. Firstly, the greater uncertainty of the return on investment to intangible assets (as compared to tangible assets), partly due to risk of imitation as an effect of limited appropriability and partial excludability of knowledge, means that commercialising an idea for a new product may require swift deployment of resources (Andrews and de Serres, 2012; Hao and Haskel, 2011). Changes over time in regulation or in the way regulation is enforced may generate regulatory uncertainty for investors, thereby increasing the (perceived) risk that costs and benefits of investing may also change over time. Secondly, regulations for flexible product and labour markets can help to create favourable conditions for fostering profitmaking, which can enhance the availability of internal sources of financing. Based on an empirical analyses of 32 countries and 30 industries (1990–2014), the OECD (2018) suggests indeed that, due to a lack of collateral and stronger asymmetry of information, investment in intangibles is financed more often through internal than external sources.

Overall, we would expect a significant difference in terms of the role of the regulatory framework across asset types.

2.3. Other forms of public intervention

Government intervention can mitigate market failures by lowering the risks and associated costs a company faces directly through grants and public investment or indirectly through tax incentives. Governments can also stimulate investment in R&D by helping firms to access finance (e.g. through direct loans, loan guarantees, state-backed venture capital or public procurement). Becker (2014) supports this view by suggesting to support R&D cooperation stimulates private R&D, such as direct/indirect support for business R&D, investment in university research and high-skilled human capital, although results differ in some cases. This ambiguity is partly attributable to the large array of policy instruments used to provide public support (Aristei et al., 2015) and their individual effectiveness, which in turn depends on many factors, including design and implementation, appropriate targeting and complementarity between instruments. For instance, many EU Member States use their tax system to stimulate investment in R&D and training. Such indirect instruments (e.g. tax credits), depending on their design, administration and implementation, can be effective in stimulating investment in intangibles (Criscuolo et al., 2016).

Public intervention may be particularly important in terms of intangible assets as specific characteristics of intangible assets may lead to market and system failures (including the failure of capital markets to properly assess risks, costs and benefits) and consequently under-investment in intangible assets. Intangibles tend to be non-rival, which may generate increasing returns to scale and may ultimately lead to quasi-monopolistic positions (Andrews and de Serres, 2012) and positive network externalities[14] can reinforce this phenomenon. Lev (2001) discusses comprehensively spill-overs arising from intangibles. Crouzet and Eberly (2018) argue indeed that specific characteristics of intangibles may have enabled the rise in industry concentration observed over the last two decades and point out that intangibles are associated with at least two drivers of rising concentration: market power and productivity gains.

Hence, from a theoretical point of view, public intervention may be presumably more relevant with a view at investment decisions concerning intangible than tangible assets.

2.4. Financial conditions

Financial conditions, such as interest rates, debt-to-equity ratio and leverage of the banking sector, are arguably important drivers of investment. The individual cost of financing is naturally a key determinant of investment decisions; irrespective of the asset type to be invested in. For investment that involves the participation of both the public and private sectors, the availability of financial instruments, mechanisms and policies that allocate appropriately risks to each of the parties is key in making private participation viable. The availability of external finance also influences a firm's choices on whether to bear the costs necessary to enter into new

[14] Positive network externalities arise when the value of a good or service increases with the number of users (e.g. subscribers to social networks). This may lead to a winner-takes-all outcome, i.e. network effects can lead to cases of natural monopoly or create high barriers to entry, i.e. limiting competition in areas where competitive pressures might raise efficiency.

markets, thereby shaping the level of competition and incentives to invest (EIB, 2016).

While this applies to investments both in tangible and intangible assets, the higher uncertainty and lower appropriability, excludability, separability, verifiability and transferability – or "sunkenness" according to Haskel and Westlake (2017) as described above – of intangibles may specifically affect the capacity to secure the necessary funding resources. In fact, as mentioned above, investment in intangibles is financed more often through internal than external sources (OECD, 2018). Moreover, uncertainty on return to investment is likely to be higher for intangibles due to their often exploratory nature than for tangibles, which are more conducive to replication through standard routines (Hunter et al., 2005). Intangible assets are difficult to use as collateral because of their specific features such as limited separability and transferability (Webster and Jensen, 2006; Hotchkiss et al., 2008; Gilson et al., 1990). In fact, investing firms frequently point to a lack of tangible collateral as an obstacle to accessing credit markets (see e.g. Montresor and Vezzani, 2014) and this holds even more so if the envisaged investment should be intangible. Apart from the fact that intangibles may serve only to some extent as collateral, also the mechanisms for disclosing information on intangible assets in corporate reporting appear to be a barrier for investment in intangibles and could arguably be improved through narrative reporting,[15] as proposed e.g. by Andrews and de Serres (2012) and OECD (2012). In this regard, Hochberg et al. (2018) highlight that patents are increasingly pledged to secure financing. This argument is consistent with previous evidence suggesting that the market value of a firm tends to be increasingly driven by its productive stock of intangibles rather than by the firm's tangible assets as the link between market and book value of a company has increasingly decoupled over the recent decades (Lev and Gu, 2016).

Overall, given the discussed evidence, we would expect a significant difference in the role of financial conditions as a determinant of investment across asset types.

2.5. Human capital and complementarities between different types of capital

The availability of human capital is also found to be a determinant of investment and complementarities between human and other types of capital have been frequently emphasised.[16] High stocks of human capital stimulate absorptive capacity, tend to fuel new ideas and thus trigger investments and create spill-overs. Acemoglu (1996), for example, shows that firms are willing to invest more in physical capital if the workforce is raising its education and skills levels. Lucas (1990) argues that lower stocks of human capital restrict capital inflow in poor countries. Barro (1991) suggests that if human capital has positive spillover effects (as hypothesised e.g. in Lucas, 1988), upskilling will lead to higher rates of investment, both in human and in physical capital, and, as a result, to higher per capita growth. Finally, the availability of human capital can be seen as a major driver of business investment (EIB, 2018).

Human capital may be particularly important for investment in intangible assets. High levels of skills such as tertiary, technical, cross-cutting transversal (including for example creativity) but also socio-behavioural (such as managerial skills) are found to be a pre-requisite for successfully investing in most intangible assets (Abramovitz and David, 2000; Galor and Moav, 2004). The variety of intangible assets indeed calls for a diverse set of skills. For R&D, in particular, achieving a critical mass in terms of specific knowledge and skills accumulation is fundamental and a strong science and knowledge base is needed to allow corporate R&D investment to 'build on the shoulders of giants' (Caballero and Jaffe, 1993). Moreover, as Haskel and Westlake (2017) argue, synergies (for instance with human capital) may be particularly important when it comes to intangible assets. In fact, in terms of synergies across intangible assets as defined in Corrado et al., 2005, some investment can be productive only if the appropriate complementary assets exist such as ICT hardware, software and training of staff (Haskel and Westlake, 2017; Goldin and Katz, 1998). Accordingly, factors hindering investment in one type of assets may affect the probability to invest in and the productivity of complementary assets. For studies of complementarities between tangible and intangible assets types, and the corresponding importance for policy making see e.g. Autor et al. (2000); Brynjolfsson and Hitt (2000, 2003), Black and Lynch (2001); Brynjolfsson et al. (2002); Polder et al. (2010); Pastor-Augustin et al. (2011); Crass and Peters (2014); Hosono et al. (2016); Belitz et al. (2017); Corrado et al.(2017); Mohnen et al. (2018), and Goodridge et al. (2019, *forthcoming*).

Overall, we would expect human capital to matter most for investment in intangibles, and potentially in particular investment in R&D if human capital is measured through educational attainment.

3. Empirical analysis

In this section, we discuss our empirical approach to estimate the relationships between investments in tangible and intangible assets on the one hand and a set of its potential drivers and barriers on the other hand. We are particularly interested in detecting differences in the role of these barriers and drivers across assets (both between tangibles and intangibles and between NA-intangibles and non-NA- intangibles). In the previous Section we discussed determinants of investment along five categories, in particular in view of how they could affect in particular investment in intangible assets. For the empirical analysis we choose – based on data availability - several relevant proxy variables per category. As we discussed in Section 2, complementarities between different asset types are also relevant for determining investment and we will provide some exploratory evidence on this issue.

In the remainder of this Section we first discuss the data and definitions of variables due to be tested (Section 3.1) and then turn to the estimation methodology (Section 3.2). For further details of the variables used, see Table A1 in Supplementary material.

3.1. Data and variable definition

For our analysis, we use data for investment in intangible and tangible assets, capital stocks and proxies for the potential drivers and barriers identified in the previous section. The remainder of this section discusses these variables one by one. Descriptive statistics are shown in Table A1 in Supplementary material, while Figs. A1–A3 in Supplementary material illustrate the distribution of key variables across countries and over time.

3.1.1. Investment and capital stocks

We use investment and capital stock data for tangibles, NA-intangibles and non-NA-intangibles. The data for intangible investment and stocks stems from experimental academic data

[15] Narrative reporting is a descriptive section in the annual reports (documents reporting on companies' activities throughout the preceding year) that uses non-financial information to give a picture of a firm's business, market position, strategy, performance and future prospects.

[16] Note that, following Corrado et al., 2005, spending on training of own staff and to some extent also on accumulated tacit knowledge within a company is considered here as investment in intangible assets (see Table 1), but human capital as such is commonly not capitalized. For a discussion of where to draw a line when defining intangible assets see, for instance, Thum-Thysen et al., 2017a and 2017b.

elaborated by the INTAN-invest network[17] (see Corrado et al., 2012). The INTAN-invest database is a harmonised (open access) database on macro-economic intangibles across a selection of countries, which complements and updates the work done by two earlier EU-funded research projects (INNODRIVE and COINVEST). Similar to the data provided by the EUKLEMS network, the INTAN-Invest dataset is also produced by a scientific consortium rather than by statistical institutes. However, where possible, the methodology used in the National Accounts is applied. INTAN-Invest data, generally, is based on an extension of the asset boundary to include non-NA-intangibles as investment rather than intermediate consumption in production statistics. The database covers the NACE-coded business sectors A-N, R, S[18] excluding the real estate sector L and provides data for 1995–2013 and the EU-15 Member States.[19] Previous applications of this dataset include work by Corrado et al. (2012, 2014, and 2016) or e.g. Iona-Lasinio et al. (2011).

Investment in tangible capital was taken from the Eurostat National Accounts database, converted into a Euro chain-linked series with base year 2010. To be consistent with the data for intangibles stemming from the INTAN-Invest database, our GVA data capture the equivalent sectors discussed above. Investment in NA-intangibles and non-NA-intangibles in current prices and national currency was taken from the INTAN-invest database, converted into Euros by using exchange rates available from Eurostat and deflated by means of a GVA deflator computed based on GVA in current and previous year prices (also taken from Eurostat).

We also use a measure for the total capital stock, composed of tangible, NA-intangible and non-NA-intangible capital. Tangible capital and NA-intangible capital stocks were taken from the Eurostat National Accounts database in Euros and chain-linked with base year 2010.[20] Chain-linked non-NA-intangible capital stocks were taken from the INTAN-Invest database[21] and converted into Euros by using exchange rates available from Eurostat.

3.1.2. Macro-economic conditions

The macro-economic conditions for investment are proxied by Gross Value Added (GVA) over the lagged capital stock. Note that GVA needs to be adjusted for the fact that non-NA-intangibles are counted as investment rather than as intermediate consumption. Such adjusted data is available in the INTAN-Invest database in current prices and national currency. We followed the same procedure as outlined above, i.e. converted the data based on a GVA deflator and Eurostat's exchange rates.

3.1.3. Regulatory barriers

As indicators for regulatory barriers, we chose widely used indicators for product market- and labour market- regulation. On the product market side, we use the economy-wide OECD's Product Market Regulation index as described in Koske et al. (2015). These indicators are available every five years between 1998 and 2013. We linearly interpolated and extrapolated to obtain values for the missing years. These indicators measure the barriers for entry and could therefore proxy barriers for investment. Another set of commonly used indicators for product market regulation are the World Bank's Ëase of Doing Businessïndicators. These indicators approximate the respective quality of the business environment. An enabling business environment may indeed encourage investment in certain types of assets. As a proxy for labour market regulations, we use an indicator constructed by the OECD on employment protection legislation (EPL). The database contains measures of strictness for various scenarios temporary contracts, permanent contracts, individual and collective dismissals. The latter measures additional administrative costs arising when dismissing more than one worker at a time. This was the indicator turning out to be most significant among the EPL indicators in our regressions.[22] Flexibility of labour markets can play a role for investment decisions as more risky investment may require the possibility to hire or lay-off workers easily.

3.1.4. Public investment

As outlined in the previous section, public investment could be another potential driver for private investment. As a proxy we assume a widely used measure, namely public R&D investment as a percentage of GDP (available on Eurostat). To asses the role played by public-private cooperations, we include (as a proxy) the number of publications by authors whose affiliation information contains both academic and corporate organisation types over the total population.

3.1.5. Financial conditions

Proxies for 'financial conditions' were mainly taken from the OECD's Ffinancial dashboardänd the European Commission's annual macro-economic database AMECO. Arguably, access to finance is a key enabling factor for investment. As outlined above, it is typically rather difficult to use intangible assets as collateral, i.e. corresponding investment tends to be rather financed through internal funds. We use the long-term interest rate, which proxies the conditions to receive funding from the financial market (EIB, 2016). We also took into account the debt-to-equity ratio of financial corporations and the leverage of the banking system (both taken from the OECD's financial dashboard), which provide an alternative indicator for conditions to receive funding from the financial market. To measure the importance of internal funding of the corporate sector, we also consider the gross savings by the corporate sector as a share of Gross Value Added (GVA), taken from AMECO. Other measures of internal funding include the gross operating surplus and leverage of the non-financial sector (again taken from the OECD's financial dashboard).

3.1.6. Human capital

The INTAN-Invest data for intangibles we use includes ffirm-specific trainingäs one type of non-NA assets (see Table 1), which arguably is a component of 'human capital'. However, human capital is certainly broader since it includes all sorts of skills beyond those acquired in firm-specific training and can be seen as the available accumulated knowledge in the workforce (education and experience or learning by doing). As mentioned in Section 2, this form of human capital is neither capitalized in the national accounts

[17] See www.intan-invest.net. Updating the database is based on voluntary cooperation by the academic project partners. The analyses presented in this paper are based on an intermediate update made available to us (in 2017).

[18] Namely agriculture, forestry and fishing (A), mining and quarrying (B), total manufacturing (C), electricity, gas and water supply (D-E), construction (F), wholesale and retail trade, repair of motor vehicles and motorcycles (G), transportation and storage (H), accommodation and food services (I), information and communication (J), financial and insurance activities (K), professional, scientific, technical, administrative and support service activities (M-N) and arts, entertainment, recreation and other service activities (R-S).

[19] Namely AT, BE, DE, DK, EL, ES, FI, FR, IE, IT, LU, NL, PT, SE and the UK.

[20] Note that data on stocks of NA-intangibles were not available in previous year prices in the Eurostat National Accounts database for LU and PT.

[21] As capital stocks were not available in this update, we used the chain-linked stocks in national currency available on www.intan-invest.net and applied the GVA deflator and exchange rate from Eurostat. As these stocks were only available up to 2010 we applied the Perpetual Inventory Method (PIM) following Corrado et al. (2012) to build the stocks until 2013.

[22] Results remain largely robust to when including additionally the strictness of EPL for individual dismisssals on regular contracts (which is non-significant except for the investment regression for tangibles).

nor part of the non-NA investment according to INTAN-Invest. To approximate the availability of human capital not stemming purely from firm-specific trainings, we chose tertiary educational attainment (available from the Labour Force Survey data on Eurostat). Arguably, other skills, such as managerial skills, could also be relevant and it would be interesting to test this. However, they are more difficult to measure. We also check whether on-the-jobs skills mismatch (overqualification and underqualification) is correlated with investment in intangible and tangible assets. This measure was constructed on the basis of data from the Labour Force Survey data available on Eurostat. Economies with inefficient job matching systems may suffer from frictions that could reduce investment in certain assets.

3.2. Methodology

3.2.1. Regression model

To test the potential determinants of intangible and tangible investment empirically, we estimate an investment equation based on an accelerator model as described in IMF (2015), which relates investment in intangible and tangible assets to a series of variables under the broad categories of drivers and barriers, namely: (1) regulatory framework; (2) availability of human capital; (3) other forms of public intervention, and; (4) financial conditions. The main idea of the acceleration principle is that changes in economic output lead to changes in a desired capital stock and, hence, to investment (Knox, 1970).

In our regressions investment in time t and country i, I_{it} (intangible or tangible) is modelled as a function of a desired capital stock K^*_{it}, potentially some lags thereof (to account for a slow adjustment of the capital stock to its desired level) and depreciation δ_i (see Oliner et al., 1995):

$$I_{it} = \sum_{j=0}^{J} \omega_j \Delta K^*_{it-j} + \delta_i K_{it-1} \quad (1)$$

where j indicates the respective number of time lags. Based on the accelerator model, which postulates that changes in the desired capital stock are proportionally related to changes in economic output, we can write:

$$\Delta K^*_{it} = c \Delta Y_{it} \quad (2)$$

Inserting Eq. (2) in (1), dividing equation by K_{it-1}, introducing an error term ε_{it}, a fixed effect γ_i, and lagging the output term by one year to somewhat correct for possible endogeneity issues, altogether yields the following econometric model:

$$\frac{I_{it}}{K_{it-1}} = \gamma_i + \sum_{j=1}^{N} \beta_{1j} \frac{\Delta GVA_{it-j}}{K_{it-1}} + \varepsilon_{it} \quad (3)$$

The model is augmented, firstly, by enlarging the National Accounts' asset boundary to also include non-NA-intangibles (hence these intangibles are treated as Gross Fixed Capital Formation rather than as intermediate consumption) and, secondly, the other potential explanatory factors of investment such discussed above and denoted by DRI_{it-1} (drivers):

$$\frac{I_{it}}{K_{it-1}} = \gamma_i + \sum_{j=1}^{N} \beta_{1j} \frac{\Delta GVA_{it-j}}{K_{it-1}} + \beta_2 DRI_{it-1} + \varepsilon_{it} \quad (4)$$

In this model, the accelerator term $\frac{\Delta GVA_{it-j}}{K_{it-1}}$ captures the macroeconomic conditions.

3.2.2. Estimation

The model is estimated for each asset category separately (all intangibles, NA-intangibles, non-NA-intangibles and tangibles) based on annual data for 13 of the EU-15 Member States[23] over the period 1995–2013. We use a fixed-effect panel estimator with standard errors corrected for heteroscedasticity and intra-group correlation. We chose to use a fixed effects regression model as it controls for time-invarying unobservable factors and avoids strong independence assumptions, which would need to made when using the random effects regression model. In order to control for a sharp downturn related to the Great Recession during the late 2000s and early 2010s which affects the dependent variables (investment ratios) and, more pronouncedly, the accelerator term, we add a control variable in 2009 and an interaction term between this crisis dummy variable and the accelerator term.[24]

IMF (2015) suggests adding a constant in Eq. (1), which would imply including the term $\frac{1}{K_{it-1}}$ in Eq. (4). This specification was tested, but the constant was found to be non-significant when controlling also for the accelerator term. This could point to presence of multicollinearity. Similarly, further lags of the capital stock were included, but, beyond the first lag, no significant results were found. To control for possibly remaining autocorrelation of the residuals, we report errors robust to heteroscedasticity and intra-group correlation as mentioned above.

To select a final set of variables to be included in the model, we estimated the accelerator model described in Eq. (4) for each asset category by: (1) including one significant indicator per barrier or driver category as described in Section 2 simultaneously, and (2) including one additional explanatory variable DRI_{it-1} at a time. This approach was chosen to avoid possible multicollinearity issues. We also test for statistical differences in coefficients across the regressions with simultaneously included indicators. The results of the respective Wald tests are provided in Table 4.

Several potential caveats of the regressions should be mentioned. Firstly, multi-collinearity could be an issue as we expect several high pairwise correlations between the independent variables, which could be exacerbated by the relatively small sample. In particular, interest rates and the accelerator term could be highly correlated. We therefore report uncentered Variance Inflation Factors (VIF)[25], the ratio of variance in a multi-variate model divided by the variance of the model with a single variable. The highest VIF in our regression model including several drivers is below 10, which is somewhat reassuring.

Secondly, in order to somehow address the possible endogeneity of the regressors, we lag our variables. One could also argue that the explanatory variables intervene in the determination of the accelerator term (or desired level of capital) and, therefore, make it less endogeneous. This argumentation could imply the need to estimate the model in a two-step procedure, which may also entail problems. Firstly, it is less efficient as we would insert an estimated variable into the main equation and, secondly, it could be challenging to find instrumental variables that are correlated with the accelerator term while not directly affecting investment. Given these issues, we opted for a single step estimation approach. Nevertheless, given

[23] Note that data for the total capital stocks in the business sector are not available for Luxemburg (in previous year prices) and Portugal and these Member States therefore needed to be dropped from the sample.

[24] Including a full set of time dummies in a regression model with a small sample would cause problems related to over-specification and an insufficient number of degrees of freedom (and the degrees of freedom are effectively even smaller as in a panel dataset the observations are not independent of each other). Over-specification leads to problems such as inflated standard errors for the regression coefficients.

[25] See for instance Belsley et al. (1980).

Table 2
Investment regressions, introducing selected determinants per category (public support, availability of human capital, finance and regulation) by asset type, including determinants simultaneously.

	(1) Total intangibles	(2) NA-intangibles	(3) Non-NA-intangibles	(4) Tangibles
Accelerator term	0.120***	0.0426***	0.0774***	0.264***
	(0.0241)	(0.0113)	(0.0169)	(0.0285)
Tertiary education	0.0730***	0.0378***	0.0352*	0.0811
	(0.0210)	(0.00906)	(0.0162)	(0.0522)
Long-term interest rate	−0.0687**	−0.0164*	−0.0523**	−0.225***
	(0.0276)	(0.00797)	(0.0224)	(0.0272)
Employment protection legislation	−0.638***	−0.599***	−0.0390	−0.225
(strictness of collective dismissals)	(0.169)	(0.174)	(0.239)	(0.289)
Constant	5.572***	2.967***	2.604***	8.175***
	(0.636)	(0.602)	(0.850)	(0.673)
Country FE	yes	yes	yes	yes
Crisis dummy	yes	yes	yes	yes
Interaction crisis dummy & accelerator	yes	yes	yes	yes
Overall R-squared	0.275	0.384	0.221	0.0473
Within R-squared	0.492	0.506	0.373	0.654
Between R-squared	0.258	0.373	0.232	0.0719
Highest VIF, uncentered	9.465	9.465	9.465	9.465
Number of observations	194	194	194	194
Number of countries	13	13	13	13

Notes: Explanatory variables are added in lag-form as described in the main text. All variables are expressed in percentages except EPL, which is expressed on a scale of 0-6. NA-intangibles refer to those intangible asset types that are included in the National Accounts' measure of Gross Fixed Capital Formation (GFCF), namely computerised information and some categories of innovative properties (e.g. mineral exploration, R&D and intellectual property rights). Non-NA-intangibles refer to those intangible asset types that are captured as expenditure or intermediate consumption in the national accounts. We include a time trend in the regression model when it is significant, namely in regression (4).
Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

the caveats mentioned above, we do not claim causality but rather correlation among the variables in the model.

4. Results

Tables 2 and 3, below, present the results from the regression model described in Eq. (4) in Section 3, including a set of representative indicators for the five dimensions discussed in Section 2. In Table 2 results show regressions in which the indicators are included simultaneously and Table 3 shows results for models in which we add each indicator separately to avoid issues arising from multi-collinearity.[26] This allows including other indicators, such as skills mismatch, debt-to-equity ratio, gross savings of the corporate sector, product market regulations as well as governance quality indicators from the World Bank, and public investment in research in the regressions. Other variables were also included such as the indicators for alternative financing (venture capital, gross-operating surplus and surplus-to-debt ratios of non-financial corporations), taxation (corporate income tax rates, implicit tax rates), quality of intellectual property rights (IPR), shares of SMEs and allocative efficiency. However, the latter variables do not seem to be significantly correlated with investment in intangible assets within the fixed effects framework with error terms robust to heteroscedasticity and intra-group correlation. The time horizon might be too short for some of those indicators and for others maybe the cross-country variation could be more important.[27] The 'robust' option may also inflate t-statistics in small samples.

We find significant correlations between investment in intangible assets and a large number of variables used as proxies for each of the different dimensions of potential determinants mentioned above in Section 2. This points to the relevance of **macro-economic conditions, the regulatory framework, other forms of public intervention, financial conditions and human capital (and complementarities across different types of capital)** as determinants of investment: the accelerator term matters in terms of a proxy for macro-economic conditions, tertiary education and skills mismatch indicators matter as a proxy for the availability of human capital (overqualification is positively related with investment in intangibles while underqualification, which could be interpreted as an indicator of lack of relevant skills, is negatively related); flexibility in both product- and labour markets matters as a proxy for the regulatory framework; the long-term interest rate, gross savings of corporations and the debt-to-equity ratio matter as a proxy for financial conditions; and public R&D intensity and science-business linkages matter as a proxy for other forms of public intervention (beyond the regulatory framework).

The relationship of some determinants with investment differs significantly between investment in tangible and intangible assets and between NA- and non-NA-intangibles. Wald tests (presented in Table 4) confirm differences in particular for the interest rate (which seems to matter more for tangibles and non-NA-intangibles) and employment protection legislation (which seems to matter more for intangibles in general and NA-intangibles in particular). In Table 3 we can see that public R&D intensity is significantly and positively correlated with investment in intangible assets and NA-intangibles, while its correlation with investment in tangible assets and non-NA-intangibles is not significant. Below we will discuss these issues in more detail.

The stringency of the **regulatory framework** (employment protection legislation, product market regulations proxied by the OECD's Product Market Regulation indicator or by the World Bank's Ease of Doing Business indicator) was found to be negatively correlated with investment in intangibles, but less so with investment in tangibles (see Tables 2 and 3). This finding is in line with the previous findings discussed in Section 2, namely that flexible resource allocation could be favourable in particular for investment in intangibles due to its inherent greater uncertainty and the consequential need to deploy resources flexibly. Moreover, we discussed that

[26] See Tables A3-A6 in the Annex for more detailed results.
[27] As discussed above, we chose to use a fixed effects regression model, which controls for time-invarying unobservable factors and avoids strong independence assumptions which would need to made when using the random effects regression model.

Table 3
Investment regressions, introducing selected determinants per category (public support, availability of human capital, finance and regulation) by asset type, including determinants separately.

	(1) Total intangibles	(2) NA-intangibles	(3) Non-NA-intangibles	(4) Tangibles
Tertiary education	0.0927***	0.0472***	0.0455**	0.00440
	(0.0248)	(0.0124)	(0.0157)	(0.0295)
Overqualification	0.146**	0.0682***	0.0782	−0.0530
	(0.0635)	(0.0199)	(0.0469)	(0.0800)
Underqualification	−0.0581*	−0.0243	−0.0338*	0.0542
	(0.0294)	(0.0136)	(0.0187)	(0.0332)
Long-term interest rate	−0.127**	−0.0572**	−0.0698**	−0.217***
	(0.0467)	(0.0258)	(0.0257)	(0.0282)
Debt-to-equity ratio	−0.0640	−0.0318	−0.0322	−0.167***
	(0.0371)	(0.0214)	(0.0189)	(0.0292)
Gross savings corporations	0.0312	0.0342*	−0.00303	−0.133
	(0.0452)	(0.0190)	(0.0318)	(0.0973)
Product Market Regulation index	−0.670*	−0.390**	−0.280	1.889**
	(0.330)	(0.148)	(0.227)	(0.751)
Doing Business: Construction permits	0.0585***	0.0218***	0.0367***	0.0478
	(0.00706)	(0.00539)	(0.00532)	(0.0483)
Doing Business: Trade across borders	0.0127*	0.0124***	0.000316	−0.000815
	(0.00674)	(0.00257)	(0.00455)	(0.0106)
Employment protection legislation	−0.746**	−0.618*	−0.128	−0.692***
(strictness of collective dismissals)	(0.332)	(0.329)	(0.124)	(0.163)
Public R&D intensity	3.394***	2.391***	1.003	−3.009
	(1.065)	(0.634)	(0.854)	(2.651)
Public-private co-publications	0.0128***	0.00728***	0.00555**	0.0118*
	(0.00293)	(0.00178)	(0.00239)	(0.00591)

Notes: NA-intangibles refer to those intangible asset types that are included in the National Accounts' measure of Gross Fixed Capital Formation (GFCF), namely computerised information and some categories of innovative properties (e.g. mineral exploration, R&D and intellectual property rights). Non-NA-intangibles refer to those intangible asset types that are captured as expenditure or intermediate consumption in the national accounts. All variables are expressed in percentages except the indicator for employment protection legislation in terms of strictness of collective dismissals and the indicator for product market regulations, which are expressed on a scale of 0–6, Ease of Doing Business indicators which are expressed as a distance to the frontier (a higher value indicates a smaller distance to the frontier) and public-private co-publications which are expressed in terms of the number of publications. Explanatory variables are added in lag-form. All regressions include an accelerator term, a control for the economic crisis, an interaction between the accelerator term and the crisis and country fixed effects. We include a time trend in the regression model when it is significant, namely in regression (4).
Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4
Wald test statistics for Table 2.

p-values Wald test for no systematic difference	all intangibles vs. tangibles	NA intangibles vs. non-NA intangibles
accelerator term	0.13	0.78
tertiary education	(*)	0.75
long-term interest rate	0.00	0.00
employment protection legislation	(*)	(*)

Notes: This table shows p-values for Wald tests with the Null hypothesis that there is a no significant difference between the two tested coefficients. A value smaller than 0.05 signifies that we cannot accept the Null hypothesis at a 95% confidence level. The symbol (*) signifies that in one of the respective two models that are being compared the coefficient of the respective independent variable is not statistically significant.

regulations creating favourable conditions for profitmaking could enhance building up sources of internal funding, which we discussed is comparably more important for investment in intangibles compared to tangibles. In terms of investment in tangible assets and when including indicators separately in the regressions (see Table 3), we find stringency of employment protection legislation and a greater distance to the frontier in terms of the World Bank's Doing Business indicators to be negatively correlated with investment in tangible assets while the OECD's indicator for product market regulations was found to be positively and significantly associated with investment in tangible assets. We believe that the latter finding of a positive correlation is driven by a strong structural decline in investment in tangible assets over the whole sample period, which occurs simultaneously with a declining stringency of product market regulations but is attributable to other factors. A time trend would only be able to control for this structural decline in investment tangible assets if the trend was homogeneous across all countries.

In terms of **other forms of public support,** the results indicate that public R&D intensity seems to matter for investment in intangibles and most for investment in NA-intangibles. This finding is intuitive as investment in NA-intangibles includes private R&D, which is known to benefit largely from public R&D. In terms of science-business linkages, which are proxied by public-private co-publications, we find a statistically significant relationship with investment in intangibles, NA- and non-NA-intangibles. For investment in tangible assets the relationship is positive but significant at a lower confidence level.

In terms of **financial conditions**, the results indicate that long-term interest rates as well as debt-to-equity ratios are statistically more strongly associated with investment in tangible than with investment in intangible capital. In Section 2 we discussed a possible explanation for our finding: intangible capital tends to be rather financed by internal funds, which would make it less dependent on factors related to external financing such as bank lending (interest) rates. This is to some extent confirmed by the finding that gross savings of corporations (an internal source of funding) seem to be positively associated with investment in NA-intangible assets (see Table 2), while we do not find a significant correlation between gross savings of corporations and investment in tangible assets. What could also explain our finding is that issues related to the Great Recession seem to affect the long-term interest rate and investment in tangible assets more strongly than investment in intangibles (see Graph 1 and Graph A2). Graph 1, shows indeed that investment in intangibles remained relatively stable over the years of financial crisis, while investment in tangible assets dropped

notably in the light of financial turmoil. This observation is to some extent also confirmed by the coefficients on the accelerator terms in the regressions (1)-(4): Even though Wald tests indicate that there is no statistical difference between the coefficients of the accelerator term across asset types as described above, there is still a visible numerical difference.

In terms of **human capital,** evidence suggests that tertiary education is important for intangible investment (and both NA- and non-NA-intangibles), while it is insignificant for investment in tangible assets. This may derive from the fact that intangible capital is potentially more skill-intensive than tangible capital. Consistently, on-the-jobs skills mismatch, measured on the basis of all qualification groups, is found to matter negatively in the case of under-qualification and positively in the case of over-qualification for intangible investment (see Table 2), suggesting that the relevance of qualifications is also of importance.

Finally, we find some exploratory evidence that suggests **complementarities** in terms of investment choices between intangible and tangible assets and among certain types of intangible assets when controlling for the accelerator effect and other controls (see Table A7 in Supplementary material). Production function estimations would be needed to analyse complementarities in terms of output. However, our exploratory evidence presented here feeds nicely into the discussion concerning 'industrial commons' (Pisano and Shih, 2009), which refers to the complex web of collective R&D, engineering and manufacturing capabilities that are needed to sustain innovation (and investment at large). The availability of local suppliers and technical skills is thus seen as a positive externality that facilitates rapid innovative solutions to challenges, thus spurring on further innovation. In another contribution to this special issue, Coad and Vezzani (2019) discuss this more in detail.

5. Conclusion

In this paper, we have examined potential determinants of investment in intangibles in Europe and analysed whether the factors that tend to hold back investment may be the same as for tangible assets. For this purpose, based on a dataset providing estimates concerning investments in intangible assets, including those that are not captured in the National Accounts, relevant determinants were empirically explored both jointly and separately in order to unveil systematic differences. We were especially interested in how to potentially unlock investment in intangible assets (thus complementing the compelling literature looking at investment in general or specifically at tangible assets).

Overall, our evidence suggests a significant impact on investment in intangibles in terms of the main categories of determinants identified in this paper. Our assessment of the determinants of investment in different asset types suggests that tangible and intangible assets indeed appear to be affected somewhat differently by some key drivers and barriers. For instance, the regulatory framework seems to be more relevant for investment in intangibles while financial conditions and, in particular, the availability of external funding appears to be more important for tangible investment. In turn, investment in intangibles is rather funded from internal resources, which makes such investment arguably less dependent on bank lending rates. Moreover, evidence of complementarities between investments across different asset types suggests that a barrier to investment relevant for one asset type may indirectly impede investment in other assets too as there are synergies among different asset types, notably between tangible and intangible assets but also between different types of intangible assets.

These findings - as well as our reflections on where differences in terms of the role of determinants across asset types may stem from (e.g. specific characteristics of intangibles) - raise several possible policy implications for public authorities:

The emergence of knowledge-based industries with a high relevance of intangible assets raises new issues and policy challenges. For instance, the non-rivalry of intangible assets (or 'scalability' as Haskel and Westlake, 2017 put it) may lead to increasing returns to scale and, in extreme cases, ultimately to monopolistic positions (Andrews and de Serres, 2012), while positive network externalities can reinforce this tendency as observed for instance in the digital economy. Other specificities may work in the opposing direction. For instance, due to spillovers arising from knowledge diffusion and externalities, social returns to intangible investment tend to be higher than corresponding private returns, which gives rise to expect under-investment from a societal perspective. Moreover, there are some specific features of intangibles (e.g. scalability and non-excludability), which *inter alia* make them less easy to be used as collateral and, therefore, more reliant on internal financing (i.e. savings) than physical capital (OECD, 2018), which could lead firms to underinvest in such assets.

Systematic reporting of investment in all relevant intangibles (and thus going beyond the SNA asset boundary) could improve corporate governance and market transparency and, moreover, help to understand relevant economic trends such as the trajectory of investment figures. It could also facilitate getting access to finance (Andrews and de Serres, 2012). In this regard, Hochberg et al. (2018) highlight that e.g. patents are increasingly pledged to secure financing. This argument is consistent with previous evidence suggesting that the market value of a firm tends to be increasingly driven by its productive stock of intangibles rather than by the firm's tangible assets as the link between market and book value of a company have increasingly decoupled over the recent decades (Lev and Gu, 2016). The development of new standards for accounting and corporate disclosure may help to close the information gap in terms of intangible assets, to better understand their link with economic performance and eventually to also facilitate access to finance.

There is a case for policy action arising from certain characteristics of intangibles, which ultimately can lead to underinvestment in research. In fact, evidence from our analyses suggests *inter alia* that public spending on R&D as well as public-private partnership in research can be drivers for investment in particular in intangibles. Hence, policy may directly stimulate investment in intangible assets and the creation of a knowledge-based economy. This can be done by means of direct public contribution such as investing in public R&D and building a strong science base, promoting business-science linkages and knowledge transfer, etc. Crowding-in private investment could be envisaged since this can be an effective tool to reach a socio-economically optimal level of investment in intangible assets (see for instance European Commission (2017) for an economic rationale of crowding-in private investment by public R&I funding).

In addition, investment in human capital emerges as important for fostering investment in intangible assets, pointing to the need for well-integrated education systems targeting early as well as lifelong learning. In fact, the growing importance of investment in intangibles amplifies the need of developing human capital and this general trend may also have profound implications for employment and earnings inequality. For instance, a knowledge-based economy rewards certain types of skills, including also corporate skills, and those who perform nonroutine manual and cognitive tasks (while rewarding as well investors who ultimately own much of the intangibles; see OECD, 2013).

Finally, improving the quality of the regulatory framework could play a crucial role in unlocking investment in intangible assets. Policy could ensure competitive markets and business-friendly regulations that enable efficient allocation of resources while allowing firms to make (and reinvest) profits. Policy action in this respect is

the more important as product market and labour market regulations can also mutually reinforce each other as Ciriaci et al (2019) show for the case of location choices of R&D companies.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.strueco.2019.06.010.

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