Organisation for Economic Co-operation and Development

ECO/WKP(2019)99

Unclassified **English - Or. English**

ECONOMICS DEPARTMENT

PRODUCTIVITY GROWTH AND FINANCE: THE INTANGIBLE ASSETS CHANNEL – A FIRM LEVEL ANALYSIS

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ABSTRACT /RESUME

Productivity Growth and Finance: The Intangible Assets Channel – A firm level analysis

Using a cross-country firm level panel dataset from 1995 to 2015, this paper revisits the finance–productivity nexus by looking at the role of intangible assets. It argues that due to their specific characteristics, such as valuation uncertainty and lower pledgeability, financing the purchase of intangible assets is more difficult than that of tangible assets. As a result, financial frictions are expected to be more binding for productivity growth in sectors where intangibles have become a pivotal component in firms production function. The analysis relies on a panel fixed effects econometric approach, several indices to capture financial frictions at the firm level and a new measure of intangible intensity at the industry level. We provide evidence that financial frictions act as a drag on productivity growth and especially so with respect to firms operating in intangible intensive sectors. These findings, which are robust to alternative specifications, shed light on the role of financial factors in explaining the productivity slowdown in OECD countries and provide support for using intangible intensity as a new dimension to proxy the relative exposure of industries to financing frictions.

JEL Classification codes: D22, D24, G31, O33.

Keywords: Productivity, financial constraints, intangible assets.

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Croissance de la Productivité et Finance : le Rôle des Actifs Incorporels – Une analyse au niveau de l'entreprise

Cet article revisite la relation entre finance et productivité en mettant l'accent sur le rôle joué par les actifs incorporels. L'analyse exploite des données d'entreprises couvrant les pays de l'OCDE sur une période allant de 1995 à 2015. Cet article fait valoir qu'en raison de leurs caractéristiques spécifiques, telles qu'une plus grande incertitude sur leur valeur et difficulté à être utiliser en tant que garantie d'emprunt, le financement des actifs incorporels est plus difficile que celui des actifs corporels. En conséquence, les frictions financières devraient être plus contraignantes pour la croissance de la productivité dans les secteurs où les actifs incorporels sont devenus une composante essentielle de la fonction de production des entreprises. L'analyse empirique exploite des données de panel et repose sur un modèle à effets fixes, plusieurs indices capturant les frictions financières au niveau de l'entreprise ainsi qu'une nouvelle mesure d'intensité en actifs incorporels au niveau de l'industrie. Les résultats confirment que les frictions financières agissent comme un frein à la croissance de la productivité et que cet effet est d'autant plus important que les entreprises opèrent dans des secteurs intensifs en actifs immatériels. Ces résultats qui apparaissent robustes à l'utilisation de spécifications alternatives mettent en lumière le rôle des facteurs financiers dans le ralentissement de la productivité des pays de l'OCDE et plaident en faveur de l'utilisation d'une mesure d'intensité en actifs immatériels pour capturer l'exposition des industries aux frictions financières.

Classification: D22, D24, G31, O33.

Mots-clés: Productivité, contraintes financières, actifs incorporels

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Productivity and Finance: The Intangible Assets Channel – A firm level analysis

By Lilas Demmou, Guido Franco and Irina Stefanescu[1]

1. Introduction

1. Over the last two decades, many advanced economies experienced a sharp slowdown of productivity growth. Among a wide range of potential explanations, such as slowing technological diffusion, misallocation, weak business dynamism and measurement error, several authors stress the relevant role played by financing frictions.[2] Indeed, they provide evidence that financial constraints induce sluggish investment and impede firms to implement productive projects both in manufacturing and services industries.

2. During the same period, intangible assets have grown in importance in many OECD economies, as the growth rate of intangible investment has often exceeded that of tangible investment. New technologies have seen unprecedented development, and investment into software, patenting, organization and distribution networks have generated new intangible assets, which have become a pivotal component of the production function for many firms.[3] Moreover, most of aggregate productivity growth is driven by innovative sectors that strongly rely on intangible assets, such as ICT producing sectors and high tech manufacturing.[4]

[1] Lilas Demmou, Guido Franco and Irina Stefanescu are members of the OECD Economics Department (Email: lilas.demmou@oecd.org; guido.franco@oecd.org; irina.stefanescu@oecd.org). The authors would like to thank Luiz de Mello, Alain de Serres, Peter Gal and Giuseppe Nicoletti (all from the OECD Economics Department), as well as Alberto Pozzolo (Università degli Studi del Molise) and seminar participants at "Università di Roma Tor Vergata" for helpful comments. Sarah Michelson (also from the Economics Department) provided excellent editorial support.

[2] Levine and Warusawitharana (2016), Kalemli-Ozcan et al. (2017), Manaresi and Pierri (2017), Mian et al. (2017) and Duval et al. (2018) are exemplifying recent studies on the effects of financing constraints on investment and productivity. Hopenhayn (2014) and Restuccia and Rogerson (2013, 2017) provide a comprehensive survey of the literature on the extent and the detrimental consequences of resources misallocation. Moreover, Decker et al. (2017) and Andrews et al. (2016) investigate respectively the relevance of business dynamism and of the slowing technological diffusion. Finally, Syverson (2017) investigates the measurement error hypothesis.

[3] Corrado and Hulten (2010); Corrado et al. (2012, 2016); Andrews and De Serres (2012). Refer to Figure A.1 and Figure A.2 for some aggregate descriptive evidence.

[4] See, for instance, Gal et al. (2018) and the ECB Economic Bulletin (October, 2017). Further, there is ample evidence that innovative intangible capital and productivity are positively related. First, innovation generates new demand by improving quality and increases firms' efficiency by reducing costs. Second, it leads to a more efficient allocation of resources across firms, as companies that successfully invest in intangibles, increasing their innovation potential, gain market shares and, eventually, displace inefficient ones. Refer to Hall (2011) for a review of the literature.

3. This paper argues that, despite their aggregate rise, intangible assets often fall short of desired levels, because financing the acquisition of intangibles is more difficult than that of tangibles. As a result, especially in these innovative sectors in which intangibles are structurally needed most, financial constraints become even more binding in harming productivity growth.

4. The divergence between the internal and external costs of capital is particularly large for intangible assets.[5] First, asymmetry of information makes more difficult for an external investor to evaluate the quality of and the risks associated with innovative projects, making the return on investment highly uncertain.[6] Furthermore, the effectiveness of measures targeted at reducing information asymmetries, such as more transparency and full disclosure, is limited, as many innovative practices generate non-rival knowledge and could be easily imitated by competitors or appropriated by the financier. As a consequence, firms are reluctant to reveal their innovative ideas to capital market participants, reducing the quality of the signal about their projects.[7] Second, intangible assets are more difficult to pledge as collateral when searching for external capital. Compared to tangible assets, their valuation is more volatile and they tend to be firm-specific, generating contracting issues. They are harder to redeploy and have a significantly lower liquidation value, reducing the share debtors can capture in case of default.[8] Third, intangible investment is more uncertain also for the company itself. Companies with large intangible investments face "intangible risks" that are difficult to hedge, as the insurance industry is only at the early stages of finding solutions to insure firms against them.[9] It follows that moral hazard issues related to a principal agent problem between shareholders and managers could also arise, leading to under-investment in intangibles: risk averse managers might restrict these risky investments in order to reduce the possibility of bankruptcy associated with excessive or unsecured debt, especially when internal funds are limited.[10]

5. Overall, financing conditions are more likely to impact sectors that are structurally more dependent on intangible assets, indicating that the availability of finance plays a much more decisive role in determining the productivity dynamics of firms operating in these sectors. Combined with their strong productive potential, this implies that the benefits arising from the relaxation of financing frictions are potentially larger in intangible intensive sectors.

6. Our main contribution consists in investigating how the impact of financing constraints on firm-level productivity growth is mediated by sectoral intangible intensity, and in showing that indeed the structure of assets (tangible versus intangible) significantly alters the nature of this relationship. To the best of our knowledge, this paper is one of the first studies to test

[5] Hall and Lerner (2010) provides a detailed discussion on the reasons why the gap is considerably higher for financing R&D and, more generally, innovative activities.

[6] Himmelberg and Petersen (1994); Barth et al. (2001). Scherer and Harhoff (2000) stress that the return from the innovation process is extremely skewed (e.g., Pareto distributed), a fact that exacerbates the process of the valuation of innovative investments.

[7] Bhattacharya and Ritter (1983); Anton and Yao (2002); Gans et al. (2002). The argument that knowledge is non-rival, reducing incentives to invest in innovation and disclose innovative projects goes back to Nelson (1959) and Arrow (1962).

[8] Hart and Moore (1994); Brown et al. (2009); Hall and Lerner (2010).

[9] The Economist (23*rd* August 2018).

[10] Hall and Lerner (2010).

empirically the mechanisms linking financial frictions, intangible assets and productivity, and brings novel evidence into the debate on what could potentially resume productivity growth.

7. The analysis relies on panel firm level data extracted from the Orbis database. Our sample covers about 1.4 million unique firms from 29 countries, including both manufacturing and services industries, during the 1995-2015 period. The dataset contains detailed and harmonized balance sheet information, which enables us to relate firms financial (e.g., leverage, cash holdings, investment) to production conditions. The richness and the heterogeneity of the information at the firm level allows to investigate several new dimensions which cannot otherwise be disentangled at the more aggregate level.[11] Using sector level data, Arquie' et al. (2018) show that the positive impact of financial development on labour productivity is more pronounced for intangible intensive sectors. Two distinct channels could drive these findings: an absolute level effect on the productivity of each firm and a relative effect on how efficiently resources are allocated across firms. Our firm level analysis permits to isolate unambiguously the former channel.

8. To test that financial constraints are more binding in relatively more intangible intensive sectors, our empirical strategy relies on a fixed effects panel data model, where the dependent variable is firm level productivity. The effect of interest is captured by the interaction term between a firm level time-varying measure of financial constraints and a sector-varying measure of intangible intensity. The model includes firm fixed effects to absorb the unobserved firm-specific heterogeneity that simultaneously affect financial conditions and production, firm level time-varying controls to account for potential omitted variable bias and higher order fixed effects to control for all country-sector time varying shocks (country by sector by time dummies). Hence, our identification occurs by exploiting within firm variance in a given country, sector and year. A critical element of the empirical approach is the fact that intangible intensity is completely exogenous to our firm level productivity. Following the methodology described in Peters and Taylor (2017), the sector level (but country and time constant) intangible intensity is calculated by aggregating information from all the U.S. listed firms in Compustat, from 1990 to 2006. Our final data from Orbis subsequently excludes all U.S. firms (listed and unlisted) from the analysis. The underlying assumption is that, in the absence of financial constraints, the production function for a given sector implies an optimal asset mix between tangible and intangible capital. Intangible intensity is thus akin to a sectoral technological characteristic that, in a frictionless world, should not vary across countries. Using U.S. as our benchmark is motivated, as in Rajan and Zingales (1998), by its well-developed and relatively frictionless financial markets, particularly with respect to listed firms in the years preceding the financial crisis. In such an environment, the intangible assets equilibrium level comes closer to optimal levels. We further check the cross-sectional stability of the relation of interest by estimating, for each year, repeated cross-sectional regressions in the spirit of Fama and MacBeth (1973) and Kashyap and Stein (2000), controlling for country-sector specific characteristics.

9. Our results confirm that the detrimental impact of financial constraints on productivity growth is larger in intangible intensive sectors, suggesting that intangible intensity captures a new dimension of the relative exposure of industries to financing frictions. In our baseline panel specification, moving from the 25^{th} to the 75^{th} percentile in the distribution of the financial constraints index explains 14% of the change in productivity in high intangible intensive sectors and only 10% in low intangibles intensive sectors. The differential effect is significant at the 1% level and substantial in size, as it implies a 40% increase in the relevance of financing frictions. These findings are consistent to a wide range of robustness checks, including alternative firm

[11] Concerning the relevance of the heterogeneity at the firm level see, for instance, Melitz (2003).

level financial constraints measures, various productivity estimates, different sectoral intangible intensity variables and several sample splits. Moreover, the effect remains highly significant (as well as stable over time), if we exclusively exploit cross-sectional variation.

10. Finally, we also extend our framework and provide preliminary evidence about the collateral channel and other framework conditions that could amplify or mitigate the impact of financial constraints on productivity growth. We find that the estimated differential effect is lower for firms with higher collateral compared to their peers and for firms operating in countries with more developed credit markets or more advanced contract enforcement procedures.

11. The remainder of the paper is organized as follows. In Section 2, we discuss related literature. Section 3 describes the data and presents some preliminary descriptive statistics, while Section 4 explains the details of empirical framework employed in the analysis. In Section 5, we discuss our findings and provide a wide range of robustness checks. Section 6 concludes.

2. Related literature

12. The paper is mainly related to two strands of literature. The first strand investigates the impact of financial constraints on firm level innovation and productivity. The second strand examines the effect of intangible investments on productivity, devoting particular attention to the measurement of intangible assets.

2.1. The impact of financial constraints on innovation and productivity

13. The relationship between financial frictions and innovation has been studied from both a theoretical and an empirical perspective.[12] Facing financial constraints, firms cut their investment in R&D to reduce liquidity risks (Bond et al. (2005), Aghion et al. (2010), Aghion et al. (2012) and De Ridder (2016)). More broadly, they invest less in intangible assets, which are more difficult to pledge as collateral (Garcia-Macia (2015) and Duval et al. (2018)). Financially constrained firms are more likely to invest in tangible assets in order to increase their debt capacity, providing a guarantee and an enforceable outside option for creditors (Almeida and Campello (2007) and Campello and Hackbarth (2012)). Further, Caggese (2016) finds that constrained firms might undertake less radical innovation, suggesting that financial markets might actively shape not only the extent but also the nature of the R&D undertaken (Kerr and Nanda (2015)). In line with this argument, Acharya and Xu (2017) provide evidence that, in external finance dependent industries, public firms, which usually face lower constraints, have a better innovation profile compared to their private counterparts.

14. In general, most studies show that higher credit availability spurs firms' innovation. For instance, Benefratello et al. (2008) and Cornaggia et al. (2015) show that local banking development affects the probability of innovation and that increased banking competition following deregulatory events boosts innovation activities in private small firms more than in large corporations. However, Brown et al. (2009) and Hall and Lerner (2010) find that small young firms, which are relatively more constrained, face difficulties to finance investment in

[12] For a review of the parallel strand of literature disentangling the peculiar features characterizing the financing of R&D and other innovative activities, refer to Hall and Lerner (2010) and Kerr and Nanda (2015), as well as to the discussion about the difficulty to finance intangibles exposed in the introduction.

intangibles with debt, and as a result, innovative activities can be prohibitive especially in the presence of high initial fixed costs (Midrigan and Xu, 2014).[13]

15. Moving to the literature that examines the link between financial constraints and productivity at the firm level, most papers found evidence of a significant negative relationship. Firms facing high financing frictions might not be able to capture profitable and productive investment opportunities. For instance, Kalemli-Ozcan et al. (2017) document that the decline in investment in the aftermath of the recent financial crisis was more severe for firms linked to weaker banks. Using panel data on firms operating in France, Great Britain, Italy and Spain, Levine and Warusawitharana (2016) show that firms facing more severe financing frictions exhibit a higher sensititivity of future productivity growth to debt growth, confirming their model prediction that an increase in financial constraints leads to reduced productivity growth. Exploiting a large matched firm-bank dataset, covering credit relationships of Italian corporations over more than a decade, Manaresi and Pierri (2017) show that higher credit availability is associated with higher productivity growth and that positive credit shocks induce more innovation, IT adoption, exporting activity and better management practices.[14] Similarly, Dorr et al. (2017), using loan-level data on syndicated lending in Italy, exploit the heterogeneous exposure of Italian banks to foreign borrowers in distress and provide evidence that a negative shock to bank credit supply decreases firms investment and productivity. Focusing on eleven advanced economies, Duval et al. (2018) show that firms that entered the Great Financial Crisis with weaker balance sheets experienced a sharper decline in total factor productivity growth relative to their less vulnerable counterparts after the crisis. Accordingly, Ferrando and Ruggieri (2018), using firm level data tracking eight euro-area countries, find a negative estimate for the elasticity of TFP with financial constraints, especially with respect to small and young firms. Also less recent papers provide comparable findings: for example, Gatti and Love (2008) show that Bulgarian firms' access to finance is positively associated with their productivity, while Butler and Cornaggia (2011), exploiting an exogenous shift in demand for U.S. corn and a triple differences testing procedure, demonstrate that productivity increased the most for firms operating in counties with greater access to finance.[15]

2.2. Intangible assets and their impact on productivity

16. A large literature emphasizes the role of a broad range of intangible assets in stimulating productivity growth at the firm level. Comparing the findings of several studies, Hall (2011) highlights that, even tough measures of innovation are still imperfect, there is evidence of a positive relationship between intangible capital, innovation, productivity and growth. The effect

[13] In support of these claims, Peters et al (2017) show that the cost of generating innovations is significantly smaller for firms that are maintaining ongoing R&D investment rather than beginning to invest in R&D.

[14] In this respect, Manaresi and Pierri (2017) note that "negative credit shocks might hurt small firms by forcing managers / entrepreneurs to divert time and effort from productivity improvements in order to create relationships with new lenders (e.g., managerial inattention)".

[15] The misallocation literature also points to the fact that financing frictions could have negative effects on the efficient allocation of inputs across firms, harming aggregate productivity. Exemplifying studies are Buera et al. (2011), Gilchirst et al. (2013), Midrigan and Xu (2014), Moll (2014), Gamberoni et al. (2016), Larrain and Stumpner (2017) and Franco (2018).

is stronger with respect to product rather than process innovation.[16] By developing a model of endogenous productivity change resulting from investment in knowledge and by deriving, in this setting, a novel estimator for production functions based on panel data on Spanish firms, Doraszelski and Jamandreu (2013) provide evidence that R&D plays a decisive role in determining differences in productivity across firms and the evolution of firm level productivity over time; firms that perform R&D have a distribution of expected productivity that stochastically dominate the one of companies that do not perform it. Using data on German manufacturing firms, Crass and Peters (2014) find that R&D and human capital have a strong positive effect on productivity.

17. Overall, there is a growing recognition that, aside from investments into R&D, patents or software, which have been for a long time perceived as key drivers of innovation, other types of intangible assets such as databases, designs, managerial skills, organization and distribution networks have become increasingly important (Bloom and Van Reenen (2007); Andrews and De Serres (2012); Marrocu et al. (2012)). In particular, these new types of intangible assets are complementary to the traditional ones, implying that efficiency depends precisely on the ability of firms to contemporaneously invest on both (McAfee and Brynjolfsson (2012); Crass and Peters (2014); Andrews et al. (2018)).

18. Intangible assets are more difficult to measure compared to tangibles, as most related expenses are not capitalized on balance sheets. The literature has made significant progress in this regard, and more recently a few papers started to estimate their size and their contribution to productivity growth. For example, Corrado et al. (2005, 2009, 2012, 2013) and Corrado and Hulten (2010, 2014) estimate intangible assets at the aggregate country-sector level. Following their contributions, the role of intangible assets for aggregate growth has been re-assessed. Corrado et al. (2005) and Corrado and Hulten (2010) add intangible capital in a Solow-Jorgenson-Griliches sources of growth famework and show that intangibles had overtaken tangibles to become the largest source of growth; further, they find that the full recognition of intangibles, due to the adjustments in real output figures, could induce a change in U.S. measured productivity of approximately 0.25 percentage points per year in recent years. Similar evidence has been provided, for example, by Barnes and McClure (2009) for Australia, Baldwin et al. (2012) for Canada, and Corrado et al. (2012), Niebel et al. (2013), Chen et al. (2014) for the European Union.

19. More recently, following previous work by Lev and Radhakrishnan (2005), Eisfeldt and Dimitris (2013), Falato et al. (2013) and Eisfeldt and Papanikolaou (2014), Peters and Taylor (2017) suggest a new approach to estimate intangible assets at the firm level, according to which intangible capital is measured as the sum of knowledge and organizational capital. The authors re-examine the neoclassical theory of investment based on the original Tobin's *q* proxy and show that, despite being originally designed to explain physical investment, it explains intangible investment equally well and total investment (tangible plus intangible) even better. Further, they develop a new Tobin's *q* measure accounting for intangible capital and they find it better captures firms' investment opportunities in increasingly service and technology based economies.

[16] The empirical findings on the latter are relatively more noisy, because revenue productivity measures incorporate market-power. It follows that firms' revenue productivity falls when they become more efficient if they operate in the inelastic portion of their demand curve.

3. Data and descriptives

3.1. Firm level data

20. The firm level data we use are obtained from the Orbis database, which is provided by the consulting firm Bureau Van Dijk. Orbis is an umbrella product that combines information from regulatory and other sources in order to collect balance sheet and ownership data about companies worldwide. The advantage from using Orbis is twofold. First, it has a good coverage compared to "Compustat type" data, as it covers many of small and private firms (e.g., listed firms are 1% of the sample). Second, it has an advantage over "Census type" data, as it links production and financial data.

21. Our unbalanced panel covers the 1995-2015 period and encompasses firms located in 29 countries.[17] The United States are excluded from the sample, because they provide the benchmark to build the intangible intensity measure. Both manufacturing and services industries are included. More specifically, we analyze firms belonging to industries whose two-digits codes are within the 10-82 range according to Nace Rev.2 classification; the only exceptions are sectors 20 (Manufacture of Chemical and Chemical Products) and 68 (Real Estate Activities), for which it was not possible to construct a reliable intangible intensity measure from US Compustat data, the utilities sectors (from 36 to 39), as their investment decisions are very often strongly driven by country specific regulations, and the financial sectors (from 64 to 66), due to the peculiarity of their production process.

22. To ensure the comparability of firm level information across countries and sectors, we adopt the data cleaning procedures routinely applied at the OECD, which are based on insights from Gal (2013), Kalemli-Ozcan et al. (2015), Gal and Hijzen (2016) and Gopinath et al. (2017). The variable "year" is created by using the rule that, if the closing date is before 1st of July, the account is classified to the previous year. We consider exclusively full year unconsolidated accounts and perform some basic checks to evaluate implausible values, excessively large shifts in relevant variables over short periods of time and relationships violating accounting norms.[18] Firms not fulfilling these basic criteria are dropped from the sample, as well as firm-year observations with missing values on variables that are decisive to our purposes (e.g., value added, number of employees, fixed assets, total assets, profitability, interest payments). In order to obtain internationally comparable values over time, all firm level nominal variables are deflated by using two digits industry deflators - when these deflators are missing, we fill in missing values using higher order inflation (e.g. grouped 2 digits, 1 digit, macro-sectors); then, we apply country-industry level PPPs, using as a reference 2005 US dollars. Moreover, very small firms - those having less than 3 employees throughout the whole sample period - are excluded to avoid concerns related to the quality of the data and their consistency over time. Finally, given the aim to exploit exclusively within firm variation, we reduce the unbalancedness of the panel by retaining only firms that report at least for three consecutive periods.[19]

[17] Australia, Austria, Belgium, China, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Latvia, Luxembourg, Netherlands, Poland, Portugal, Russia, Slovenia, Spain, Sweden, South Africa, Turkey and United Kingdom.

[18] In order to avoid double-counting, we always privilege unconsolidated accounts over consolidated ones. The only exception is allowed for those firms reporting solely consolidated accounts, which are retained if no unconsolidated accounts are reported during the whole sample period

[19] Table A.1, Table A.2 and Table A.3 report the number of observations and of unique firms by year, country and sector, respectively. Table A.4 shows size classes by country.

23. The following subsections provide an overview on how the main variables employed in the analysis are constructed, while Table 1 reports their basic pooled descriptive statistics.

Table 1. Basic pooled descriptive statistics

Variable	Obs (mln)	Mean	SD	P5	P25	P50	P75	P95
Labor Productivity	12.6	10.70	0.78	9.50	10.27	10.70	11.14	11.91
Total Factor Productivity	12.4	10.40	0.82	9.13	9.94	10.40	10.88	11.71
Labor Productivity Growth	10.8	-0.00	0.51	-0.71	-0.17	0.00	0.17	0.70
Total Factor Productivity Growth	10.6	-0.00	0.48	-0.63	-0.15	0.00	0.16	0.62
DFS Index, vA	9.7	5.07	1.86	1.88	3.75	5.00	6.56	8.13
DFS Index, vB	9.7	5.08	1.85	1.88	3.75	5.31	6.56	8.13
DFS Index, vA2	12.6	1.94	1.85	0.00	0.00	1.25	2.50	5.00
DFS Index, vB2	12.6	1.96	1.85	0.00	0.00	1.25	2.50	5.00
DFS Index, pca	9.7	0.00	1.61	-2.76	-1.21	0.09	1.22	2.54
WW Index, num	9.5	-0.66	0.09	-0.82	-0.72	-0.66	-0.60	-0.52
WW Index, cat	9.5	5.50	2.87	1.00	3.00	5.00	8.00	10.00
WW Index, norm	9.5	0.00	1.00	-1.66	-0.63	0.01	0.64	1.65
SAFE Index, vA	12.1	5.50	2.87	1.00	3.00	5.50	8.00	10.00
SAFE Index, vB	12.1	5.50	2.87	1.00	3.00	5.00	8.00	10.00
Labor (Number of employes)	12.6	71	1816.51	2	4	8	21	129
Age	12.5	16	12.91	3	7	13	21	41
Total Assets (mln, 2005 US \$)	12.6	11.70	346.00	0.09	0.35	1.02	3.65	31.80
Tangible Fixed Assets (mln, 2005 US \$)	12.5	3.02	371.00	0.003	0.03	0.13	0.59	6.52
Ebitda (mln, 2005 US \$)	12.6	1.07	40.40	-0.05	0.02	0.07	0.29	2.71
Financial Leverage Ratio	12.6	0.19	0.23	0.00	0.01	0.15	0.31	0.64
Interest Coverage Ratio	12.6	91.74	825.12	-9.86	1.91	5.62	19.97	256.41
Cash Holdings over Total Assets	12.1	0.12	0.15	0.00	0.01	0.06	0.18	0.46
Current Ratio	12.5	1.83	3.03	0.41	0.95	1.25	1.86	4.67
Equity over Non-Current Liab.	10.2	13.38	57.26	-0.30	0.45	1.63	5.69	49.49
ROA	12.6	0.04	0.13	-0.17	0.00	0.03	0.09	0.25
Cash Flow over Total Assets	12.5	0.06	0.12	-0.10	0.02	0.06	0.11	0.25
Long Term Debt over Total Assets	12.6	0.12	0.19	0.00	0.00	0.02	0.17	0.53
Tangible Fixed Assets over Total Assets	12.5	0.23	0.23	0.01	0.05	0.15	0.35	0.72
Firms Sales (Yearly) Growth Rates	11.0	0.06	0.44	-0.38	-0.11	0.01	0.15	0.65

Note: This table reports the descriptive statistics – number of observations, mean, standard deviation (SD) and the 5*th*, 25*th*, 50*th*, 75*th* and 95*th* percentiles - for all the productivity measures that are employed as dependent variables in the econometric analysis, as well as for the financial constraints indices and their components. If not otherwise specified, statistics are pooled across countries, sectors and time, and refer to the whole 1995-2015 sample period and to all countries and sectors included in the sample. TFP is calculated by applying the GMM Wooldridge (2009) procedure, while labor productivity consists in the ratio between value added and the number of employees. Growth rates are calculated annually as the difference between each log productivity measure and its lagged value. Details on the construction of financial constraints indices and balance sheet variables are provided in the text and the following tables (Table 2 and Table 10)
Source: OECD calculations on Orbis data.

3.2. Productivity

24. Our main dependent variable is (log) firm level productivity. As we do not observe firm level prices, but only 2-digits industry deflators, all the productivity measures employed are revenue based.[20]

25. The logarithm of total factor productivity, estimated through the GMM Wooldridge (2009) value added based procedure, is our baseline measure. The advantage of applying this methodology is twofold. On the one side, it overcomes the OLS simultaneity bias, that is, inputs' choices are not independent from unobserved shocks.[21] On the other side, it internalizes the Ackerberg, Caves and Frazer (2006) critique on the estimation of the labor coefficient in both Olley and Pakes (1996) and Levinsohn and Petrin (2003) semi-parametric approaches. We proxy the capital input with the deflated value of fixed assets, the labor input with the number of employees and adopt intermediate inputs (e.g., material costs) as an instrument for unobserved productivity. To check the consistency of our findings, we also employ (log) labor productivity, calculated as the logarithm of value added per employee. The two measures are highly correlated (Table A.5).

26. The distribution of both measures is well behaved, as their logarithmic transformation resembles a Normal distribution, even though with more pronounced tails. As shown in Figure A.3, the distributions slightly shifted to the left over time, suggesting a tendency towards a worsening of average firms' productivity driven by a longer left and a shorter right tail.[22] Figure A.4 reports the average levels and growth rates of both total factor productivity (left panels) and labor productivity (right panels) by groups of firms, classified according to either their size or age. Larger and older firms are on average more productive, while larger and younger firms experienced higher productivity growth during the sample period.

3.3. Financial constraints

27. Firm-level financing constraints are not directly observable using balance sheet information. Starting with the influential paper by Fazzari et al. (1998), the literature has proposed a wide range of competing measures, each presenting its own advantages and disadvantages, and none outperforming the others.[23]

28. Fazzari et al. (1998) develop an indirect measure of financial constraints based on the argument that constrained firms could not rely on external finance and need to use internal funds in order to finance investments. To test their hypothesis that investment is sensitive to available

[20] Revenue based productivity is influenced by producer-specific demand, as, for example, higher prices would lead to higher productivity estimates, confounding quality changes with increased market power. Ghilchirst (2017) shows that, during the recent financial crises, financially constrained firms tended to raise prices; hence, especially in the second half of the sample period, the price effect would work against our findings.

[21] Firms are able to modify their production decisions even during the same year, after experiencing a shock. For example, if firms observe a positive shock in February, they might decide to increase production - by increasing their inputs' level - for the given year already in March. The econometrician, instead, could not be aware of such a decision. As a consequence, in a standard OLS, the error term would be correlated with the regressors and the estimated capital and labor coefficients biased.

[22] Notice, however, that the increase in sample coverage over time might be partially driving these shifts.

[23] For a comprehensive review of the literature, see Silva and Carreira (2012).

cash flow only for constrained firms, they a-priori classify firms as constrained or unconstrained depending on whether they pay dividends or not; then, they regress cash flow and Tobin's Q on investment separately for each group. This approach is challenged by Kaplan and Zingales (1997), which criticize both the arbitrariness of the a-priori classification and the validity of cash flow sensitivities. To support their claims, the authors suggest a new methodology to classify firms, which is based on qualitative data obtained from companies' reports, and provide antithetical empirical evidence compared to Fazzari et al. (1998) by regressing a set of financial variables - namely, cash flow, market-to-book, leverage, dividends, and cash holdings - over the qualitative categories in an ordered logit model.[24] Following this debate, several authors advanced alternative indirect measures of financial constraints.[25] Nonetheless, indirect measures only provide a test of the presence of constraints within a class of firms and do not produce a firm specific and time varying indicator.

29. To overcome this limitation, various studies rely on a two-steps procedure that builds on the insights from Fazzari et al. (1998) and Kaplan and Zingales (1997). First, they classify firms into groups based on qualitative information on their financial conditions. Second, using a non-linear estimation model, they regress several determinants of financing frictions over the qualitative categories and use the estimated coefficients as weights to build a continuous index as a linear combination of the determinants. For instance, Lamont et al. (2001) propose the famous Kaplan-Zingales (KZ) index, which is built using the scores of the ordered logit model in Kaplan and Zingales' (1997).[26] In line with this, Ferrando et al. (2015) exploits the ECB "Survey on the access to finance of SMEs in the euro area" (SAFE), which reports the answers to several questions aimed at assessing firms' financial conditions.[27] The discrete value index obtained from the combination of the answers is regressed over a set of financial variables in a probit model. Given the qualitative nature of the a-priori classifications, which extensively limits the range of firms that could be included in the analysis, subsequent users of these indices proceed by extrapolating out coefficients to their own sample.[28]

[24] They show that those firms classified as less financially constrained exhibit a significantly greater investment-cash flow sensitivity than those firms classified as more financially constrained. Moreover, they argue theoretically that there is no reason for the sensitivity of investment to cash flow to increase monotonically with the degree of financing constraints.

[25] For example, Almeida et al. (2004) propose an indirect measure of constraints based on the cash flow sensitivity of cash. They suggest that constrained firms need to hoard cash by saving it out of cash flows in order to be able to catch investment opportunities, while unconstrained firms do not; it follows that one should observe a positive relationship between cash holdings and cash flows for firms facing financing frictions.

[26] An analogous procedure is followed by Hadlock and Pierce (2010), which use the same qualitative text-based approach to a-priori classify firms. However, they obtain their own index (HP Index) of financial constraints using a parsimonious specification that employs exclusively size, the square of size and age as predictors.

[27] Namely, four questions: whether loans applications were rejected; whether loans were only partially granted; whether firms rejected the loans due to excessively high borrowing costs; whether firms did not apply for a loan as they feared to be rejected. The SAFE survey covers a representative sample of firms in seven euro-area countries. Other exemplifying studies exploiting survey data are Guiso (1998), Becchetti and Trovato (2002), Beck et al. (2008) and Savignac (2008).

[28] See Farre-Mensa and Ljungqvist (2016) for a detailed discussion on coefficients out of sample extrapolation and for a review of the literature. An exception is the recent work by Ferrando and Ruggieri (2018). It has a similar two steps structure, but the initial classification is achieved by combining

30. Other papers, such as Whited and Wu (2006), follow a different path that does not rely on the above two-step procedures, but rather on a structural model initially proposed by Whited (1992). Their approach consists in estimating the Euler equation resulting from the model, where the structural parameter for the shadow cost of capital is projected into the following variables: cash flow to assets, a dummy capturing whether the firm pays a dividend, long-term debt to total assets, size, sales growth, and industry sales growth. The resulting vector of coefficients is then used to build a continuous index.

31. A third strategy, which avoids the assumptions behind either an a-priori partitioning or a structural model, is proposed by Musso and Schiavo (2008). They develop a class ranking index, building a score from a number of proxies: size, profitability, current ratio, cash flow generating ability, solvency, trade credit over total assets and repaying ability. For each firm, each dimension enters the index as a ranked deviation from sector-year mean. The rank is assigned based on the position of the firm-year observation in the resulting distribution.

32. Acknowledging that this large strand of literature studying direct measures of financial frictions at the firm level is unconclusive and that each method entails ad hoc choices which might impact on our findings, we horse-race several financial constraints indices as follows. First, we use two indices proposed in the literature, which present a "traditional structure" - namely, the ones developed by Whited and Wu (2006) and Ferrando et al. (2015) - and we build some variants of them to reduce the problem of coefficients out of sample extrapolation.[29] Second, we propose a new synthethic index, from now on referred to as "DFS Index", which builds on the insights from Musso and Schiavo (2008).

33. All indices, however, fulfill three basic criteria. First, they combine information from several measures. The reliance on a single variable would not allow us to fully assess firms' financial conditions: a firm might be illiquid, but strong fundamentals could compensate for the temporary financial distress; or, similarly, a firm might be highly leveraged but liquid and, thus, able to catch investment opportunities. Second, in order to allow the exploitation of within firm variation, they are time-varying. Third, they take into account potentially different degrees of financial constraints, going beyond a sharp classification of firms into a constrained and an unconstrained category.

3.3.1. Indices with a traditional structure

34. We construct the widely used Whited and Wu (2006) index by extrapolating out of sample Whited and Wu's reported coefficient estimates:

quantitative (and not qualitative) information on changes in investment, debt and equity structure, as well as on financing gaps and interest payments conditions.

[29] Two alternative widely used "traditional" indices would have been the Kaplan-Zingales, as developed by Lamont et al. (2001), and the Hadlock and Pierce (2010) ones. We are not able to compute the former, as the unlisted firms in our sample evidently lack information on their market value, making impossible to evaluate Tobin's *q*. The latter index, instead, is left apart as it exploits exclusively information on total assets and age, neglecting any contribution from firms' fundamentals, which we expect to be decisive for the many unlisted small and medium sized firms in our sample.

$$
\begin{aligned}
WW\ Index\ = & (-0.091 * CashFlowOverTotAssets) \\
& + (-0.044 * LogTotalAssets) \\
& + (0.021 * LongDebtOverTotAssets) \\
& + (-0.062 * DummyProfits) \\
& + (-0.035 * FirmSalesGrowth) \\
& + (0.102 * AverageSalesGrowth)
\end{aligned}
\qquad \textbf{(1)}
$$

Variables entering the equation with a negative sign are expected to lessen financial constraints the higher their value, while the opposite holds for those with a positive loading.[30]

35. The main concern with the practice of out-of-sample extrapolation of index coefficients is parameter stability across firms and over time - an issue that is even more compelling in our case, as our cross-country sample differs in several dimensions from the Compustat data used by Whited and Wu (2006). To reduce these concerns and take into account cross-country and cross-sector heterogeneity with respect to the contribution of each characteristic in shaping firms overall financial condition, we also compute, based on the WW index, two relative measures of financing frictions.[31] First, we take the median value of the index for each country-sector pair and calculate the deviation from the country-sector median for each firm; we then split into deciles the distribution of the deviations, so that higher deciles contain relatively more financially constrained firms ("WW_cat"). Second, to explicitly control for the potentially different variability of financing constraints within countries and sectors, we build a second alternative version of the index by classifying firms into deciles according to the distribution of the normalized - separately within each country-sector - WW scores ("WW_norm").

36. Next, we adopt two different versions of the index developed by Ferrando et al. (2015) based on the SAFE survey, extrapolating coefficients out of sample as in Ferrando and Ruggieri (2018):

$$
\begin{aligned}
SAFEIndex = & -1.88 + (0.71 * LeverageRatio) \\
& + (-0.51 * ROA) \\
& + (-0.28 * InterestCoverageRatio) \\
& + (-1.20 * CashHoldings) \\
& + (-0.21 * TangibleFixedAssets) \\
& + (-0.05 * LogTotAssets)
\end{aligned}
\qquad \textbf{(2)}
$$

37. First, given that the sample underlying the SAFE survey is relatively more similar to ours if compared to Compustat data, we simply take the deciles of the distribution of the index ("SAFE_vA"). Second, we follow the same strategy used to obtain the "WW_cat" index by calculating deciles of the distribution of the deviations from the median value of the SAFE score in each country-sector pair ("SAFE_vB").

[30] Due to data availability, we deviate from the original index by substituting the dummy variable that captures whether the firm pays a dividend with a dummy variable that takes value 1 if a company reports strictly positive net profits and 0 otherwise.

[31] For the sake of clarity, the original version of the index, calculated as in Equation 1, will be labelled "WW_num" throughout the paper. Further, notice that sectors are defined at the 2-digits level, according to Nace Rev.2 classification.

3.3.2. The "DFS" index

38. We propose a new synthethic index ("DFS Index"), which builds on the approach of Musso and Schiavo (2008) and does not suffer from the concerns associated to coefficients extrapolation. It collapses information from eight variables: size (proxied by total assets), age, financial leverage ratio (ratio of short plus long term financial debt over total assets), return on assets (ROA), current ratio (current assets over current liabilities), cash to assets ratio (cash holdings over total assets), interest coverage ratio (ratio of ebitda over interest payments) and the ratio of shareholder funds over total liabilities. These variables are chosen based on their relevance in the literature and their ability, when combined, to carry information on the various dimensions characterizing firms' financial conditions (e.g., performance indicators, financial fragility, structure of the external funding).

39. In practice, the DFS index is built as follows. For each of the eight variables, we calculate the deviation from the country-sector-(year) median.[32] The resulting distributions of deviations from the median are clustered into quintiles, so that, for each firm-year observation, we have eight scores that range from 1 to 5, in which 1 contains the smallest value (e.g., observations that are far below the group median). A small value could be indicative either of a constrained or an unconstrained firm, depending on the variable considered. For example, being in the first quintile of the cash to assets ratio (deviations from the median) distribution suggests that the firm is not liquid and, thus, relatively constrained compared to its peers; on the contrary, a similarly low value on the financial leverage ratio would suggest that the firm is not leveraged relative to its peers and, thus, unconstrained. We use economic theory and findings from the literature to classify variables depending on their positive (financial leverage ratio) or negative (the other seven variables) loading with respect to financial constraints and homogeneize the scores accordingly, to always have low scores indicating unconstrained firms.[33]

40. Following Musso and Schiavo (2008), we aggregate the information in two ways: the sum of the eight scores; the number of variables for which the firm belongs to the fifth (more constrained) category. The resulting indices are rescaled on a $0-10$ basis, with higher values being associated to more constrained firms. Finally, in order to keep into account the correlations across the variables included in the index and avoid the excessive loading resulting from those carrying related content, we elaborate an additional aggregation strategy based on a principal component analysis (first component) performed over the eight scores.[34]

[32] We develop two versions of the DFS index. In one of the two ("vA"), the reference group is given by a country-sector-year cell; in the other ("vB"), the time dimension is disregarded and each country-sector becomes the reference group. The latter will be our baseline index.

[33] Loosely speaking, for the seven variables with a negative loading, we invert the score based on quintiles. For example, observations in the fifth quintile of the profitability distribution (very profitable) are given a score equal to one, as being profitable is supposed to relax financial constraints; those in the fourth are given a score equal to two and so on, to have low scores indicating unconstrained firms.

[34] It follows that, in the end, we have five variants of the DFS index: sum of the eight scores and each country-sector-year as the reference group ("DFS_vA"); count of variables for which the firm belongs to the fifth category and each country-sector-year as the reference group ("DFS_vA2"); sum of the eight scores and each country-sector as the reference group ("DFS_vB"); sum of variables for which the firm belongs to the fifth category and the eight scores and each country-sector as the reference group ("DFS_vB2"); principal component analysis and each country-sector as the reference group ("DFS_PCA").

41. All the indices - the traditional ones and the DFS, with all their variants - are highly and positively correlated with each other (Table 2), suggesting that indeed they capture similar information, as one would expect.[35]

Table 2. Correlation among financial constraints indices

	DFS, vA	DFS, vB	DFS, vA2	DFS, vB2	DFS, pca	WW, num	WW, cat	WW, norm	SAFE, vA	SAFE, vB
DFS Index, vA	1.00									
DFS Index, vB	0.97	1.00								
DFS Index, vA2	0.78	0.74	1.00							
DFS Index, vB2	0.75	0.78	0.90	1.00						
DFS Index, pca	0.91	0.93	0.69	0.72	1.00					
WW Index, num	0.40	0.42	0.33	0.35	0.27	1.00				
WW Index, cat	0.45	0.47	0.41	0.44	0.29	0.81	1.00			
WW Index, norm	0.45	0.46	0.42	0.44	0.29	0.85	0.95	1.00		
SAFE Index, cat1	0.42	0.43	0.26	0.28	0.27	0.72	0.60	0.59	1.00	
SAFE Index, cat2	0.43	0.45	0.33	0.35	0.24	0.52	0.65	0.63	0.76	1.00

Note: This table displays all the pairwise correlation coefficients among the various financial constraints indices employed in the analysis. The "DFS" indices consist in a revisited version of the financial constraints index developed by Musso and Schiavo (2008); among them, in those labelled as "vA" ("vB"), the reference group is a given country-sector-year (country-sector) cell. In "vA2" ("vB2"), the aggregation strategy changes: not the sum of the scores for each component of the index as in "vA" ("vB"), but rather the number of variables for which the firm lies in the fifth quintile of the distribution. The "pca" version is built from a principal component analysis (first component) on the scores of each variable included in the index. The indices labelled as "WW" are based on coefficients extrapolation from Whited and Wu (2006); the "num" affix indicates the absolute version, while "cat" ("norm") is the relative version based on deciles of the distribution of the deviations from the country sector median (of the distribution of the normalized scores). Similarly, those labelled as "SAFE" are built on coefficients extrapolation based on the outcome of the SAFE survey, as reported by Ferrando et al (2015); "vA" stands for the absolute index expressed in deciles, while "vB" is its relative version. Further details are provided in the text.
Source: OECD calculations on Orbis data.

3.4. Intangible intensity

42. Intangible intensity is defined as the ratio of intangible assets to total assets (tangible and intangible). To measure it at the sector level, we exploit Compustat data on US listed firms and follow the methodology proposed by Peters and Taylor (2017), according to which intangible capital is defined as the sum of knowledge and organizational capital.[36] Knowledge-based capital includes a firm's capitalized spending to develop knowledge, patents, or software, while the organization- based is computed by capitalizing a fraction of the Selling, General and Administrative expense (SG&A), which includes advertising to build brand capital, human capital, customer relationships and distribution systems.[37] Calculations at firm-level are

[35] Moreover, again unsurprisingly, they are negatively correlated with productivity, either expressed in levels or in growth rates (Table A.6).

[36] Similar methodologies are described in Eisfeldt and Dimitris (2013), Eisfeldt and Papanikolaou (2014), Falato et al. (2013), Lev and Radhakrishnan (2005).

[37] The technical details of the calculation are as follows. Intangible assets are calculated as the sum between externally purchased and internally created intangible capital, which, according to the U.S accounting standards, are subject to different rules. Intangible assets that are purchased externally (patents or through a firm acquisition) are included on balance sheet as part of intangible assets (Compustat item

performed over the 1990-2006 period to avoid incorporating the distortionary effects of the financial crisis, characterized by a sharp worsening of aggregate financial conditions.

43. Our baseline measure of intangible intensity is calculated as the sum of intangible assets over the sum of total assets over the period for each firm. This procedure allows to incorporate the possibility of having lumpy intangible investment expenses across years. Then, to aggregate at sector level, we take the median-firm intangible intensity ratio of each sector. The resulting measure, which is sector-varying but country and time constant, is employed either as a continuous variable (*IntK_cont*) or as a "0 − 1" categorical variable with respect to the median sector (*IntK_cat*).[38]

44. Table 3 reports intangible intensity by sector along with its two components, the knowledge and the organizational pieces, and shows substantial variation across sectors in the level of intangible intensity. The highest ratio is observed for the Pharmaceutical and the Programming and Information sectors, albeit a different composition. The lowest ratio is observed in the Transport sectors. Figure 1 provides further graphic evidence on the relevance and composition of intangible assets, confirming that they constitute an important share of all assets both in manufacturing and services, even though some differences emerge on the relative importance of knowledge and organizational capital.

45. Looking at the evolution over time, Figure 2 shows that the ratio between intangible assets and total assets has increased, suggesting that intangible assets have become increasingly important in the production function, as they have grown faster than the stock of tangible capital.[39] Nonetheless, as shown in Figure A.5, despite the sharp increase over time of the stock of intangibles, as well as of their share in total assets, the ranking among sector in terms of intangible intensity is almost constant. This evidence suggests indeed that intangible intensity is akin to a sectoral structural feature and provides further support to the methodological framework described in the next section.

46. Next, we check whether, moving to our cross-country sample, firms experience different productivity levels and growth rates depending on the intangible intensity of the sector they belong to. As expected, the top panels of Figure 3 highlight that firms in highly intensive sectors experienced a slightly positive productivity growth during the sample period, while sectors relying less on intangibles have, on average, zero or negative growth. Moreover, the bottom panels show that intangible intensive sectors are on average also slightly more productive.

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intan). These intangible assets are further separated based on whether the asset is directly identifiable (such as a patents), in which case it is booked under *Other Intangible Assets*, or not identifiable, and classified as *Goodwill*. Intangible assets that are created internally are expensed on the income statement and almost never appear as assets on the balance sheet, with a few small exceptions when the internally created intangibles are capitalized (e.g., legal costs, consulting fees, registration fees incurred in developing a patent or trademark). Peters and Taylor (2017) strategy to estimate internal intangible capital consists in capitalizing intangible investments as reported in income statements.

[38] To test the robustness of our findings, we also build an alternative measure (*IntK_med*): we calculate the ratio of intangibles over total assets for each firm-year; then, for each firm, we find the median value over the period and, finally, take the industry median for each sector. *IntK_cont* and *IntK_med* are highly correlated (0.97). Their correlations with the knowledge and organizational components are 0.58 and 0.60 respectively.

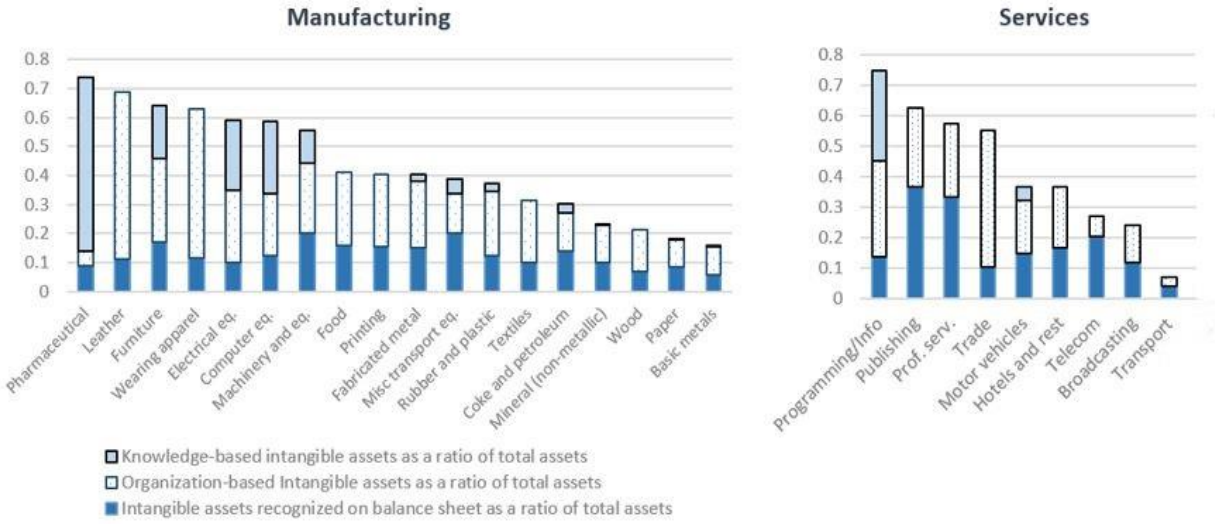
[39] As noted by Goodridge et al. (2013), the surge in intangibles has been particularly pronounced in the late 1990s, when the internet, together with related new softwares and machinery, was introduced.

Table 3. Intangible intensity by sector

Sector	Sector name	Intangible Capital Intensity			
		Smooth	Median	Knowledge-based	Organization-based
D10T12	Food	0.42	0.41	0.00	0.25
D13	Textiles	0.31	0.31	0.00	0.21
D14	Wearing apparel	0.63	0.63	0.00	0.52
D15	Leather	0.64	0.69	0.00	0.58
D16	Wood	0.30	0.21	0.00	0.14
D17	Paper	0.21	0.18	0.00	0.09
D18	Printing	0.37	0.41	0.00	0.25
D19	Coke and petroleum	0.31	0.30	0.03	0.13
D21	Pharmaceutical	0.81	0.74	0.60	0.05
D22	Rubber and plastic	0.36	0.37	0.03	0.22
D23	Mineral (non-metallic)	0.24	0.23	0.00	0.13
D24	Basic metals	0.20	0.15	0.00	0.10
D25	Fabricated metal	0.42	0.40	0.02	0.23
D26	Computer eq.	0.63	0.59	0.25	0.21
D27	Electrical eq.	0.63	0.59	0.24	0.25
D28	Machinery and eq.	0.54	0.56	0.11	0.24
D29	Motor vehicles	0.40	0.37	0.05	0.17
D30	Miscellaneous transport eq.	0.46	0.39	0.05	0.14
D31T33	Furniture	0.67	0.64	0.18	0.29
D41T43	Construction	0.38	0.38	0.00	0.22
D45T47	Trade	0.56	0.55	0.00	0.45
D49T53	Transport	0.10	0.07	0.00	0.03
D55T56	Hotels and rest	0.39	0.37	0.00	0.20
D58	Publishing	0.65	0.63	0.00	0.26
D59T60	Broadcasting	0.23	0.24	0.00	0.12
D61	Telecom	0.37	0.27	0.00	0.07
D62TD63	Programming and information	0.78	0.75	0.30	0.31
D69T82	Professional services	0.62	0.57	0.00	0.24

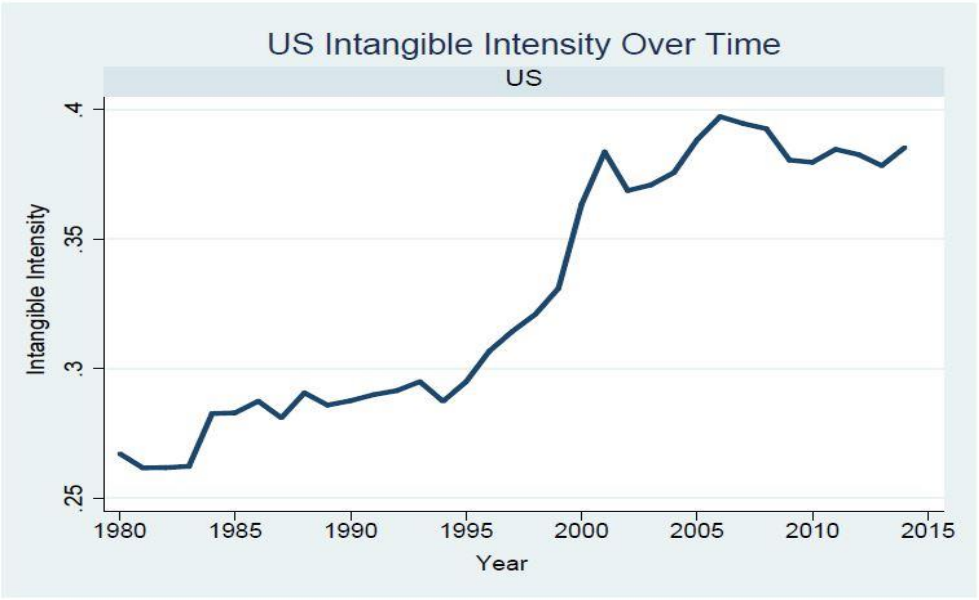
Note: The table reports intangible intensity calculated from COMPUSTAT for all U.S. firms from 1990 to 2006. The smooth version of intangible intensity, which is our baseline, is measured as the sum of intangible assets over the sum of total assets over the period for each U.S. listed firm with available data in Compustat; firm level estimates are aggregated at sector level by taking the median-firm intangible intensity ratio of each sector. The median version, instead, is calculated as the ratio of intangibles over total assets for each firm-year; then, for each firm, we find the firm median over the period and, finally, take the industry median for each sector. The knowledge- and organizational-based measures are described in the text. Notice that, however, being the knowledge and the organizational components calculated separately on the basis of median sector values, their sum does not necessarily sum up to overall intangible intensity, because sector median-firm values and the median firm could be different across the two dimensions.
Source: OECD calculations on Compustat data.

Figure 1. US intangible assets intensity by sector, and its components



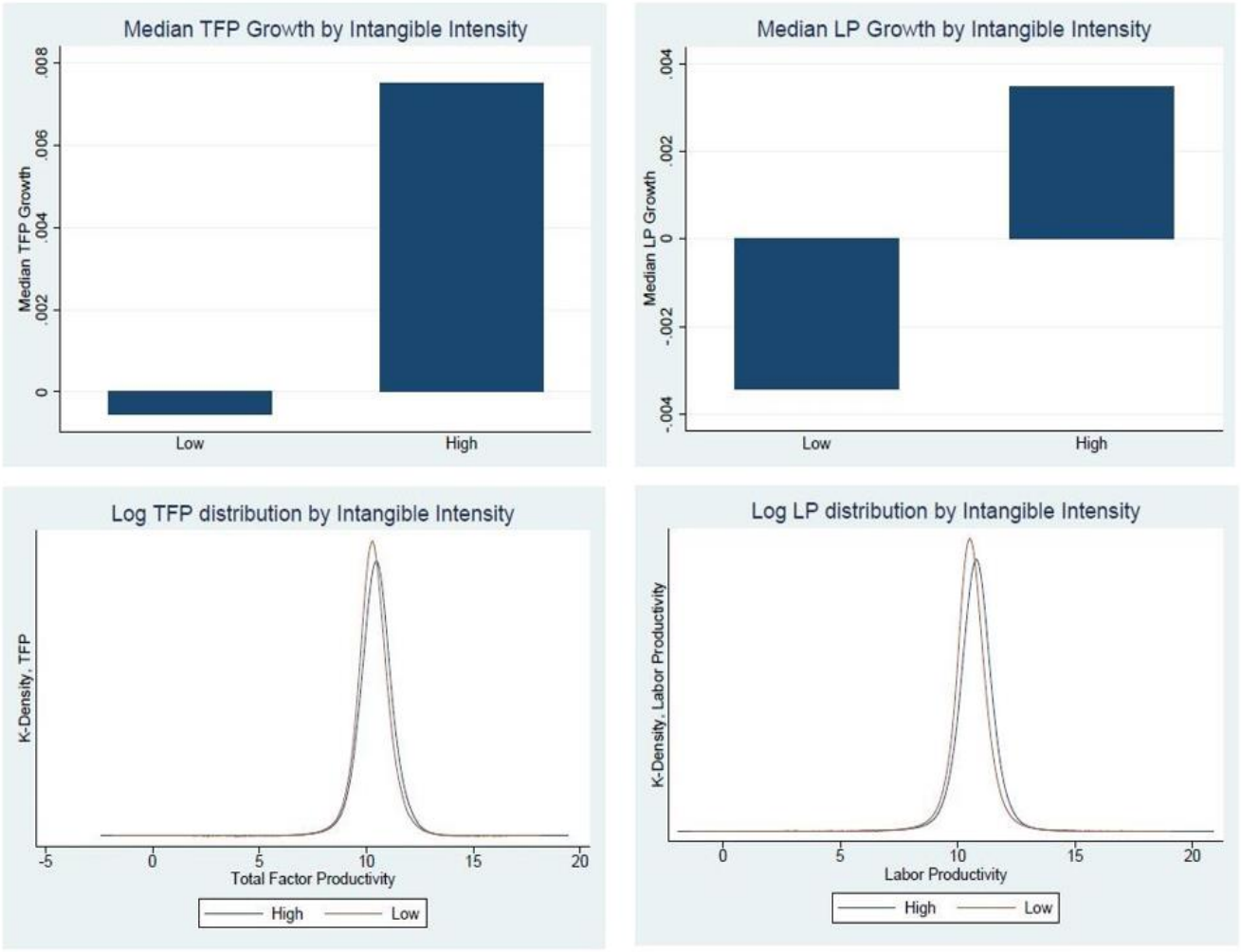
Note: The figure shows intangible intensity across sectors, calculated as the median sector level value of the ratio between intangible assets and total assets (intangible plus tangible). The sample includes all U.S firms in Compustat, excluding financial, utilities and public service. It further differentiates intangible assets into knowledge- and organization- based assets, as in Peters and Taylor (2017). Notice that, being the knowledge and the organizational components calculated separately on the basis of median sector values, their sum does not necessarily sum up to overall intangible intensity, because sector median-firm values and the median firm could be different across the two dimensions.
Source: OECD calculations on Compustat data.

Figure 2. US intangible intensity over time



Note: The figure shows the evolution over time of intangible assets intensity, calculated as intangible assets over total assets (intangible plus tangible). The sample includes all U.S firms in Compustat, excluding financial, utilities and public service.
Source: OECD calculations on Compustat data.

Figure 3. Productivity growth rates and distribution by intangible intensity



Note: This figure presents the log total factor productivity (left panels) and the log labor productivity (right panels) median growth rates (top panels) and distributions (bottom panels), grouping firms according to their belonging to an intangible intensive sector. Our measure of intangible intensity, which is calculated as intangible assets over total assets, is based on U.S firms in Compustat, excluding financial, utilities and public service. High intangible intensive sectors are those whose intangible intensity is above the median sector, while those below the median are defined as Low.
Source: OECD calculations on Orbis and Compustat data.

4. Methodology

47. We test our hypothesis that the impact of financial constraints on productivity growth is more binding in intangible intensive industries compared to non-intensive ones by estimating the following panel fixed effects model:

$$Y_{icst} = \beta_0 + \beta_1 FC_{ics,(t-1)} + \beta_2\left(FC_{ics,(t-1)} * Z_s\right) + \beta_3 \boldsymbol{X}_{ics,(t-1)} + \beta_4\left(\boldsymbol{X}_{ics,(t-1)} * Z_s\right) + \delta_i + \delta_{cst} + \epsilon_{icst} \quad \textbf{(3)}$$

The subscripts *i*, *c*, *s*, *t* stand for firm, country, sector and time, respectively; the dependent variable *Y* is the log of total factor productivity; the variable FC captures financial constraints at the firm level, while Z_s is our intangible intensity measure; the vector $\boldsymbol{X}$ includes a set of firm level controls - namely, the log of total assets, ebitda and age; δ_i indicates firm fixed effects and δ_{cst} country by sector by time dummies.[40]

48. We estimate Equation 3 by OLS, taking into account the possibility of arbitrary heteroskedasticity (White correction).[41] The parameters of interest are the within coefficients β_1 and β_2, that we expect to be both negative, so that changes in financial constraints reduce productivity and do so by more in intangibles intensive sectors relative to non-intensive ones. To attenuate the natural concerns with respect to the potential endogeneity plaguing the relationship between financing frictions, intangible assets and productivity, we proceed as follows.

49. First, we use an extremely rich fixed effects structure: firm fixed effects absorb the unobserved firm-specific heterogeneity that might simultaneously affect financial conditions and production; the triple interacted country-sector-year fixed effects control for the effects of all time varying shocks at the country-sector level, so that we take into account, for example, that certain countries are in a growth and investment phase or that certain (countries and) sectors are developing faster, attracting relatively more funds. To clarify, given our fixed effects structure, identification occurs by exploiting exclusively within firm variation in a given country-sector-year cell.

50. Second, intangible intensity is calculated at sector level by aggregating information from U.S. listed firms Compustat data; having excluded U.S. firms from the analysis, this choice ensures that our measure is completely exogenous to productivity. The assumption underlying this measure is that, in the absence of financial constraints, the production function for a given sector implies an optimal asset mix between tangible and intangible capital and that intangible intensity is akin to a sectoral technological characteristic that, in a frictionless environment, should not vary across countries. U.S. listed firms, which operate in a country with an extremely developed financial market, are expected to be close to the unconstrained benchmark and their demand for intangible assets should approximate for the optimal sectoral intangible investment level.

51. Third, we include all firm level regressors with a time lag to further reduce the simultaneity bias and use the usual set of firm level controls employed by the literature, together with their interactions with intangible intensity, to control for the potential omitted variable bias

[40] If not otherwise stated, the same notation is used throughout the paper. Notice that, due to our fixed effects structure, we evaluate the impact of financing frictions on *productivity growth*, even though our dependent variable is expressed in levels.

[41] Moreover, we also run several robustness checks to be sure that cross-correlations within specific clusters do not impact on the residuals.

arising from firm time-varying characteristics.[42] Moreover, the relative (to the reference group, such as the country-sector) nature of our financial constraints indices reduces by construction concerns with respect to the correlation between financing frictions and intangible intensity.[43]

52. Besides performing common robustness checks to be sure our findings do not depend on either measurement or statistical choices, we provide additional evidence by adopting an alternative empirical framework in the spirit of Fama and MacBeth (1973) and Kashyap and Stein (2000). More specifically, given that in our baseline the use of firm fixed effects allows to exploit exclusively within firm variation, we isolate cross-sectional effects by running, separately for each year in the sample, the following regression:

$$\Delta Y_{icst} = \beta_0 + \beta_1 FC_{ics} + \beta_2 (FC_{cs} * Z_s) + \beta_3 Y_{ics} + \beta_4 \boldsymbol{X}_{ics} + \beta_5 (\boldsymbol{X}_{ics} * Z_s) + \delta_{cs} + \epsilon_{ics} \quad \textbf{(4)}$$

53. The operator "Δ" stands for the first difference of the variable it precedes; given that TFP is expressed in log terms, its first difference is a good approximation of the rate of growth of productivity. Identification would occur exclusively through cross-sectional variation across firms within country-sector cells and we expect again β_1 and, crucially, β_2 to be negative. Firm level explanatory variables, including TFP levels to control for potential convergence effects, enter the estimated equation with a lag. While, of course, one could not infer causality from this model, it is an effective way to check the cross-sectional stability of the relation of interest.

5. Results

5.1. Baseline findings

54. Table 4 and Table 5 report our baseline findings, which are based on the categorical intangible intensity measure ("0 − 1", with respect to the median sector). In Table 4, we use the conventional indices used in the literature, while in Table 5 the several versions of our "DFS" index. Independently of the firm-level financial constraints measure chosen, firms facing higher constraints experience lower productivity growth and, as conjectured, the effect is significantly larger in intangible intensive sectors.

[42] As a matter of fact, any omitted time-varying variable which is positively correlated with financial constraints would lead to spurious confirmation of our story. The three controls included are expected to reflect relevant changes affecting each firm over time, without plaguing the model with the extremely high collinearity that horse-racing numerous additional regressors would cause.

[43] Indeed, the correlation is bounded in the (-0.02, 0.03) interval, depending on the financial constraints index chosen. A high correlation would have implied that we were simply looking at the relationship between the square of financing frictions and productivity.

Table 4. Baseline regression, traditional financial constraints indices

Dependent Variable: TFP					
Intangible Intensity Measure: IntK_cat (0-1)	(1)	(2)	(3)	(4)	(5)
Financial Constraints Indices	WW_num	WW_cat	WW_norm	SAFE_vA	SAFE_vB
Financial Constraints	**-0.915*** **	**-0.024*** **	**-0.071*** **	**-0.012*** **	**-0.009*** **
	(-91.9)	**(-104.4)**	**(-95.7)**	**(-40.8)**	**(-37.9)**
Financial Constraints * Intangible Intensity	**-0.375*** **	**-0.008*** **	**-0.028*** **	**-0.002*** **	**-0.001** **
	(-28.9)	**(-26.0)**	**(-29.1)**	**(-5.2)**	**(-2.4)**
Log of Total Assets	0.121***	0.123***	0.121***	0.148***	0.151***
	(87.5)	(88.9)	(87.2)	(125.7)	(131.8)
Total Assets * Intangible Intensity	-0.035***	-0.030***	-0.035***	-0.016***	-0.015***
	(-19.3)	(-16.6)	(-19.8)	(-10.6)	(-10.4)
Ebitda	0.008***	0.008***	0.011***	0.008***	0.008***
	(4.0)	(4.1)	(3.6)	(3.7)	(3.7)
Ebitda * Intangible Intensity	0.006**	0.006**	0.003	0.008***	0.008***
	(2.1)	(2.2)	(0.8)	(2.7)	(2.7)
Log of Age	0.007***	-0.000	0.007**	-0.004**	-0.004*
	(2.6)	(-0.1)	(2.6)	(-2.1)	(-1.9)
Age * Intangible Intensity	0.021***	0.018***	0.021***	0.016***	0.016***
	(5.9)	(5.1)	(5.9)	(6.2)	(6.2)
Observations	7,459,986	7,459,986	7,459,881	10,008,230	10,008,230
R-squared	0.819	0.818	0.819	0.809	0.809
Country-Sector-Year FE	**YES**	**YES**	**YES**	**YES**	**YES**
Firm FE	**YES**	**YES**	**YES**	**YES**	**YES**

Note: T-statistics in parentheses; standard errors clustered at the firm level. Significance Level: *10%, **5%, ***1%. The dependent variable is the log of total factor productivity, estimated according to the GMM Wooldridge (2009) approach. Financial constraints at firm-level are proxied by a different index in each specification. The indices labelled as "WW" are based on coefficients extrapolation from Whited and Wu (2006); the "num" affix indicates the absolute version, while "cat" ("norm") is the relative version based on deciles of the distribution of the deviations from the country sector median (of the distribution of the normalized scores). Similarly, those labelled as "SAFE" are built on coefficients extrapolation based on the outcome of the SAFE survey, as reported by Ferrando et al (2015); "vA" stands for the absolute index expressed in deciles, while "vB" is its relative version. Further details are provided in the text. Intangible Intensity is a categorical binary variable that takes value 1 if sectoral intangible intensity is above the median and 0 if below the median. Intangible intensity is measured as the sum of intangible assets over the sum of total assets over the 1990 to 2006 period for each U.S. listed firm with available data in Compustat; firm level estimates are aggregated at sector level by taking the median-firm intangible intensity ratio of each sector. The remaining explanatory variables are included as controls; while the details about their construction and sources are provided in the text, it is worth noticing that ebitda is divided by 10 mln to adjust the scale of the coefficient. All specifications include firm and country by sector by year fixed effects.
Source: OECD calculations on Orbis and Compustat data.

Table 5. Baseline regression, DFS financial constraints indices

Dependent Variable: TFP					
Intangible Intensity Measure: IntK_cat (0-1)	(1)	(2)	(3)	(4)	(5)
Financial Constraints Indices	DFS_vA	DFS_vB	DFS_vA2	DFS_vB2	DFS_PCA
Financial Constraints	**-0.029*** **	**-0.030*** **	**-0.018*** **	**-0.019*** **	**-0.034*** **
	(-93.3)	**(-94.3)**	**(-64.6)**	**(-68.3)**	**(-103.1)**
Financial Constraints * Intangible Intensity	**-0.012*** **	**-0.012*** **	**-0.007*** **	**-0.007*** **	**-0.013*** **
	(-29.5)	**(-30.1)**	**(-20.3)**	**(-20.1)**	**(-30.9)**
Log of Total Assets	0.168***	0.168***	0.165***	0.165***	0.176***
	(138.1)	(138.1)	(134.6)	(134.4)	(144.0)
Total Assets * Intangible Intensity	-0.019***	-0.019***	-0.017***	-0.017***	-0.015***
	(-11.8)	(-12.0)	(-10.9)	(-10.9)	(-9.4)
Ebitda	0.006***	0.006***	0.007***	0.007***	0.006***
	(3.6)	(3.6)	(3.7)	(3.7)	(3.6)
Ebitda * Intangible Intensity	0.005**	0.005**	0.006**	0.006**	0.005**
	(2.3)	(2.3)	(2.4)	(2.4)	(2.2)
Log of Age	-0.017***	-0.019***	-0.020***	-0.029***	-0.013***
	(-7.7)	(-8.5)	(-8.8)	(-12.5)	(-6.0)
Age * Intangible Intensity	0.011***	0.011***	0.007**	0.004	0.013***
	(4.0)	(3.7)	(2.4)	(1.4)	(4.5)
Observations	8,098,713	8,098,713	8,098,713	8,098,713	8,098,713
R-squared	0.816	0.816	0.807	0.807	0.816
Country-Sector-Year FE	**YES**	**YES**	**YES**	**YES**	**YES**
Firm FE	**YES**	**YES**	**YES**	**YES**	**YES**

Note: T-statistics in parentheses; standard errors clustered at the firm level. Significance Level: *10%, **5%, ***1%. The dependent variable is the log of total factor productivity, estimated according to the GMM Wooldridge (2009) approach. Financial constraints at firm-level are proxied by a different index in each specification. The "DFS" indices consist in a revisited version of the financial constraints index developed by Musso and Schiavo (2008); among them, in those labelled as "vA" ("vB"), the reference group is a given country-sector-year (country-sector) cell. In "vA2" ("vB2"), the aggregation strategy changes: not the sum of the scores for each component of the index as in "vA" ("vB"), but rather the number of variables for which the firm lies in the fifth quintile of the distribution. The "PCA" version is built from a principal component analysis (first component) on the scores of each variable included in the index. Further details are provided in the text. Intangible Intensity is a categorical binary variable that takes value 1 if sectoral intangible intensity is above the median and 0 if below the median. Intangible intensity is measured as the sum of intangible assets over the sum of total assets over the 1990 to 2006 period for each U.S. listed firm with available data in Compustat; firm level estimates are aggregated at sector level by taking the median-firm intangible intensity ratio of each sector. The remaining explanatory variables are included as controls; while the details about their construction and sources are provided in the text, it is worth noticing that ebitda is divided by 10 mln to adjust the scale of the coefficient. All specifications include firm and country by sector by year fixed effects.
Source: OECD calculations on Orbis and Compustat data.

55. The magnitude of the effect is substantial. Consider, for example, the second model in Table 5, in which we use the "DFS_vB" index to proxy for financial constraints.[44] Compare two firms, one at the 75^{th} (DSF_vB = 6.56) and one at the 25^{th} (DSF_vB = 3.75) percentile of the

[44] From now on, for the sake of brevity, the discussion proceeds by using this index as the benchmark. We choose the "DFS_vB" index for two reasons. First, each country-sector is the most appropriate reference group: on the one side, it allows to compare firms with the majority of their competitors; on the other side, it is large enough to guarantee a sufficient number of observations within each group in our data. Second, the sum of the scores is the most comprehensive aggregation strategy, so that all dimensions are taken into account.

financial constraints distribution; their difference in terms of financial constraints (2.81) explains 14.4% of their changes in productivity if they operate in highly intangible intensive sectors, while 10.3% in low intangible ones.[45] The 4.1% differential effect, as shown by the interacted term "Financial Constraints Index * Intangible Intensity", is significant at the 1% level and implies a 40% increase in the relevance of financing frictions; moreover, its size is consistent across indices, varying between 5.5% (WW_num) and 1.2% (SAFE_vB).[46]

56. Overall, these findings suggest that, especially in those innovative sectors in which investment in intangibles is a key driver of productivity, financing constraints act as a drag on productivity growth. One potential explanation is that intangibles are harder to finance: they are often firm-specific, so that their valuation is complex and uncertain (e.g., asymmetric information issues); moreover, they are difficult to be pledged as collaterals when sourcing for external capital, due to their lower liquidation value. It follows that firms operating in these sectors are more sensitive to financing conditions and that intangible intensity emphasizes a new dimension in describing the relative exposure of industries to financing frictions in the new digital economy.

5.2. Robustness

5.2.1. Intangible intensity measures

57. In the baseline framework, we measure intangible intensity with a "0 − 1" categorical variable to reduce the potential attenuation bias arising from the extent to which the benchmark country (U.S.) differs from a frictionless economy. A natural concern, given the nature of the empirical approach and the relevant role played by our intangible intensity measure, is whether the "0 − 1" partition in low versus high intangible intensive sectors is too extreme. To address it, the first specification in Table 6 employs the continuous measure of intangible intensity ("IntK_cont"). Results are equally significant and similarly relevant in size. The comparison between two firms at the mean of the financial constraints distribution, but one belonging to a sector in the first quartile of the intangible intensity distribution (e.g., "Coke and Petroleum") and one to a sector in the fourth quartile (e.g., "Computer Equipment"), shows that financial constraints explain approximately 3.7% more of the variation in productivity in the latter sector compared to the former.

58. In specification (2), we use an alternative continuous proxy for intangible intensity, while in specifications (3) and (4) we distinguish between the knowledge and the organizational

[45] Indeed, the standard deviation of our dependent variable (TFP) equals 0.82; the regression coefficient equals −0.030 for non-intensive sectors, while (−0.030 − 0.012) = −0.042 for highly intangible intensive sectors. The reported effects are calculated as follows: [Coefficient * (P75index - P25index)] / TFP Standard Deviation.

[46] It is worth noticing how the control variables included in the analysis have, in general, the expected sign. The full effect of total assets and profitability on productivity changes is strongly positive, albeit their differential impact on intangible intensive sectors differs: total assets are slightly less relevant in these sectors, while the role of profitability is consistently higher. The evidence about age is more noisy, but relatively older firms are found to have an advantage in innovative sectors (e.g., higher reputation, credit history). As these findings are consistent across specifications, the coefficients of the control variables are not reported in the following tables for the sake of brevity; yet all controls and their interactions with intangible intensity are always included in the analysis. Full tables are available upon request.

components of intangible intensity.[47] The effect of interest is confirmed in all specifications. The size of the differential effect is larger with respect to organizational intensive sectors rather than knowledge intensive ones; this finding might be explained by the fact that knowledge assets, such as patents, are relatively less difficult to be pledged as collaterals if compared to human capital or distribution networks (Figure 4). Finally, in Table 7 we check whether adopting a continuous measure affects our findings when using different financial constraints indices; reassuringly, it does not.

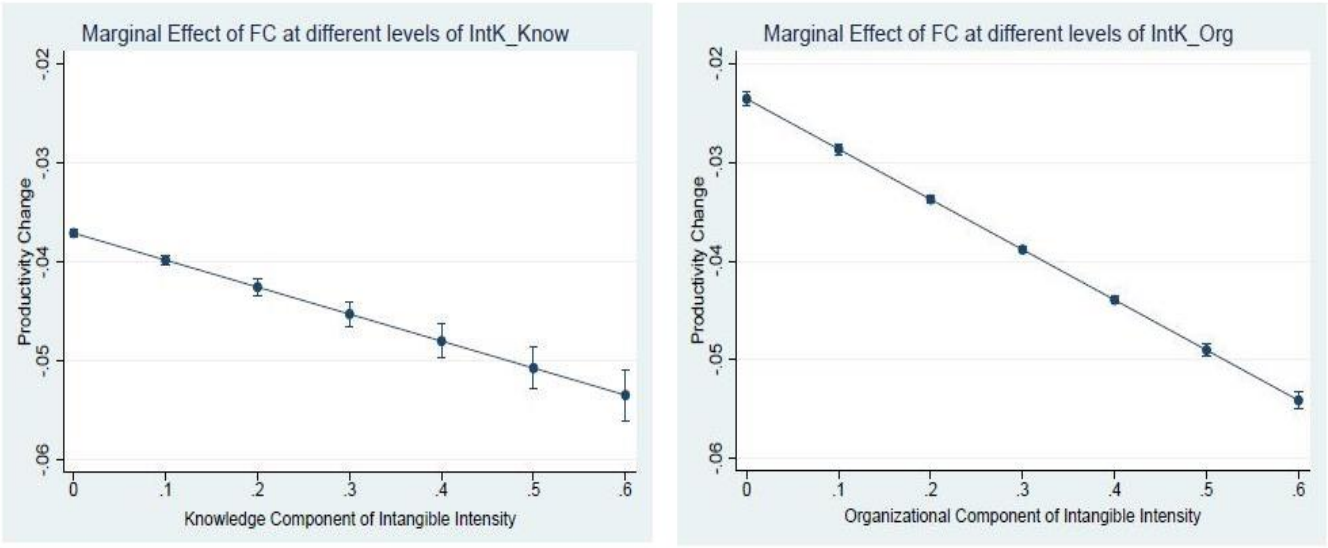
Table 6. Robustness, alternative intangible intensity measures

Dependent Variable: TFP				
Financial Constraints Index: DFS_vB	(1)	(2)	(3)	(4)
Intangible Intensity Measures	IntK_cont	IntK_Med	IntK_Know	IntK_Org
Financial Constraints	**-0.029*** **	**-0.028*** **	**-0.037*** **	**-0.023*** **
	(-48.1)	**(-47.0)**	**(-172.1)**	**(-49.6)**
Financial Constraints * Intangible Intensity	**-0.018*** **	**-0.022*** **	**-0.027*** **	**-0.050*** **
	(-15.1)	**(-17.3)**	**(-9.5)**	**(-32.1)**
Observations	8,098,713	8,098,713	8,098,713	8,098,713
R-squared	0.816	0.816	0.816	0.816
Set of Controls (Singularly and Interacted with IntK)	**YES**	**YES**	**YES**	**YES**
Country-Sector-Year FE	**YES**	**YES**	**YES**	**YES**
Firm FE	**YES**	**YES**	**YES**	**YES**

Note: T-statistics in parentheses; standard errors clustered at the firm level. Significance Level: *10%, **5%, ***1%. The dependent variable is the log of total factor productivity, estimated according to the GMM Wooldridge (2009) approach. Financial constraints at firm-level are proxied by our baseline index, "DFS_vB. Each specification employs a different measure of intangible intensity. In specification (1), intangible intensity is measured as the sum of intangible assets over the sum of total assets over the period for each U.S. listed firm with available data in Compustat; firm level estimates are aggregated at sector level by taking the median-firm intangible intensity ratio of each sector. In specification (2), we calculate the ratio of intangibles over total assets for each firm-year; then, for each firm, we find the median value over the period and, finally, take the industry median for each sector. Specifications (3) and (4) exploit separately the two sub-components (details in the text) of intangible intensity: the knowledge and the organizational pieces, respectively. All specifications include firm and country by sector by year fixed effects, as well as the usual set of controls (total assets, ebitda and age, together with their interactions with intangible intensity).
Source: OECD calculations on Orbis and Compustat data.

[47] In specification (1), intangible intensity is measured as the sum of intangible assets over the sum of total assets over the period for each U.S. listed firm with available data in Compustat; firm level estimates are aggregated at sector level by taking the median-firm intangible intensity ratio of each sector. In specification (2), we calculate the ratio of intangibles over total assets for each firm-year; then, for each firm, we find the median value over the period and, finally, take the industry median for each sector.

Figure 4. Marginal effect of financing frictions on productivity growth



Note: This figure presents the marginal effect of financing frictions on productivity growth at different levels of knowledge intangible intensity (left panel) and of organizational intangible intensity (right panel). The marginal effects are calculated on the basis of specifications (3) and (4) in Table 6. Knowledge-based capital includes a firm's spending to develop knowledge, patents, or software, while the organization-based is computed by using a fraction of the Selling, General and Administrative expense (SG&A), which includes advertising to build brand capital, human capital, customer relationships and distribution systems. Both measures are based on U.S. listed firms Compustat data; additional details are provided in the text.
Source: OECD calculations on Orbis and Compustat data.

Table 7. Robustness, continuous intangible intensity and alternative financial constraints indices

	Dependent Variable: TFP								
Intangible Intensity Measure: IntK_cont	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Financial Constraints Indices	WW_num	WW_cat	WW_norm	SAFE_vA	SAFE_vB	DFS_vA	DFS_vA2	DFS_vB2	DFS_PCA
Financial Constraints	**-0.937*** **	**-0.024*** **	**-0.070*** **	**-0.010*** **	**-0.007*** **	**-0.029*** **	**-0.019*** **	**-0.020*** **	**-0.033*** **
	(-49.4)	**(-54.4)**	**(-49.3)**	**(-18.8)**	**(-16.4)**	**(-48.3)**	**(-35.8)**	**(-37.3)**	**(-53.6)**
Financial Constraints * Intangible Intensity	**-0.400*** **	**-0.011*** **	**-0.036*** **	**-0.005*** **	**-0.005*** **	**-0.017*** **	**-0.008*** **	**-0.008*** **	**-0.018*** **
	(-10.5)	**(-12.2)**	**(-12.6)**	**(-4.3)**	**(-5.7)**	**(-14.1)**	**(-7.5)**	**(-7.8)**	**(-14.4)**
Observations	7,459,986	7,459,986	7,459,881	10,008,230	10,008,230	8,098,713	8,098,713	8,098,713	8,098,713
R-squared	0.818	0.818	0.818	0.809	0.809	0.816	0.807	0.807	0.816
Set of Controls (Singularly and Interacted with IntK)	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Country-Sector-Year FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Firm FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**

Note: T-statistics in parentheses; standard errors clustered at the firm level. Significance Level: *10%, **5%, ***1%. The dependent variable is the log of total factor productivity. Intangible Intensity is a continuous variable. Financial constraints at firm-level are proxied by a different index in each specification. The details on each index are provided in the text and in Table 2. All specifications include firm and country by sector by year fixed effects, as well as the usual set of controls (total assets, ebitda and age, together with their interactions with intangible intensity).
Source: OECD calculations on Orbis and Compustat data.

5.2.2. Firm level variables

59. We repeat our calculations by employing value added based (log) labor productivity as dependent variable. Even though the approach by Wooldridge (2009) addresses most of them, the estimation of total factor productivity might raise several measurement issues, that are absent when dealing with labor productivity.[48] Table 8 and Table 9 show that our results are unchanged independently of the intangible intensity and financial constraints measures used: the effect is still highly significant and its size comparable. Indeed, when comparing a firm at the 75^{th} and another firm at the 25^{th} percentile of the financial constraints distribution, the overall portion of labor productivity changes explained by financing frictions is slightly lower than the one on of TFP (6.8% and 11.3% for low and high intangible intensive sectors respectively), but the size of the differential effect is unaffected (4.3%).

Table 8. Robustness, labor productivity as dependent variable

Dependent Variable: Labor Productivity					
Financial Constraints Index: DFS_vB	(1)	(2)	(3)	(4)	(5)
Intangible Intensity Measures	IntK_cat	IntK_cont	IntK_Med	IntK_Know	IntK_Org
Financial Constraints	**-0.019*** **	**-0.019*** **	**-0.017*** **	**-0.026*** **	**-0.013*** **
	(-57.4)	**(-29.3)**	**(-28.1)**	**(-114.8)**	**(-26.8)**
Financial Constraints * Intangible Intensity	**-0.012*** **	**-0.017*** **	**-0.020*** **	**-0.027*** **	**-0.047*** **
	(-27.8)	**(-13.4)**	**(-15.4)**	**(-9.1)**	**(-28.4)**
Observations	8,153,060	8,153,060	8,153,060	8,153,060	8,153,060
R-squared	0.757	0.757	0.757	0.757	0.757
Set of Controls (Singularly and Interacted with IntK)	**YES**	**YES**	**YES**	**YES**	**YES**
Country-Sector-Year FE	**YES**	**YES**	**YES**	**YES**	**YES**
Firm FE	**YES**	**YES**	**YES**	**YES**	**YES**

Note: T-statistics in parentheses; standard errors clustered at the firm level. Significance Level: *10%, **5%, ***1%. The dependent variable is the log of value added based labor productivity. Financial constraints at firm-level are proxied by our baseline index, "DFS_vB". Each specification employs a different measure of intangible intensity. In specification (1) intangible intensity is a categorical binary variable that takes value 1 if sectoral intangible intensity is above the median and 0 if below the median, while in model (2) it is a continuous variable. In both cases, intangible intensity is measured as the sum of intangible assets over the sum of total assets over the 1990 to 2006 period for each U.S. listed firm with available data in Compustat; firm level estimates are aggregated at sector level by taking the median-firm intangible intensity ratio of each sector. In specification (3), we calculate the ratio of intangibles over total assets for each firm-year; then, for each firm, we find the firm median over the period and, finally, take the industry median for each sector. Specifications (4) and (5) exploit separately the two sub-components (details in the text) of intangible intensity: the knowledge and the organizational pieces, respectively. All specifications include firm and country by sector by year fixed effects, as well as the usual set of controls (total assets, ebitda and age, together with their interactions with intangible intensity).
Source: OECD calculations on Orbis and Compustat data.

[48] See the data section for a discussion of the advantages of the Wooldridge (2009) methodology.

Table 9. Robustness, labor productivity as dependent variable and alternative financial constraints indices

Dependent Variable: Labor Productivity									
Intangible Intensity Measure: IntK_cat (0-1)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Financial Constraints Indexes	WW_num	WW_cat	WW_norm	SAFE_vA	SAFE_vB	DFS_vA	DFS_vA2	DFS_vB2	DFS_PCA
Financial Constraints	**-0.720*** **	**-0.019*** **	**-0.056*** **	**-0.010*** **	**-0.008*** **	**-0.019*** **	**-0.011*** **	**-0.012*** **	**-0.023*** **
	(-70.2)	**(-79.5)**	**(-73.3)**	**(-34.4)**	**(-31.0)**	**(-56.6)**	**(-36.3)**	**(-39.4)**	**(-66.7)**
Financial Constraints * Intangible Intensity	**-0.397*** **	**-0.009*** **	**-0.030*** **	**-0.003*** **	**-0.001*** **	**-0.012*** **	**-0.007*** **	**-0.007*** **	**-0.013*** **
	(-29.7)	**(-27.7)**	**(-29.6)**	**(-6.8)**	**(-3.6)**	**(-27.3)**	**(-19.0)**	**(-18.7)**	**(-29.3)**
Observations	7,514,943	7,514,943	7,514,838	10,085,411	10,085,411	8,153,060	8,153,060	8,153,060	8,153,060
R-squared	0.761	0.761	0.761	0.756	0.756	0.757	0.756	0.756	0.757
Set of Controls (Singularly and Interacted with IntK)	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Country-Sector-Year FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Firm FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**

Note: T-statistics in parentheses; standard errors clustered at the firm level. Significance Level: *10%, **5%, ***1%. The dependent variable is the log of value added based labor productivity. Financial constraints at firm-level are proxied by a different index in each specification; the details on each index are provided in the text and in Table 2. Intangible Intensity is a categorical binary variable that takes value 1 if sectoral intangible intensity is above the median and 0 if below the median. All specifications include firm and country by sector by year fixed effects, as well as the usual set of controls (total assets, ebitda and age, together with their interactions with intangible intensity).
Source: OECD calculations on Orbis and Compustat data.

60. Next, in Table 10, to be sure that the assumptions behind the construction of our indices are not driving the results, we test whether they are consistent if we proxy financing constraints with simple balance sheet variables that are widely used in the literature - namely, financial leverage ratio (short term plus long term debt over total assets), cash to total assets (ratio of cash holdings over total assets), interest coverage ratio (ratio of ebitda over interest payments), cash flow over total assets (ratio of cash flows over total assets). As expected, more leveraged firms, as well as firms with less cash holdings, lower cash flows and interest coverage ratio, experience lower productivity growth and the impact of these financial characteristics is larger in intangible intensive sectors.

Table 10. Robustness, balance sheet variables singularly

Dependent Variable: TFP								
Balance Sheet Financial Item	Financial Leverage				Interest Coverage Ratio			
Type of Balance Sheet Variable	Continuous		Quintiles		Continuous		Quintiles	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intangible Intensity Measures	IntK_cat	IntK_cont	IntK_cat	IntK_cont	IntK_cat	IntK_cont	IntK_cat	IntK_cont
Balance Sheet Financial Item	**-0.026*** **	**-0.013** **	**-0.004*** **	**-0.001**	**0.007*** **	**0.006*** **	**0.036*** **	**0.039*** **
	(-10.1)	**(-2.5)**	**(-12.5)**	**(-1.4)**	**(17.5)**	**(8.2)**	**(121.3)**	**(67.0)**
Balance Sheet Financial Item * Intangible Intensity	**-0.057*** **	**-0.100*** **	**-0.007*** **	**-0.016*** **	**0.002*** **	**0.005*** **	**0.010*** **	**0.006*** **
	(-17.4)	**(-9.9)**	**(-17.3)**	**(-12.5)**	**(3.5)**	**(3.8)**	**(26.7)**	**(5.1)**
Observations	10,443,551	10,443,551	10,443,551	10,443,551	10,443,551	10,443,551	10,443,551	10,443,551
R-squared	0.806	0.806	0.806	0.806	0.806	0.806	0.808	0.808
Set of Controls (Singularly and Interacted with IntK)	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Country-Sector-Year FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Firm FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**

Dependent Variable: TFP								
Balance Sheet Financial Item	Cash to Total Assets				Cash Flow over Total Assets			
Type of Balance Sheet Variable	Continuous		Quintiles		Continuous		Quintiles	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Intangible Intensity Measures	IntK_cat	IntK_cont	IntK_cat	IntK_cont	IntK_cat	IntK_cont	IntK_cat	IntK_cont
Balance Sheet Financial Item	**0.142*** **	**0.123*** **	**0.019*** **	**0.017*** **	**0.337*** **	**0.418*** **	**0.042*** **	**0.046*** **
	(45.1)	**(18.5)**	**(62.8)**	**(29.0)**	**(95.8)**	**(56.9)**	**(150.8)**	**(82.5)**
Balance Sheet Financial Item * Intangible Intensity	**0.065*** **	**0.121*** **	**0.004*** **	**0.009*** **	**0.163*** **	**0.026***	**0.012*** **	**0.007*** **
	(16.1)	**(9.3)**	**(10.6)**	**(7.8)**	**(34.1)**	**(1.8)**	**(34.0)**	**(6.3)**
Observations	10,040,817	10,040,817	10,040,817	10,040,817	10,428,942	10,428,942	10,428,942	10,428,942
R-squared	0.809	0.809	0.809	0.809	0.807	0.807	0.809	0.809
Set of Controls (Singularly and Interacted with IntK)	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Country-Sector-Year FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Firm FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**

Note: T-statistics in parentheses; standard errors clustered at the firm level. Significance Level: *10%, **5%, ***1%. The dependent variable is the log of total factor productivity. Financial constraints at firm-level are proxied by a different financial item: financial leverage (top left panel; ratio of financial debt over total assets); interest coverage ratio (top right panel; ratio of ebitda over interest payments, divided by 1000 to adjust coefficients scale); cash to total assets (bottom left panel; ratio of cash holdings over total assets); cash flow over total assets (bottom right panel; ratio of cash flows over total assets). Further, each financial item is expressed either as a continuous variables or as a categorical variable based on quintiles. Intangible Intensity is either a categorical binary variable that takes value 1 if sectoral intangible intensity is above the median and 0 if below the median ("IntK_cat") or a continuous variable ("IntK_cont"). All specifications include firm and country by sector by year fixed effects, as well as the usual set of controls (total assets, ebitda and age, together with their interactions with intangible intensity).
Source: OECD calculations on Orbis and Compustat data.

5.2.3. Statistical and sample checks

61. In Table 11, we report the outcome of several robustness checks aimed at investigating whether specific parts of the sample or a precise statistical strategy are driving our findings. First, we exclude firms operating in countries with a very low number of observations, whose sample is generally biased towards the presence of large firms and our relative measure of financing constraints might be more noisy.[49] Second, we exclude Spain, whose large shares in terms of total number of observations might have a relevant influence on the relation under scrutiny. Third, we test the consistency of our findings in different time sub-periods. We omit the first five years (1995-2000), which are plagued by lower coverage, and compare the pre- and the post-crisis periods. All findings are consistent.[50]

62. Finally, coefficients significance is unaffected by how we treat standard errors. In the baseline specification, standard errors are clustered at the firm level (e.g., the unit of the panel); when clustering at different levels, independently on how large is the definition of the cluster, the coefficients of interest stays highly significant, suggesting that we are not neglecting relevant cross-correlations that may impact on the residuals.[51]

5.2.4. Cross-sectional regressions

63. We now turn to the test of the cross-sectional stability of the relationship of interest, in order to complement the results in the panel specification, which are based uniquely on the exploitation of within firm variation. Table 12 shows that our findings are stable in the cross-section and over time, independently on whether we use the categorical (upper panel) or the continuous (bottom panel) measure of intangible intensity.

64. For each year separately and after having controlled for country-sector conditions, as well as the usual set of firm level controls, we find that more financially constrained firms tend to have lower productivity growth and that the effect is larger in high intangible intensive sectors compared to low intangible ones.

[49] We set a threshold at 3.000 observations - hence, excluding Austria, China, Greece, Indonesia, India, Russia, Turkey and South Africa. Moreover, some of these countries are emerging economies, where productivity growth is still driven more by capital accumulation rather than innovative investment.

[50] As an additional check, we also split the sample according to firms' size (e.g., we set a threshold either at 50 employees or at a value of total assets equal to 10 mln dollars). Results, which are available upon request, are consistent in both the small and the large firms' samples.

[51] In specification (6), we do not cluster, but apply the White correction for heteroscedasticity. From specification (7) to specification (12), we cluster standard errors at the following levels, respectively: country-sector-year; country-year; sector-year; sector; country.

Table 11. Robustness, sample and statistical checks

Dependent Variable: TFP -- Intangible Intensity Measure: IntK_cat (0-1)												
Financial Constraints Index: DFS_vB	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Stats Check	ExclCou	NoESP	T>2000	T>2007	T<2008	No Clu	Clu (cst)	Clu (ct)	Clu(st)	Clu(cs)	Clu(s)	Clu(c)
Financial Constraints	**-0.029*** **	**-0.025*** **	**-0.027*** **	**-0.011*** **	**-0.012*** **	**-0.030*** **	**-0.030*** **	**-0.030*** **	**-0.030*** **	**-0.030*** **	**-0.030*** **	**-0.030*** **
	(-109.3)	**(-67.3)**	**(-79.2)**	**(-23.4)**	**(-27.0)**	**(-113.2)**	**(-31.6)**	**(-16.8)**	**(-25.1)**	**(-12.1)**	**(-8.0)**	**(-6.3)**
Financial Constraints * Intangible Intensity	**-0.013*** **	**-0.014*** **	**-0.011*** **	**-0.008*** **	**-0.015*** **	**-0.012*** **	**-0.012*** **	**-0.012*** **	**-0.012*** **	**-0.012*** **	**-0.012** **	**-0.012*** **
	(-38.2)	**(-28.5)**	**(-24.7)**	**(-13.7)**	**(-27.1)**	**(-36.6)**	**(-10.2)**	**(-16.0)**	**(-7.8)**	**(-3.6)**	**(-2.5)**	**(-8.8)**
Observations	8,093,047	5,402,954	7,073,708	4,316,865	3,574,728	8,098,713	8,098,713	8,098,713	8,098,713	8,098,713	8,098,713	8,098,713
R-squared	0.816	0.839	0.820	0.842	0.845	0.816	0.816	0.816	0.816	0.816	0.816	0.816
Set of Controls (Singularly and Interacted with IntK)	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Country-Sector-Year FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Firm FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**

Note: T-statistics in parentheses; standard errors clustered at the firm level. Significance Level: *10%, **5%, ***1%. The dependent variable is the log of total factor productivity. Financial constraints at firm-level are proxied by our baseline index, "DFS_vB". Intangible Intensity is a categorical binary variable that takes value 1 if sectoral intangible intensity is above the median and 0 if below the median. Each specification differs with respect to either the reference sample or the treatment of standard errors. In specification (1), we exclude countries having less than 3000 observations (Austria, China, Greece, India, Indonesia, Russia, South Africa and Turkey), while in model (2) Spanish firms are excluded. Next, we exclude the 1995-2000 period (3), as well as we consider exclusively either the post (4) or pre (5) crisis period. In specification (6), we do not cluster standard errors, but apply White Correction for heteroscedasticity. In specifications (7) to (12), we treat standard errors by clustering as follows: country-sector-time (7); country-time (8); sector-time (9); country-sector (10); sector (11); country (12). All specifications include firm and country by sector by year fixed effects, as well as the usual set of controls (total assets, ebitda and age, together with their interactions with intangible intensity).
Source: OECD calculations on Orbis and Compustat data.

Table 12. Cross-sectional regressions

	Dependent Variable: TFP Growth -- Intangible Intensity Measure: IntK_cat (0-1)									
Financial Constraints Index: DFS_vB	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Financial Constraints	**0.000**	**-0.003****	**-0.007*****	**-0.012*****	**-0.008*****	**-0.009*****	**-0.009*****	**-0.002**	**-0.003**	**-0.003**
	(0.0)	**(-2.0)**	**(-3.0)**	**(-5.5)**	**(-2.9)**	**(-3.5)**	**(-5.2)**	**(-1.0)**	**(-1.1)**	**(-1.1)**
Financial Constraints * Intangible Intensity	**-0.007****	**-0.007*****	**-0.013*****	**-0.009*****	**-0.012*****	**-0.008*****	**-0.007*****	**-0.010*****	**-0.012*****	**-0.012*****
	(-2.0)	**(-2.7)**	**(-3.9)**	**(-2.8)**	**(-4.2)**	**(-2.8)**	**(-2.9)**	**(-2.9)**	**(-2.9)**	**(-2.9)**
Set of Controls and Country-Sector FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Observations	106,761	168,369	203,425	242,635	285,490	319,156	344,915	376,592	364,629	412,501
R-squared	0.217	0.172	0.196	0.217	0.213	0.205	0.173	0.158	0.150	0.157

	Dependent Variable: TFP Growth -- Intangible Intensity Measure: IntK_cat (0-1)									
Financial Constraints Index: DFS_vB	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Financial Constraints	**-0.003**	**-0.004***	**-0.008*****	**-0.012*****	**-0.008*****	**-0.011*****	**-0.014*****	**-0.009*****	**-0.010*****	**-0.006*****
	(-1.0)	**(-1.7)**	**(-3.5)**	**(-6.7)**	**(-4.3)**	**(-5.7)**	**(-6.5)**	**(-5.5)**	**(-5.6)**	**(-3.3)**
Financial Constraints * Intangible Intensity	**-0.014*****	**-0.012*****	**-0.010*****	**-0.010*****	**-0.009*****	**-0.009*****	**-0.008*****	**-0.008*****	**-0.009*****	**-0.008*****
	(-2.9)	**(-3.0)**	**(-3.0)**	**(-4.5)**	**(-3.6)**	**(-4.0)**	**(-3.6)**	**(-3.8)**	**(-4.2)**	**(-3.6)**
Set of Controls and Country-Sector FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Observations	418,664	509,805	506,370	521,925	516,039	539,399	646,810	641,605	589,348	474,698
R-squared	0.151	0.159	0.161	0.172	0.169	0.146	0.145	0.143	0.158	0.137

	Dependent Variable: TFP Growth -- Intangible Intensity Measure: IntK_cont									
Financial Constraints Index: DFS_vB	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Financial Constraints	**0.001**	**-0.002**	**0.000**	**-0.006**	**-0.003**	**-0.005**	**-0.009*** **	**-0.002**	**-0.000**	**-0.000**
	(0.2)	**(-0.7)**	**(0.1)**	**(-1.3)**	**(-0.9)**	**(-1.5)**	**(-3.5)**	**(-0.6)**	**(-0.1)**	**(-0.1)**
Financial Constraints * Intangible Intensity	**-0.011**	**-0.012** **	**-0.032*** **	**-0.025*** **	**-0.026*** **	**-0.019*** **	**-0.009***	**-0.014***	**-0.021** **	**-0.021** **
	(-1.6)	**(-2.2)**	**(-3.4)**	**(-2.6)**	**(-4.0)**	**(-3.1)**	**(-1.7)**	**(-1.9)**	**(-2.5)**	**(-2.6)**
Set of Controls and Country-Sector FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Observations	106,761	168,369	203,425	242,635	285,490	319,156	344,915	376,592	364,629	412,501
R-squared	0.217	0.172	0.196	0.217	0.214	0.205	0.173	0.158	0.150	0.157

	Dependent Variable: TFP Growth -- Intangible Intensity Measure: IntK_cont									
Financial Constraints Index: DFS_vB	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Financial Constraints	**0.001**	**0.000**	**-0.005**	**-0.006** **	**-0.003**	**-0.007*** **	**-0.010*** **	**-0.008*** **	**-0.008** **	**-0.004**
	(0.3)	**(0.0)**	**(-1.5)**	**(-2.3)**	**(-1.1)**	**(-2.6)**	**(-3.6)**	**(-3.0)**	**(-2.5)**	**(-1.5)**
Financial Constraints * Intangible Intensity	**-0.028*** **	**-0.025*** **	**-0.019*** **	**-0.024*** **	**-0.021*** **	**-0.019*** **	**-0.018*** **	**-0.013** **	**-0.017*** **	**-0.015*** **
	(-3.2)	**(-3.2)**	**(-3.0)**	**(-4.3)**	**(-3.2)**	**(-3.3)**	**(-3.4)**	**(-2.4)**	**(-2.8)**	**(-2.8)**
Set of Controls and Country-Sector FE	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Observations	418,664	509,805	506,370	521,925	516,039	539,399	646,810	641,605	589,348	474,698
R-squared	0.150	0.159	0.161	0.172	0.169	0.146	0.145	0.143	0.157	0.137

Note: T-statistics in parentheses; standard errors clustered at the country-sector level. Significance Level: *10%, **5%, ***1%. The dependent variable is the first difference of log of total factor productivity. Financial constraints at firm-level are proxied by our baseline index (lagged), "DFS_vB". In the top panels, intangible intensity is a categorical binary variable that takes value 1 if sectoral intangible intensity is above the median and 0 if below the median, while it is a continuous variable in the bottom panels. All specifications include country by sector fixed effects and lagged TFP levels, as well as the usual set of controls (total assets, ebitda and age, together with their interactions with intangible intensity).
Source: OECD calculations on Orbis and Compustat data.

5.3. Exploratory evidence on the collateral channel and on the impact of framework conditions

65. The inherent difficulty to collateralize intangible assets is a crucial driver of the divergence between the internal and external costs of capital with respect to the purchase of intangibles. We investigate the collateral channel by triple interacting a firm level proxy for collateral availability (ratio of tangible fixed assets to total assets) with our firm financial constraints index and intangible intensity (first model, Table 13). The positive coefficient of the triple interaction term shows that a large portion of the differential negative impact of financing constraints in intangible intensive sectors disappears for those innovative firms with available collateral. More specifically, as shown in the bottom panel of Table 13 and in Figure 5, the marginal effect of financing frictions on productivity growth declines significantly with the level of collateral in high intangible intensive sectors, while it is almost unaffected by collateral availability in low intangible intensive ones.

66. Next, we test for aggregate country level institutional and economic characteristics that could amplify or mitigate the detrimental effect of financing frictions on the productivity growth of firms operating in intangible intensive sectors. Foremost, credit availability and the quality of the legal framework are expected to relax financial constraints, and relatively more in innovative sectors.[52]

67. The second model of Table 13 confirm our conjecture with respect to the beneficial effect of credit markets depth, which is larger in intangible intensive industries: the supplementary credit flows related to more developed credit markets provide firms with additional resources to fund their projects and their impact is more pronounced in sectors where they are relatively scarce. Similarly, a high quality legal framework has a moderating effect (third model, Table 13). The enforceability of financial contracts is an important obstacle to external financing and it is reasonable to believe that having an appropriate, up to date, set of contract laws is especially favorable for those sectors in which the additional contracting issues posed by intangible assets are more severe.[53]

[52] We use domestic credit as a percentage of GDP (World Bank) to measure financial development and the availability of credit, while the contract enforcement index (World Bank, Doing Business) to proxy for the ability of the legal system to enforce contracts and resolve disputes.

[53] See, for instance, Chen (2014). Furthermore, notice that, as expected, the overall marginal effect of both credit market development and contract enforceability on firms' productivity is significantly positive when all covariates are fixed at their means.

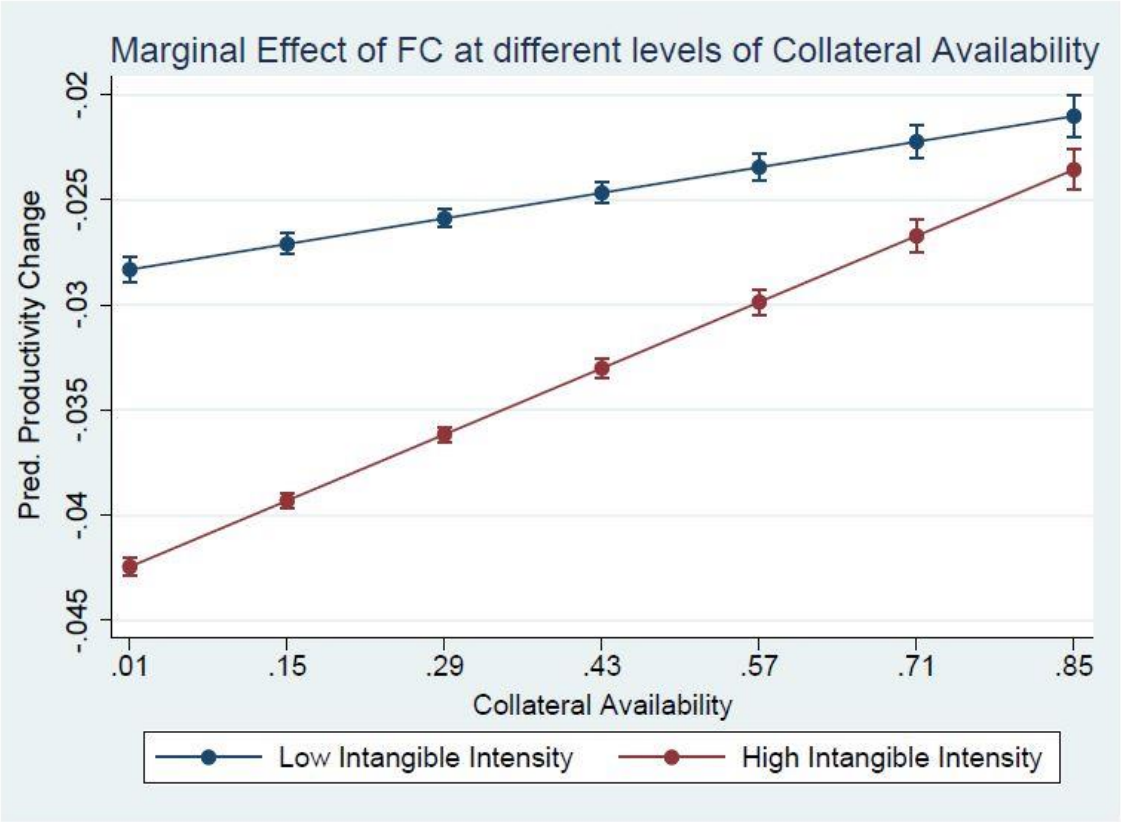
Table 13. Evidence on collateral channel and framework conditions

Dependent Variable: TFP -- Intangible Intensity Measure: IntK_cat (0-1)			
Financial Constraints Index: DFS_vB	(1)	(2)	(3)
Channels and Framework Conditions (CFC)	Collateral	CreditGDP	Contr. Enf.
Financial Constraints	**-0.030*** **	**-0.032*** **	**-0.047*** **
	(-61.6)	**(-43.5)**	**(-26.4)**
Financial Constraints * Intangible Intensity	**-0.014*** **	**-0.014*** **	**-0.013*** **
	(-22.7)	**(-15.2)**	**(-6.1)**
Financial Constraints * Intangible Intensity * CFC	**0.013*** **	**0.002** **	**0.005***
	(7.8)	**(2.4)**	**(1.8)**
Financial Constraints * CFC	**0.014*** **	0.003***	0.038***
	(11.1)	(5.3)	(13.8)
CFC	-0.369***		
	(-31.8)		
CFC * Intangible Intensity	-0.052		
	(-1.2)		
Observations	8,077,514	7,018,716	5,886,789
R-squared	0.816	0.818	0.825
Set of Controls (Singularly and Interacted with IntK and CFC)	**YES**	**YES**	**YES**
Country-Sector-Year FE	**YES**	**YES**	**YES**
Firm FE	**YES**	**YES**	**YES**

Marginal Effect of Financial Constraints				
Low Intangible Intensity	*P10 CFC*	-0.028***	-0.031***	-0.035***
		(-72.8)	(-49.4)	(-22.9)
	P50 CFC	-0.027***	-0.029***	-0.021***
		(-89.5)	(-34.8)	(-9.0)
	P90 CFC	-0.024***	-0.027***	-0.017***
		(-57.9)	(-22.4)	(-6.9)
High Intangible Intensity	*P10 CFC*	-0.043***	-0.045***	-0.047***
		(-154.1)	(-94.8)	(-65.4)
	P50 CFC	-0.039***	-0.042***	-0.030***
		(-182.3)	(-165.3)	(-102.3)
	P90 CFC	-0.029***	-0.038***	-0.027***
		(-74.1)	(-116.3)	(-64.4)

Note: T-statistics (Z-statistics) in parentheses in the upper (bottom) panel; standard errors clustered at the firm level. Significance Level: *10%, **5%, ***1%. The dependent variable is the log of total factor productivity. Financial constraints at firm-level are proxied by our baseline index, "DFS_vB". Intangible Intensity is a categorical binary variable that takes value 1 if sectoral intangible intensity is above the median and 0 if below the median. Each specification analyses a different channel or aggregate economic indicator (CFC). In specification (1) the availability of collateral at the firm level is proxied by the ratio of tangible fixed assets over total assets. The second and third indicators are country and time varying, but sector constant: domestic credit as a percentage of GDP (WB) and contract enforcement laws (WB, Doing Business), respectively. The bottom panel shows the marginal effect on productivity changes of an increase in financing frictions, either in high or in low intangible intensive sectors, at the 10^{th}, 50^{th} and 90^{th} percentiles of the CFC indicator. All specifications include firm and country by sector by year fixed effects, as well as the usual set of controls and their interactions.
Source: OECD calculations on Orbis, Compustat and World Bank data.

Figure 5. Marginal effect of financial constraints on productivity growth at different levels of collateral availability



Note: This figure presents the marginal effect of financing frictions on productivity growth at different levels of collateral availability in both high (red line) and low (blue line) intangible intensive sectors. The marginal effects are calculated on the basis of specification (1) in Table 13. Total factor productivity is estimated according to the GMM Wooldridge (2009) approach, while financial constraints at firm-level are proxied by our baseline index, "DFS_vB". Intangible Intensity is a categorical binary variable that takes value 1 if sectoral intangible intensity is above the median and 0 if below the median. Collateral availability at the firm level is proxied by the ratio of tangible fixed assets to total assets.
Source: OECD calculations on Orbis and Compustat data.

6. Conclusion

68. This paper examines how intangible assets shape the relationship between financing frictions and productivity growth at the firm-level. The analysis relies on an unbalanced panel covering firms in both manufacturing and services sectors in 29 countries during the 1995-2014 period and adopts a saturated fixed effects panel data model as the baseline methodological framework.

69. We make two contributions to the literature. First, and foremost, this work provides new empirical evidence of the links between financial constraints, intangible assets and productivity. We show that the detrimental impact of financial constraints on firms' productivity growth is consistently higher in relatively more intangible intensive sectors. Indeed, being intangible assets harder to finance due to their higher risk, uncertain valuation and difficulty to be pledged as collateral, firms operating in sectors that structurally rely on intangibles are more sensitive to financing conditions. These findings are robust to a wide range of robustness checks, including

an alternative empirical strategy, different measures for firms' productivity and financing constraints, and several variations of our intangible intensity measure. Second, building on a broad definition of intangible assets, it suggests a novel approach based on sector level intangible intensity to proxy for industries exposure to financing frictions in the new digital economy.

70. There are several extensions that can build upon the analysis in this paper. First, there is still room for improving the measurement of financial constraints at the firm level, in order to further reduce endogeneity concerns - for instance, by using firms' exposure to exogenous credit shocks as a proxy for financing frictions. Second, a relevant open question is whether sectoral intangible intensity affects the relationship between finance and allocative efficiency. On the one side, higher availability of credit might help reducing frictions that are particularly relevant in intangible intensive sectors and, thus, allow to efficiently distribute resources across units. On the other side, given the very nature of these sectors, the additional funds flowing in the economy might disproportionally favor firms owning more collaterals, which, in turn, are not necessarily those with the highest growth potential; it follows that, from an aggregate perspective, the beneficial effect on the productivity of each unit could be offset by a worsening in terms of allocative efficiency. The combination of the analyses on the first and the second moment of the productivity distribution would allow to fully understand through which channels the interaction between financing frictions and intangible intensity affects aggregate productivity growth.

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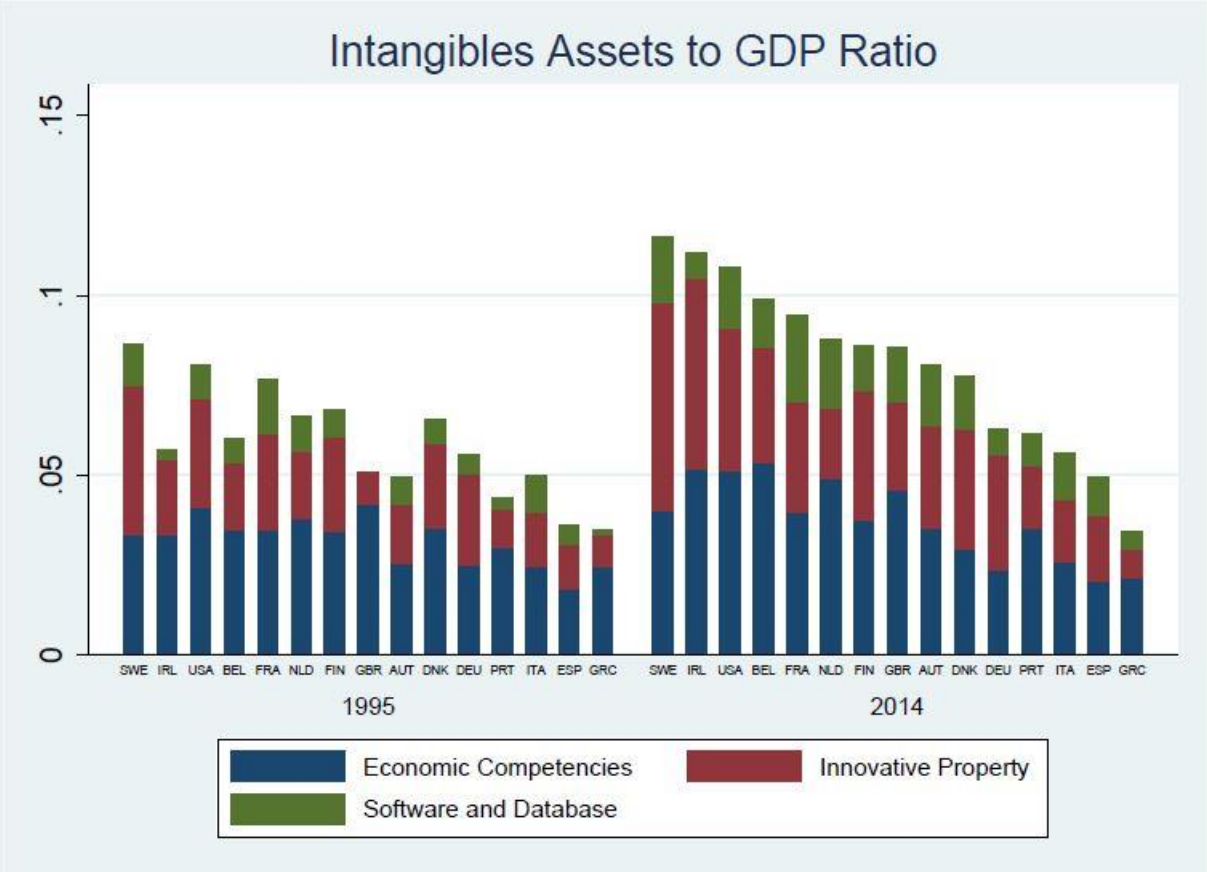
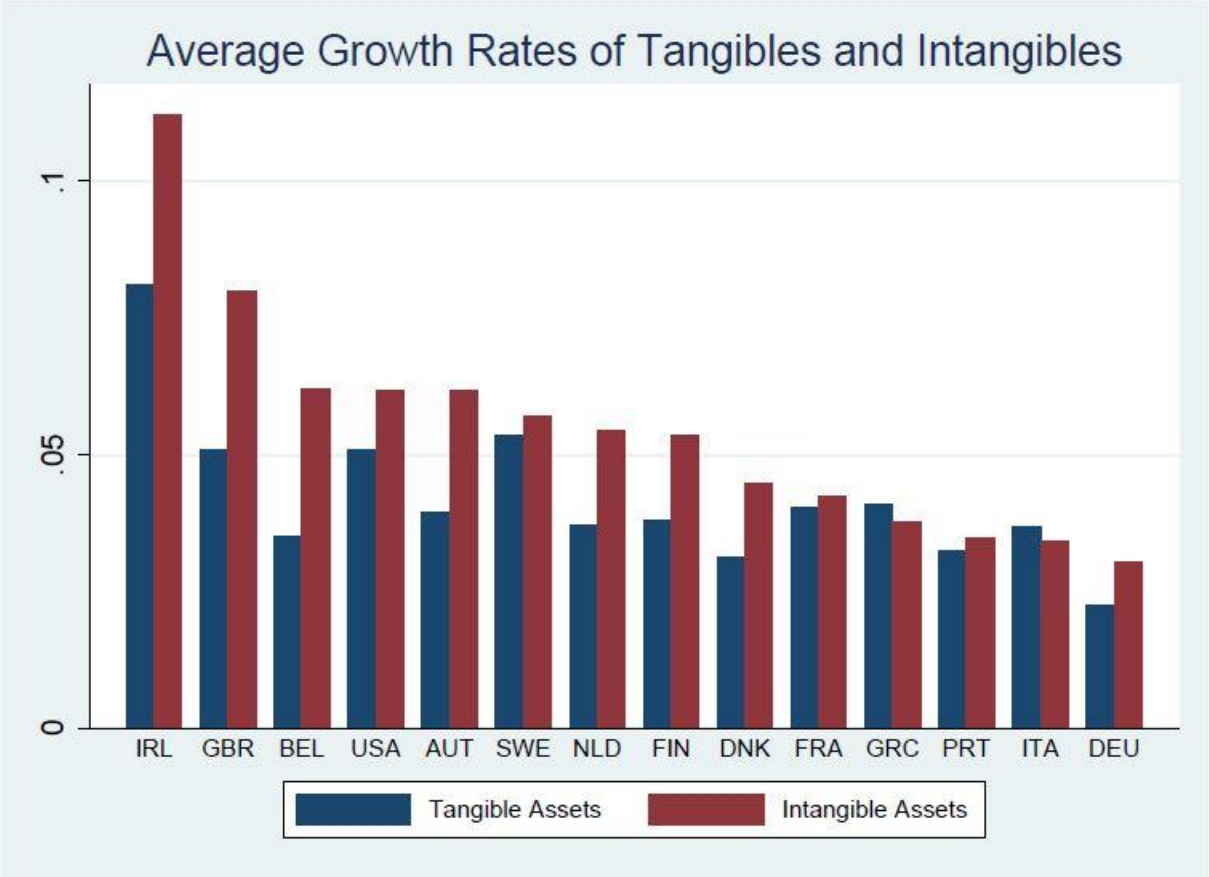
Annex A. Descriptive Statistics

Figure A.1. Increase in the stock of intangibles assets



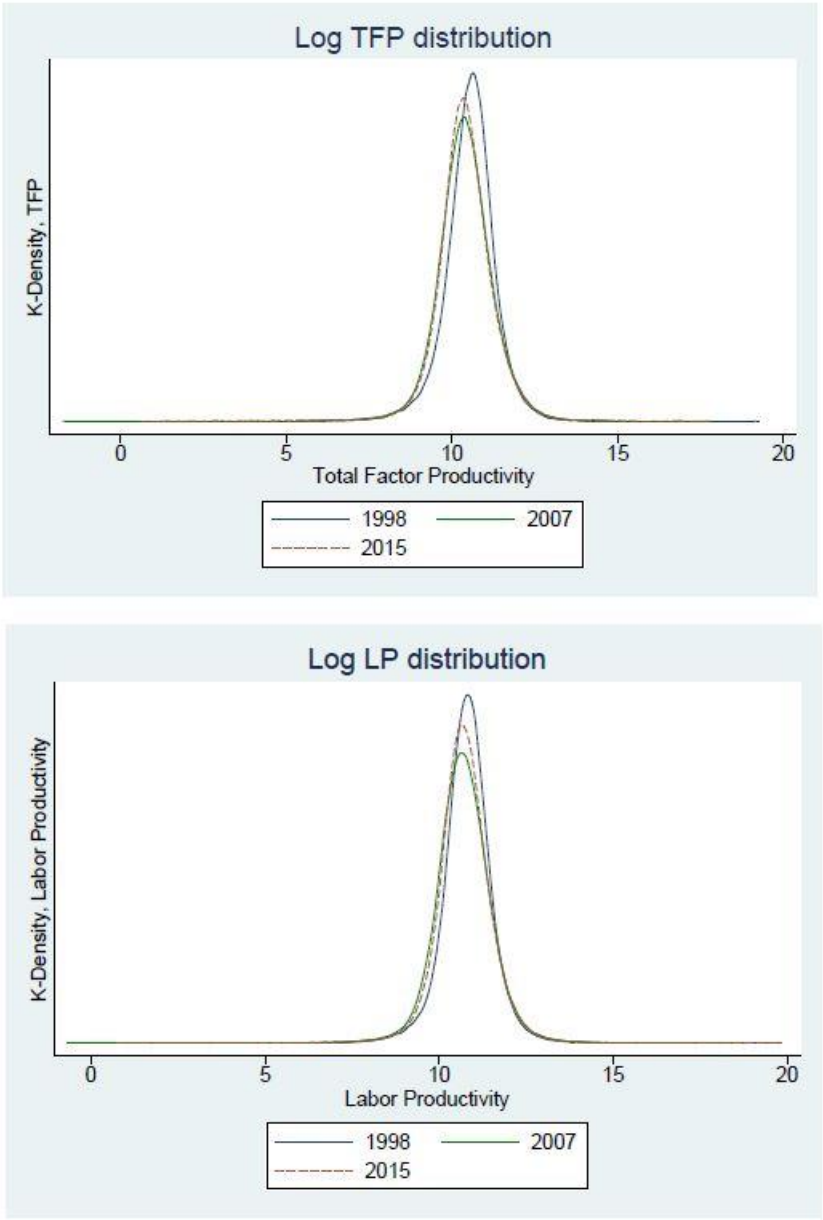
Note: This figure shows the rise in the stock of intangible assets as a share of GDP by comparing the intangibles to GDP ratio in 1995 (the only exception is Portugal, for which we use 2000, the first available date) and 2014 in a sample of OECD countries.
Source: Intangible assets are calculated as in Corrado et al. (2016) and the data are from the IntanInvest project. GDP calculations are based on the OECD National Accounts Database.

Figure A.2. Comparing growth rates of tangible and intangible assets



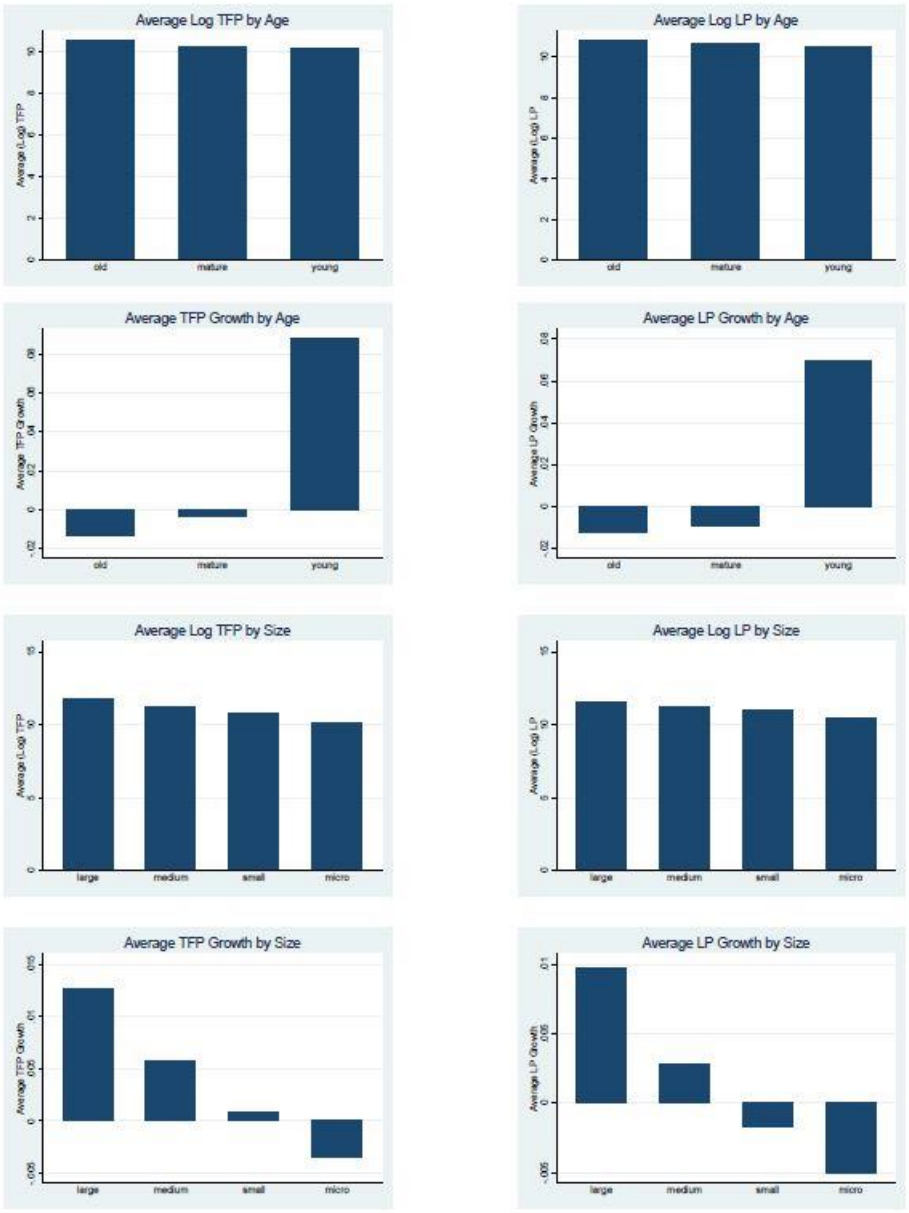
Note: The figure shows the average of the yearly growth rates in either the stock of intangible capital (red bars) or the stock of tangible capital (blue bars) for selected OECD countries during the 1995-2014 period (the only exceptions are Italy and Portugal, for which we evaluate the 2000-2014 period, due to limited data availability in earlier years).
Source: The stock of intangible assets is calculated as in Corrado et al. (2016), while calculations with respect to the stock of tangible assets are based on the OECD National Accounts Database.

Figure A.3. Productivity distribution over time



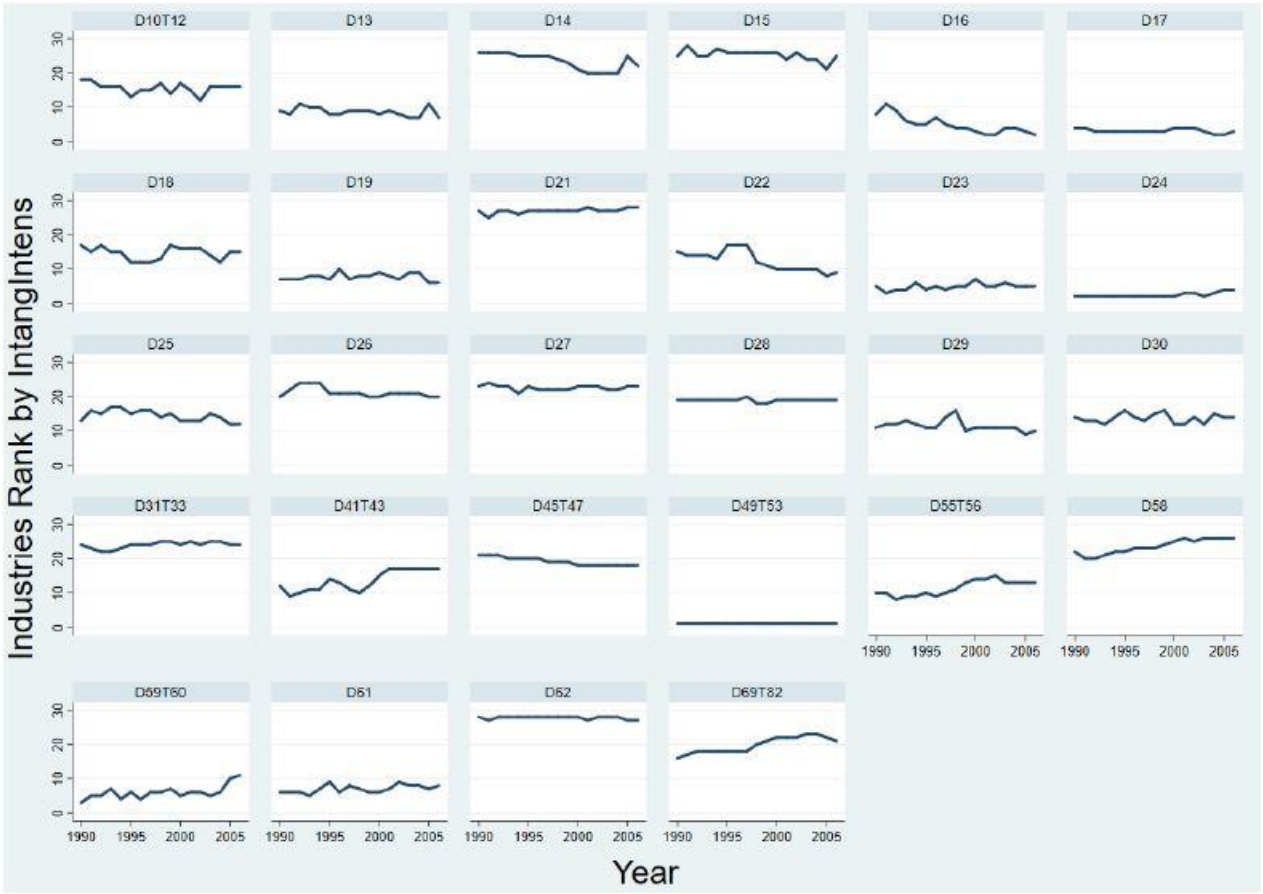
Note: This figure presents the log total factor productivity (top panel) and the log labor productivity (bottom panel) distributions at three different points in time: 1998 (blue line), 2007 (green line) and 2015 (dotted brown line).
Source: OECD calculations on Orbis data.

Figure A.4. Productivity (levels and growth rates) by size or age



Note: This figure shows average productivity levels and growth rates by group of firms. The top four panels present evidence with respect to different age classes; firms are classified as "young" if they operate since less than 5 years, "mature" if in between 5 and 10 years, while "old" if they are active by more than 10 years. In the bottom panels, firms are classified according to their size in terms of total assets: "micro" firms are those with 2 mln US $; "small" if total assets are in between 2 and 10 mln US $, while "medium" if in between 10 and 43 mln US $; "large" if total assets account for more than 43 mln US $. Averages are calculated over the pooled sample (e.g., pooled over time, countries and sectors). Left panels deal with log TFP, while right panels with log labor productivity.
Source: OECD calculations on Orbis data.

Figure A.5. US intangible assets intensity: sectors rank over time



Note: The figure shows the evolution of sectors rank in terms of intangible intensity over time (Nace Rev.2 classification). As the rank is calculated separately for each year (and relative to all other sectors), the time-varying measure of intangible intensity is employed (calculated as the median intangible intensity of all firms in a given sector-year).
Source: OECD calculations on Compustat data.

Table A.1. Number of observations by year

Year	Frequency	Percent Obs
1995	135,001	1.07
1996	210,231	1.67
1997	273,642	2.18
1998	330,411	2.63
1999	389,235	3.1
2000	442,777	3.52
2001	507,908	4.04
2002	545,076	4.34
2003	572,405	4.55
2004	610,461	4.86
2005	629,034	5
2006	782,136	6.22
2007	797,333	6.34
2008	817,864	6.51
2009	812,892	6.47
2010	787,521	6.26
2011	892,008	7.1
2012	878,544	6.99
2013	861,666	6.85
2014	720,410	5.73
2015	573,805	4.56
Total	12,570,360	100

Note: This table reports the number of observations by year, as well as the percentage shares of firms operating in each year (with respect to the whole sample).
Source: OECD calculations on Orbis data.

Table A.2. Number of observations (firm*year) and of unique firms by country

Country	Firm-Year	Percent Obs	Unique Firms
AUS	1,002	0.01	192
AUT	15,283	0.12	3,197
BEL	185,343	1.47	18,424
CHN	944	0.01	122
DEU	182,079	1.45	34,858
DNK	5,033	0.04	1,286
ESP	4,450,251	35.4	493,481
EST	6,904	0.05	1,725
FIN	246,698	1.96	36,426
FRA	1,734,075	13.79	236,986
GBR	399,365	3.18	53,438
GRC	970	0.01	136
HUN	45,778	0.36	7,600
IDN	2,256	0.02	270
IND	670	0.01	126
IRL	9,622	0.08	1,694
ITA	2,865,430	22.8	390,344
JPN	115,820	0.92	30,175
KOR	406,938	3.24	71,029
LUX	3,503	0.03	709
LVA	3,017	0.02	590
NLD	8,648	0.07	1,191
POL	4,498	0.04	762
PRT	917,382	7.3	147,987
RUS	1,403	0.01	235
SVN	78,420	0.62	13,846
SWE	877,171	6.98	101,281
TUR	1,130	0.01	202
ZAF	727	0.01	117
Total	12,570,360	100	1,648,429

Note: This table reports the number of observations by country and the percentage shares of firms operating in a given country (with respect to the whole sample). Further, the rightmost column shows the number of unique firms by country. Countries are identified by ISO-3 country codes.
Source: OECD calculations on Orbis data.

Table A.3. Number of observations (firm*year) and of unique firms by 2-digits Nace Rev.2 sector

Sector	Firm*Year	Percent Obs	Unique Firms	Sector	Firm*Year	Percent Obs	Unique Firms
10	323,667	2.57	37,857	47	1,317,278	10.48	176,394
11	48,182	0.38	5,068	49	524,526	4.17	65,246
12	1,256	0.01	140	50	19,161	0.15	2,300
13	129,264	1.03	15,017	51	6,167	0.05	728
14	125,131	1	17,067	52	186,800	1.49	23,906
15	89,448	0.71	11,178	53	12,164	0.1	1,695
16	150,557	1.2	18,913	55	230,820	1.84	30,313
17	64,791	0.52	7,005	56	529,776	4.21	84,692
18	167,425	1.33	19,713	58	97,911	0.78	13,960
19	7,083	0.06	805	59	46,377	0.37	6,626
21	23,045	0.18	2,322	60	14,534	0.12	1,983
22	164,761	1.31	18,529	61	30,288	0.24	4,419
23	182,943	1.46	21,023	62	204,725	1.63	29,766
24	77,896	0.62	8,551	63	64,641	0.51	10,031
25	626,051	4.98	75,497	69	219,750	1.75	29,224
26	112,957	0.9	14,932	70	195,152	1.55	29,255
27	112,171	0.89	13,727	71	252,517	2.01	37,938
28	310,600	2.47	36,329	72	21,731	0.17	3,158
29	79,731	0.63	9,425	73	126,513	1.01	17,840
30	28,493	0.23	3,584	74	109,861	0.87	15,586
31	148,478	1.18	17,872	75	12,753	0.1	1,863
32	104,199	0.83	13,009	77	94,841	0.75	12,393
33	136,325	1.08	17,509	78	33,747	0.27	5,166
41	796,934	6.34	115,688	79	70,455	0.56	9,212
42	122,132	0.97	17,602	80	28,570	0.23	4,003
43	1,181,260	9.4	165,798	81	153,566	1.22	22,828
45	594,470	4.73	71,188	82	148,267	1.18	22,502
46	1,908,219	15.18	230,054	Total	12,570,360	100	1,648,429

Note: This table reports the number of observations by 2-digits Nace Rev.2 sector, as well as the percentage shares of firms operating in each sector (with respect to the whole sample). Further, it shows the number of unique firms by sector.
Source: OECD calculations on Orbis data.

Table A.4. Size classes by country

	AUS	AUT	BEL	CHN	DEU	DNK	ESP	EST	FIN	FRA	GBR	GRC	HUN	IDN	IND
Employment															
1-19 empl	0.0%	0.1%	3.0%		0.4%	0.2%	23.7%	11.1%	9.2%	7.6%	0.3%	0.0%	1.6%	0.0%	0.0%
20-249 empl	1.0%	15.8%	37.0%	0.0%	11.4%	1.2%	36.7%	43.8%	22.1%	23.7%	8.9%	3.9%	30.2%	0.7%	0.1%
250+ empl	99.0%	84.1%	60.0%	100.0%	88.1%	98.6%	39.6%	45.1%	68.7%	68.7%	90.7%	96.1%	68.2%	99.3%	99.9%
Value Added															
1-19 empl	0.0%	0.5%	4.9%		0.8%	0.5%	18.9%	8.3%	6.5%	6.8%	0.5%	0.0%	4.4%	0.1%	0.0%
20-249 empl	1.3%	16.7%	36.1%	0.0%	12.3%	3.3%	35.6%	34.3%	18.6%	20.9%	9.4%	2.7%	29.0%	4.8%	0.3%
250+ empl	98.7%	82.8%	59.0%	100.0%	86.9%	96.2%	45.5%	57.4%	74.8%	72.3%	90.1%	97.2%	66.5%	95.1%	99.7%
Number of Firms															
1-19 empl	2.6%	5.4%	34.1%		20.6%	53.1%	82.1%	59.4%	74.3%	68.1%	19.8%	1.4%	26.4%	1.5%	0.9%
20-249 empl	35.0%	70.8%	59.0%	2.8%	56.3%	30.6%	17.0%	38.2%	23.4%	29.3%	60.2%	39.7%	62.7%	16.4%	10.1%
250+ empl	62.4%	23.8%	6.9%	97.2%	23.1%	16.3%	0.9%	2.4%	2.3%	2.6%	20.0%	58.9%	10.9%	82.1%	89.0%

	IRL	ITA	JPN	KOR	LUX	LVA	NLD	POL	PRT	RUS	SVN	SWE	TUR	ZAF	Total
Employment															
1-19 empl	0.3%	17.1%	16.1%	6.0%	0.4%	6.6%	0.0%	0.1%	28.3%	0.0%	14.7%	14.9%	0.0%	0.0%	7.3%
20-249 empl	4.9%	42.5%	40.7%	37.0%	11.3%	29.0%	1.3%	8.7%	36.5%	1.2%	38.3%	17.4%	1.5%	0.1%	20.0%
250+ empl	94.8%	40.3%	43.2%	57.0%	88.3%	64.3%	98.7%	91.2%	35.1%	98.8%	47.0%	67.7%	98.5%	99.9%	72.7%
Value Added															
1-19 empl	1.9%	13.7%	15.1%	5.5%	1.4%	4.0%	0.1%	0.2%	21.0%	0.0%	13.6%	11.3%	0.2%	0.0%	5.5%
20-249 empl	8.9%	38.8%	30.6%	27.5%	11.0%	28.6%	1.9%	9.8%	36.0%	0.0%	36.5%	16.9%	1.6%	0.6%	18.2%
250+ empl	89.2%	47.6%	54.3%	67.0%	87.6%	67.4%	98.0%	90.0%	42.9%	100.0%	49.9%	71.8%	98.2%	99.4%	76.3%
Number of Firms															
1-19 empl	29.3%	73.9%	67.7%	49.6%	22.1%	65.8%	2.3%	4.5%	85.8%	5.7%	77.1%	86.9%	3.0%	0.6%	73.4%
20-249 empl	49.2%	24.6%	31.0%	45.9%	60.5%	27.4%	40.3%	53.5%	13.5%	68.1%	20.8%	12.2%	27.8%	5.6%	24.0%
250+ empl	21.5%	1.5%	1.3%	4.5%	17.4%	6.8%	57.4%	42.0%	0.7%	26.2%	2.1%	0.8%	69.2%	93.8%	2.6%

Note: This table reports the share of economic activity (averaged over time) accounted for by firms belonging to three size categories, separately for each country included in the analysis. The share of economic activity is measured either in terms of employment or in terms of value added. The table section referred as "Number of Firms" counts the percentage of firms belonging to each size-category.
Source: OECD calculations on Orbis data.

Table A.5. Correlation between TFP and labor productivity, levels and growth rates

	Log TFP	TFP growth	Log LP	LP growth
Log TFP	1.00			
TFP growth	0.32	1.00		
Log LP	0.89	0.34	1.00	
LP growth	0.30	0.97	0.35	1.00

Note: This table displays all the pairwise correlation coefficients among productivity levels and growth rates variables. TFP is calculated by applying the GMM Wooldridge (2009) procedure, while labor productivity consists in the ratio between value added and the number of employees. Growth rates are calculated annually as the difference between each log productivity measure and its lagged value.
Source: OECD calculations on Orbis data.

Table A.6. Correlations between productivity and financial constraints

	TFP	TFP growth	LP	LP growth
DFS Index, vA	-0.37	-0.10	-0.30	-0.09
DFS Index, vB	-0.39	-0.10	-0.31	-0.09
DFS Index, vA2	-0.27	-0.13	-0.23	-0.11
DFS Index, vB2	-0.29	-0.13	-0.25	-0.11
DFS Index, pca	-0.30	-0.14	-0.27	-0.11
WW Index, num	-0.68	-0.16	-0.56	-0.14
WW Index, cat	-0.54	-0.16	-0.42	-0.14
WW Index, norm	-0.55	-0.18	-0.43	-0.16
SAFE Index, vA	-0.53	-0.02	-0.43	-0.02
SAFE Index, vB	-0.37	-0.01	-0.26	-0.01

Note: This table displays all the pairwise correlation coefficients between each of the various financial constraints indices employed in the analysis and each productivity measure (expressed in either levels or growth rates). TFP is calculated by applying the GMM Wooldridge (2009) procedure, while labor productivity consists in the ratio between value added and the number of employees. Growth rates are calculated annually as the difference between each log productivity measure and its lagged value. The "DFS" indices consist in a revisited version of the financial constraints index developed by Musso and Schiavo (2008); among them, in those labelled as "vA" ("vB"), the reference group is a given country-sector-year (country-sector) cell. In "vA2" ("vB2"), the aggregation strategy changes: not the sum of the scores for each component of the index as in "vA" ("vB"), but rather the number of variables for which the firm lies in the fifth quintile of the distribution. The "pca" version is built from a principal component analysis (first component) on the scores of each variable included in the index. The indices labelled as "WW" are based on coefficients extrapolation from Whited and Wu (2006); the "num" affix indicates the absolute version, while "cat" ("norm") is the relative version based on deciles of the distribution of the deviations from the country sector median (of the distribution of the normalized scores). Similarly, those labelled as "SAFE" on coefficients extrapolation based on the outcome of the SAFE survey, as reported by Ferrando et al (2015); "vA" stands for the absolute index expressed in deciles, while "vB" is its relative version. Further details are provided in the text.
Source: OECD calculations on Orbis data.