CHAPTER 13

REGULATIONS AND TECHNOLOGY DIFFUSION IN EUROPE: THE ROLE OF INDUSTRY DYNAMICS

Sara Amoroso[a], **Roberto Martino**[b]

[a] *Joint Research Centre, European Commission*
[b] *Directorate-General for Research and Innovation, European Commission*

Summary

This chapter focuses on the dynamics of innovation diffusion by analysing the impact of the regulatory framework on the gap between top firms and the followers. It expands on the existing literature by explicitly investigating the relationship between the regulatory frameworks in the labour, goods and capital markets and innovation diffusion, both directly and indirectly through the intermediate effect of business dynamism. This is particularly relevant for small firms engaging in risky activities, such as innovation, for which barriers to access to finance are tighter than for incumbent companies.

The authors developed an original index of potential technology diffusion following a consolidated approach that uses the total factor productivity distance to the technological frontier as proxy, which accounts for the potential transfer of knowledge and technology embodied in trade. The new proposed methodological approach informs on both the mediating and moderating role of business dynamism in the relationship between regulation in product, labour and capital markets and technology diffusion and thereby enriches existing literature on framework conditions and productivity.

This chapter produces evidence to inform reform efforts targeted at product, labour and capital markets while also providing insights on the impact of regulatory frameworks on technology diffusion, the latter being acknowledged recently as a key factor behind productivity dynamics.

1. The issue at stake

Subdued productivity performance has emerged as one of the main challenges facing Europe, and significantly so in the aftermath of the last economic crisis. While the slowdown in productivity growth can be traced back to the second half of the nineties, its severity has worsened in the last decade with zero or negative growth across Europe. European countries have reversed the trend only recently, and with unequal success across their regions, revealing different paths and high heterogeneity also within Member States (Iammarino et al., 2018).

When science and technology are considered to be the engines of growth, how can we rationalise the recent productivity growth slowdown and the concomitant boom in exciting new technologies? Different hypotheses have been put forward. They range from techno-pessimistic views à la Gordon (Gordon, 2012) – claiming that such slowdown is a permanent feature of modern economies that are 'physiologically' unable to bring productivity performance back to previous heights – to more optimistic views, which argue that the low growth countries are experiencing is due to the delay in the yet-to-unfold benefits from the digital revolution, caused by the slow transition from a production-oriented towards an intangible-based economy (Brynjolfsson and McAfee, 2011).

Analyses of productivity dynamics at company level provide further insights. Indeed, while productivity growth has generally slowed down, leading technological firms are still able to keep up and continue to grow. A plausible implication of this trend can be the increasing concentration of knowledge and innovation creation among a few actors and places and their lack of diffusion (Andrews et al., 2015; Andrews et al., 2016).

More specifically, innovation benefits are increasingly concentrated among frontier firms, a mechanism continually reinforced by the process of globalisation, which contributes to increasing the productivity gap between the best-performing companies and the rest. Markets tend to be highly concentrated and dominated by a few superstar companies.

At the same time, the process of technology diffusion has stalled, reducing the scope of lagging companies to catch up with the frontier leaders. On the one hand, this is driven by the greater complexity of technology, demanding higher absorption capacity in the form of prior accumulated knowledge and an adequate skills endowment, in order to be able to reap the benefits of technological change. On the other hand, adverse framework conditions may prevent a broader diffusion of innovation across firms, as they can hinder their capacity to invest and create barriers that affect the market entry of new innovative companies (Andrews et al., 2015; Brynjolfsson and McAfee, 2011). Therefore, the innovation gap between frontier firms and the rest grows wider, contributing to divergences in productivity performance.

Against this backdrop, the existing literature has analysed the impact of framework conditions on total factor productivity (TFP) dynamics, focusing mainly on the efficiency of labour, product and capital markets. The standard argument claims that excessive regulation in the product market is constraining productivity growth, as the excessive burden on companies discourages investment (Scarpetta and Tressel, 2002; Scarpetta et al., 2002). Similarly, stringent restrictions regulating hiring and firing may slow down the reallocation of the labour force from less- to more-productive firms, creating a negative effect on aggregate performance while also affecting hiring decisions, especially in downturn periods (Martin and Scarpetta, 2012; McGowan and Andrews, 2015; Thum-Thysen and Raciborski, 2017). Therefore, greater flexibility in the labour market is usually found to be linked to better productivity performance. However, a different perspective suggests that excessive deregulation may reduce firms' incentives to invest in human capital accumulation and training, with negative impacts in the medium and long term (Lucidi, 2012; Egért, 2016). Finally, barriers to access to finance are singled out as a deterrent to companies' investments, in particular for young firms engaging in innovation activities (Hall and Lerner, 2010; Agénor and Canuto, 2017; European Commission, 2018).

This chapter focuses on the dynamics of innovation diffusion by analysing the impact of the regulatory framework on the gap between top firms and the followers. It expands on the existing literature by explicitly investigating the relationship between the regulatory frameworks in the labour, goods and capital markets and innovation diffusion, both directly and indirectly through the intermediate effect of business dynamism. The latter is defined as the sum of shares of firms leaving and entering the market (churn rate) on the total number of active companies. Excessive burdens and bureaucratic barriers tend to discourage new companies from entering the market due to higher entry costs. This is particularly relevant for small firms engaging in risky activities, such as innovation, for which barriers to access to finance are tighter than for incumbent companies (Scarpetta et al., 2002; Acs et al., 2009; Agénor and Canuto, 2017).

The emphasis on the role of firm dynamics (entry and exit) as the main channel through which regulatory reforms may increase productivity growth (European Commission, 2018; de Haan and Parlevliet, 2018), via a greater diffusion of knowledge, is not sufficiently reflected in the existing studies. Hence, this work contributes to the literature in several ways.

First, we develop an original index of potential technology diffusion following a consolidated approach that uses the TFP distance to the technological frontier as the proxy (Nicoletti and Scarpetta, 2003; Buccirossi et al., 2013; Santacreu, 2015; Santacreu, 2017). We account for the potential transfer of knowledge and technology embodied in trade, a dimension that is increasingly relevant as new products, technologies and components are used across different sectors and activities (e.g. dual-use technologies, key enabling technologies, etc.). Specifically, we use a weighted average of the distance between the TFP of a firm i and the TFPs of all frontier firms in sectors that are trade-related to the sector of firm i. We use weights based on the intensity of trade in intermediate inputs between sectors.

Second, we contribute to the existing literature on framework conditions and productivity with a new methodological approach that informs on the mediating and moderating role of business dynamism in the relationship between regulation in product, labour and capital markets and technology diffusion.

Finally, the analysis and its findings are relevant for policy considerations in the European context. The slowdown in productivity growth has affected all European regions, even if with heterogeneous intensity. Member States have been asked to implement structural reforms in order to promote growth in Europe, with a specific focus on innovation as the main lever to boost productivity gains[1]. These reforms target product, labour and capital markets as crucial bottlenecks to the re-boosting of productivity and economic growth performance. This chapter produces evidence to inform those policies, whilst also providing insights into the impact of regulatory frameworks on technology diffusion, the latter being a key factor behind productivity dynamics (Andrews et al., 2016).

2. Technology diffusion

While research and innovation (R&I) are key engines of productivity growth, economies and companies can also grow by importing and adopting innovations produced elsewhere. This is particularly true for countries or regions that are far from the technological frontier and are less likely to produce innovation indigenously. Hence, foreign knowledge is an important source of productivity gains and a leverage for countries' growth, as emphasised in the literature on economic convergence. In his seminal work, Abramovitz (1986) highlighted how the potential gain from technology adoption is greater for those who lag behind, whose potential 'leap' is larger, as the technology imported would replace existing *capital technologically* superannuated. This is usually known as the advantage of backwardness: 'the larger the technological and, therefore, the productivity gap between leader and follower, the stronger the follower's potential for growth in productivity; and, other things being equal, the faster one expects the follower's growth rate to be' (Abramovitz 1986, pp. 386-387). One of the caveats is that the recipient must be able to understand and use the technology, either imported or through technology spillovers. An adequate absorption capacity is needed, which can be built via internal investment in R&I, skills

1 See also https://ec.europa.eu/info/business-economy-euro/growth-and-investment/structural-reforms/structural-reforms-economic-growth

and human capital (Falvey et al., 2007; Fu et al., 2011). The analysis in this chapter applies these arguments at the company level.

The evolutionary economics literature led by, among others, Dosi (1982) and Malerba (2002), has put forward the role of sectoral characteristics for differences in productivity. These authors show that productivity differentials are only partially related to innovation diffusion, and they depend on a 'more complex set of structural factors and sector-specific techno-economic conditions'. Castellacci (2007) shows that sectoral differentials in productivity growth in Europe are related to cross-industry differences in terms of technological opportunities, human capital, size of the market, degree of openness and appropriability conditions. In particular, when appropriability conditions are low, i.e. when it is more difficult to protect innovations from imitation, there is a greater opportunity for intra-industry knowledge diffusion and a positive effect on productivity growth.

Technology diffusion can occur via different channels: one is foreign direct investment (FDI) and trade in intermediate goods and machines, in which technology is embedded. Knowledge is diffused and can be translated into products and services as long as the recipient firm has the required absorptive capacity (Rivera and Romer, 1991; Grossman and Helpman, 1991; Santacreu, 2017). This channel is investigated in the international technology diffusion literature, upholding the view that domestic productivity growth is influenced by foreign sources of technology concentrated in a few countries, regions and companies. These actors are responsible for expanding the technological frontier. Countries that are farther from the technological frontier grow by adopting new foreign technologies, while economies closer to it grow by developing new technologies through research and development (R&D) investment (Santacreu, 2015). To this extent, international technology diffusion matters as it determines the pace at which the world's technology frontier may expand in the future (Eaton and Kortum, 1999; Eaton and Kortum, 2001; Keller, 2002; Comin and Mestieri, 2014) and the rate at which laggards can catch up. For instance, Jung and Lee (2010) find that TFP catch-up is more likely in sectors where technology is more explicit and embodied in equipment (such as electronics), and in sectors characterised by more monopolistic market structures. This allowed leading Korean companies to build innovation capacity to converge with Japanese productivity levels.

A second channel is the international knowledge spillovers that are not necessarily linked to any particular transmission form but simply stem from the stock of technology. In other words, current R&D builds on previous R&D performed globally, creating a linkage between national research and the national and global stock of knowledge (Nadiri, 1993; Keller, 2004). Since spillovers cannot be directly observed, the majority of empirical studies measures them by relating the firms' R&D investment to R&D activities, TFP (Keller, 2002), patents (Jaffe et al., 1993; Verspagen, 1993; Mancusi, 2008), or inward FDI (Aitken and Harrison, 1999) of another firm, conditional on the existence of trade flows between the countries to which the two firms belong, in the case of international knowledge spillovers (Coe and Helpmann, 1995).

However, the partially tacit, non-codified nature of technology makes its diffusion incomplete and more geographically localised (Von Hippel, 1994). The larger the tacit component of knowledge, the harder it is to import technology from abroad. In addition, the costs and capabilities needed to absorb knowledge increase with geographical distance. The transfer of tacit knowledge and its positive spillovers are bounded to take place mainly locally, building on personal interactions between or within firms and, as such, are strongly dependent on proximity (Archibugi and Filippetti, 2018).

A trend is also observed when considering innovation diffusion across economies. For instance, Bahar et al. (2014), building on the evidence of the strong decline in knowledge diffusion with geographical distance, empirically test the localised nature of knowledge transfers and confirmed that neighbouring countries share more knowledge and have similar static patterns of comparative advantage.

Knowledge flows between companies, universities and research centres across countries and regions are another source of innovation diffusion. The literature on R&D collaboration sparked by d'Aspremont and Jacquemin (1988) suggests that cooperation among firms or between companies and universities leads to knowledge spillovers, provided that the collaborating parties have a sufficient level of appropriation capabilities (Cassiman and Veugelers, 2002). Technological collaboration allows small and medium-sized enterprises (SMEs) to close the innovation gap with firms at the 'frontier' (Nieto and Santamaria, 2010) and, overall, that 'higher R&D collaboration is associated with a faster catch-up process of laggards firms very far from the national frontier, while firms close to this frontier keep pace with it' (Andrews et al., 2015, p.7). In the case of Europe, the European Research Area initiative has aimed to improve the diffusion of knowledge by promoting its free circulation together with the mobility of researchers, in an effort to maximise the benefits from knowledge spillovers (European Commission, 2018).

3. Framework conditions

Building on the above contributions, substantial literature has explored the role framework conditions have in shaping technology diffusion and differences in productivity and economic growth (Lynn et al., 1996; Nickell, 1993; Blanchard, 2004; Acemoglu et al., 2005; Buccirossi et al., 2013).

The institutions ruling the functioning of the product, labour and capital markets affect companies and their possibility to benefit from innovation outcomes. Framework conditions impact firms' decisions, including how much to invest, how to invest and whether to enter or leave the market. Transaction and entry costs may discourage small and young companies, which tend to be more innovative but are usually unable to get sufficient access to capital or to overcome cost and non-cost barriers to entry. Furthermore, framework conditions also affect the diffusion of technology, influencing the allocation of resources, including skilled workers and intangible capital, and hence companies' absorption capacity.

First, restrictive product market regulations hinder technology transfer and have a negative bearing on productivity (Crafts, 2006; Scarpetta and Tressel, 2002). The study by Scarpetta and Tressel (2002) explores the role of regulations and institutional settings in the products market in explaining TFP growth. They find that stringent regulatory settings in the product market have a negative impact on TFP and, although results are more tentative, on market access by new firms.

As regards labour market regulation, the focus is on non-wage labour costs, wages setting and hiring and firing restrictions for companies. On the one hand, the consensus seems to support the view that regulation that is too strict has negative effects on employment prospects, labour reallocation and eventually on aggregate productivity performance and growth. For instance, Tressel and Scarpetta (2004) analyse labour market institutions affecting labour adjustment costs in 18 Organisation for Economic Co-operation and Development (OECD) countries, finding that high labour adjustment costs (proxied by the strictness of employment protection legislation) decrease industry-level productivity. They argue that, when non-wage labour costs (hiring and firing costs) are high and labour market regulation does not allow for the flexible adjustment of wages, the incentives for innovation and adoption of new technologies are hindered, eventually leading to lower productivity performance. Moreover, these costs tend to discourage the entry of (especially small and medium-sized) firms into most markets (Scarpetta et al., 2002, p. 3). Consistent with this view, Thum-Thysen and Raciborski (2017) find that excessive restrictions in firing and hiring negatively affect TFP in the long term, while Balta and Mohl (2014) report that policies aimed at reducing employment protection legislation may foster productivity growth in economies engaged in a catching-up process.

On the other hand, there is some evidence suggesting that the opposite relationship may be in place. For instance, Lucidi (2012) argues that loose regulation in hiring and firing may provide companies with disincentives to invest in technological upgrade and adoption, opting for cost-competitiveness gains. Similarly, Egert (2016) reports evidence of a positive link between employment protection and TFP, suggesting that stricter restrictions in hiring and firing may incentivise companies to invest in human capital and preserve high-skilled employment. Last but not least, reforms increasing the flexibility of the labour market and reducing workers' bargaining position may have harmful effects in terms of inequality, increasing the gap between the top income shares and the rest (Jaumotte and Buitron, 2015; Dosi et al., 2017).

Among the framework conditions, constraints in accessing finance are singled out as a fundamental barrier to companies' investments, in particular for young firms engaging in innovation activities, and in the aftermath of the last economic crisis (Hall and Lerner, 2010; Agénor and Canuto, 2017; European Commission, 2018). The innovation process is far from being linear and its intrinsically higher probability of failure is a deterrent to provide innovative firms with credit (Mazzucato, 2013; Agénor and Canuto, 2017). Innovative companies may also face greater difficulties in getting access to standard bank-based sources of finance, given that their main value lies in intangible assets, such as human capital and the knowledge created by R&D activities, which are a weak form of collateral (Hall and Lerner, 2010; Brown et al., 2012). Agénor and Canuto (2017) show that the lack of access to finance, together with the high costs of monitoring innovative investments, negatively affect innovation activities whilst also providing firms with adverse incentives to invest in skills, reducing the share of workers able to engage in research activities and the overall absorption capacity. While this issue may be tackled by developed financial markets, such as, for instance, equity markets that do not require collateral, the overall wedge between the rate of return expected by external investors and that required by the entrepreneur may still be large, preventing the financing of innovative investments (Hall and Lerner, 2010). Gorodnichenko and Schnitzer (2013) find that financially constrained companies in developing and transition economies are less innovative and less likely to catch up with the innovation frontier compared to foreign firms. They also reveal a link between financial frictions and aggregate productivity indicators such as TFP and labour productivity.

Finally, business dynamism, measured as entry and exit rates, drive productivity growth as they contribute to the renewal of the business population, with new innovative firms entering the market and challenging incumbents. In turn, these industry dynamics are strongly affected by the regulatory frameworks wherein firms operate.

While studies on industry dynamics and productivity show that the entry and exit of firms makes a significant contribution to aggregate productivity growth (Foster et al., 2006), the available evidence is less conclusive concerning the relationship between business dynamism and framework conditions. Correia and Fontoura Gouveia (2017) find product market regulation has a negative impact on labour productivity, but they reach a different conclusion when employment protection legislation is considered, for which they find either a zero or slightly positive impact on labour productivity growth. Acs et al. (2009) link firms' entry decisions to knowledge spillovers and barriers to entrepreneurship, such as legal and bureaucratic constraints, and labour-market rigidities. Fuentelsaz et al. (2015) incorporate the role of the framework conditions to explore differences between incumbent firms and new entrants. In particular, they show how the informal advantages of being incumbent firms (renowned by investors, trade associations and banks and holding central positions in knowledge networks) provide them with a greater probability of survival and market share advantages. This is especially true in the context of weak market-supporting institutions, including property rights protection or the presence of financial intermediaries facilitating capital and information flows within the market. Indeed, 'in situations where market-supporting institutions are not sufficiently developed, informal ties acquire an important role in supporting economic exchanges. When formal institutions are weak, informal relationships have a greater influence on driving firm strategies and performance' (Fuentelsaz et al., 2015, p. 1782). These mechanisms at play are linked to the phenomenon of the survival of zombie firms in the market, due to their advantage as incumbents (McGowan et al., 2017).

4. Empirical analysis

4.1 Data

This chapter sets itself apart from the existing literature by assessing the impact of regulatory frameworks on technology diffusion, both directly and indirectly through the mediating and moderating effects of firm dynamics. For this purpose, we use balance-sheet information at the company level drawn from the Orbis database (Bureau Van Dijk) to compute TFP. The latter is the building block to construct our measure of technology diffusion. Firm-level data on productivity is matched with country- and sector-level data on business dynamics, human capital, and regulatory frameworks, covering the three dimensions of product, labour and capital (access to finance) market regulation from different sources. Overall, to account for all the dimensions we want to cover, we use a number of datasets at different levels of aggregation: firm-, sector-, and country-level.

TFP is our starting point to produce a measure of innovation diffusion. In order to compute TFP, we use information on turnover, value added, fixed assets, and the number of employees from the online Orbis database. Our final sample is an unbalanced panel of 1.4 million companies, from 2007 to 2017, belonging to 18 EU Member States[2]. Each company is associated

2 The countries included in the final sample are BE, BG, CZ, DE, DK, EE, ES, FI, FR, UK, HR, HU, IT, LV, PT, SE, SI and SK. To construct our final sample, we use the online version of Orbis and have restricted our selection to firms reporting balance sheet information on turnover, value added, capital, and employees for at least three consecutive years. Then we compare the coverage of our sample to the official population statistics from Eurostat, in terms of country, year, sector of activity and size class. To increase the representativeness of our data, we keep only those countries for which our sample accounts for either at least 50 % of total employment or 50 % of total gross output.

with a main sector of activity, following the NACE rev.2 classification at the 2-digit level.

Sector-specific information about business dynamics (firm entry and exit rates) is provided by Structural Business Statistics (SBS, Eurostat), covering the business economy for industry, construction, and distributive trades and services. The data are reported at 2-digit level for most of the economic activities, although some are reported as groups (e.g. '05-09' mining and quarrying or '10-12' manufacture of food products, beverages and tobacco products).

Data on the three framework conditions dimensions (product, labour, and capital market regulations) are obtained from different data sources.

To measure the degree of regulation in the product market, we use the Regulatory Impact Indicator developed by Egert and Wanner (2016) for the OECD. The indicator follows the same rationale of the Product Market Regulation indicator developed by the OECD itself, but has the advantage of being disaggregated by sector (NACE rev.2, 2 digits)[3]. Values are normalised as between 0 (low regulation) and 1 (high regulation).

To measure labour market regulation, we use the OECD's Employment Protection Legislation (EPL) indicators. The first one concerns individual and collective dismissals, while the other one is related to the regulation of wage setting. Both indicators take values between 0 and 6, where a higher value indicates stricter rules/procedures for the termination of contracts or for determining employees' wages. From these two indicators, we build a principal component-based weighted index.

Lastly, we include three indicators for the access to capital markets from the Global Competitiveness Index developed by the World Economic Forum. They capture different features of access to credit: (i) ease of access to bank loans; (ii) access to equity funding to finance innovative and risky projects; and (iii) access to finance by issuing bonds or shares on the capital market. The three indicators can take values between 1 and 7, where the higher the value, the better the performance of the capital market. From these three indicators, we build a principal component-based weighted index[4].

In addition to the three dimensions of market regulation, we control for the availability of human capital and absorption capacity, proxied by the growth rate in tertiary graduates and workers in science and technology. Country-level data on human capital is drawn from Eurostat.

Figure 13-1 includes a more detailed description of the variables and data sources, while Figure 13.2 reports the main descriptive statistics for each group of variables. The variables in bold are those used in the estimations.

3 The indicator exploits input-output matrices to measure the relevance of regulation in upstream sectors for downstream industries in each country. The rationale is that sectors using intermediate inputs from more regulated sectors are more affected by the rigidities in those sectors. We use the country-weighted version since we include country fixed-effects to account for heterogeneity in the estimates.

4 The three sub-indicators are part of the Financial Markets Development indicator in the Global Competitiveness Index, to which they contribute via a simple and weighted average. Since the three variables represent different forms of access to finance for companies, in our preliminary analysis, we have used the three indicators separately. However, they all yield similar results to those reported in this chapter.

Figure 13-1 Variables definition

Variable	Definition	Source
TFP	Computed as *Y/(L α))*, where *Y* is value added, L *and* K the number of employees and capital stock. The parameter α is derived as the labour share of output (turnover).	Orbis (Bureau van Dijk), firm-level, 2007-2017
Wage flexibility	In your country, how are wages generally set? [1 = by a centralised bargaining process; 7 = by each individual company].	World Economic Forum, country-level, 2007-2017
Hiring and firing restrictions	In your country, how would you characterise the hiring and firing of workers? [1 = heavily impeded by regulations; 7 = extremely flexible].	
Labour Market Flexibility Index (LabFlex)	Principal component-based weighted index (using 1 component loadings).	Authors' calculations
Product Market Regulation (ProdMarkReg)	The indicator measures the indirect impact of regulatory barriers to firm entry and to competition in the energy, transport and communication (ETC) sectors on all other sectors in the economy (via trade networks). We use the wider definition, including retail trade and professional services, as it is more appropriate for analysis aimed at exploiting cross-country and cross-sector variation in the data.	OECD 2013 REGIMPACT, sector-level, 2007-2016
Entry rate	Number of newly born enterprises over the number of active ones.	Structural Business Statistics (Eurostat), sector-level, 2007-2016
Exit rate	Number of economic enterprise deaths over the number of active ones.	
Churn rate	Sum of entry and exit rates of enterprises. It measures how frequently new firms are created and existing enterprises close down.	
Capital availability	In your country, how easy is it for entrepreneurs with innovative but risky projects to find venture capital? [1 = extremely difficult; 7 = extremely easy].	World Economic Forum, country-level, 2007-2017
Equity financing	In your country, how easy is it for companies to raise money by issuing shares on the stock market? [1 = extremely difficult; 7 = extremely easy].	
Access to finance	In your country, how easy is it to obtain a bank loan with only a good business plan and no collateral? [1 = extremely difficult; 7 = extremely easy].	
Access to Capital Markets Index (CapMkt)	Principal component-based weighted index (using 1 component loadings)	Authors' calculations
Human capital and absorption capacity growth	Growth rate in the number of persons with tertiary education (ISCED) and/or employed in science and technology	Eurostat, 2007-2017, sector-level

Source: Authors' own elaboration

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/partii/chapter13/figure_13-1.xlsx

Figure 13-2 Descriptive statistics

	Average	Median	Std. dev.	Min.	Max.
Turnover (EUR, thousands)	14 067	510	538 141	0	363 375 097
Value added (EUR, thousands)	4 423	197	196 281	0	340 034 292
Fixed assets (EUR, thousands)	1 989	30	81 432	0	57 306 763
No. of employees	55	5	1 593	1	648 254
log (TFP)	1.96	1.81	2.116	-19.07	21.08
Wage flexibility	4.1	4	0.82	2.2	6.2
Hiring and firing restrictions	3	2.9	0.5	2.1	6.1
Labour Market Flexibility Index	0	-0.19	1.25	-2.16	4.53
Product Market Regulation	0.12	0.088	0.092	0.0061	0.6
Exit rate	0.086	0.083	0.034	0	0.38
Entry rate	0.086	0.081	0.037	0	0.75
Churn rate	0.17	0.17	0.065	0	0.84
Capital availability	2.9	2.7	0.76	1.8	5.2
Equity financing	3.8	3.5	0.78	2.3	6.2
Access to finance	2.9	2.9	0.97	1.6	5.5
Access to Capital Markets Index	0.01	-0.63	1.64	-2.52	4.74
Human capital growth	0.03	0.02	0.02	-0.05	0.12

Science, research and innovation performance of the EU 2020

Source: Authors' own calculations

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/partii/chapter13/figure_13-2.xlsx

4.2 Methodology

Below, we illustrate the construction of our measure of potential for technology diffusion, which we then use in a mediated and moderated regression to explore the direct and indirect role of framework conditions, along with the increase in the availability of human capital.

We propose a new methodology to measure the potential for technology diffusion that combines the approach of the distance to technology frontier (Nelson and Phelps, 1966; Benhabib and Spiegel, 2005; Santacreu, 2017) with the theoretical foundations of the international trade in intermediate inputs (Caselli and Coleman, 2001; Keller, 2002; Sadik, 2008).

Unlike previous studies on the distance to technology frontier (Bertelsman et al., 2008; Andrews et al., 2016), we explicitly account for the possibility of the transfer of technology that is embodied in intermediate goods and machines (Eaton and Kortum, 1999; Rivera-Batiz and Romer, 1991; Grossman and Helpman, 1993), and that the intensity of technology diffusion is proportional to the intensity of trade between two sectors. Therefore, our measure of potential for technology diffusion is defined as:

$$TT_{ijit} = w_{jkt}\,[\ln(A_{ikt}) - \ln(\bar{A}_{jt})] \qquad (1)$$

with

$$\mathrm{w}_{jkt} = \frac{Z_{jkt}}{\Sigma_j Z_{jkt}}$$

$$\Sigma_j\, \mathrm{w}_{jkt} = 1$$

Where A_{ikt} is TFP of firm i in sector k, $\bar{A}_{jt}$ is the TFP of the leader frontier firm in sector j, w_{jkt} is a weight measuring global intermediate use by sector k of products Z of sector j (of the leader firm) at any time t[5].

Equation (1) can be decomposed as the sum of the traditional distance to the frontier, plus all the other distances to frontiers that are trade-related to firms in sectors that import products in the frontier's sector:

$$TT_{ijit} = w_{jjt}\,[\ln(A_{ijt}) - \ln(\bar{A}_{jt})] + \Sigma_{j\neq k}\, \mathrm{w}_{jkt}\,[\ln(A_{ikt}) - \ln(\bar{A}_{jt})] \qquad (2)$$

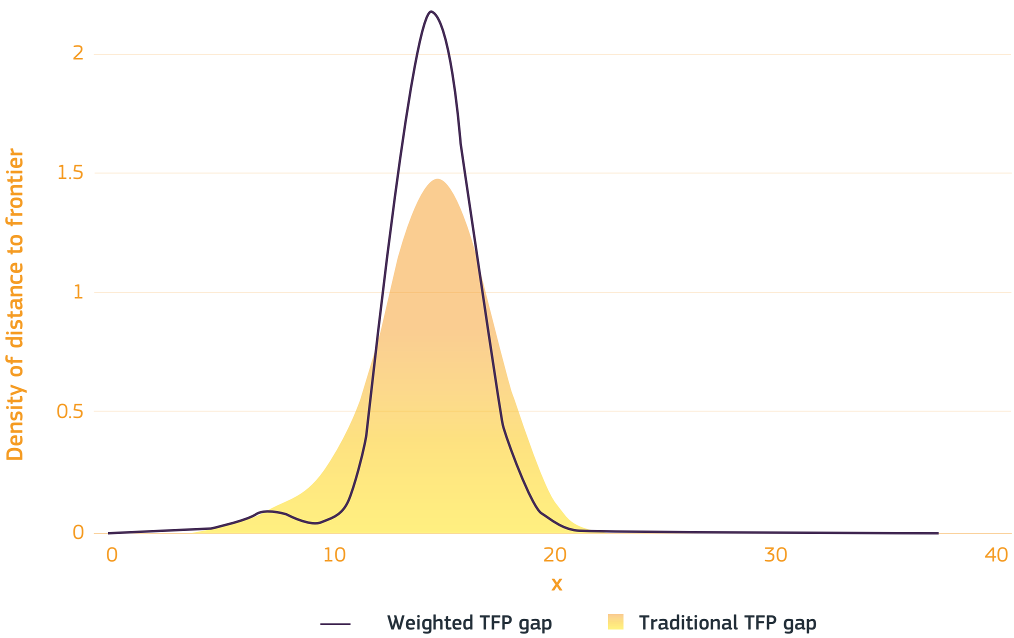
When there is no intersectoral trade ($\mathrm{w}_{jkt} = 0$), the distance from the frontier is only given by the gap with the leader firm in the same sector, as in the classical distance to the technological frontier in the literature.

Using the intensity of trade in intermediate inputs to weigh the distances to sector-specific frontiers provides a more appropriate measure of the technological gap, as it corrects for the bias arising when considering technologically unrelated sectors, such as, for instance, fishing and air transport. At the same time, it enables firms and frontiers companies operating in two different sectors that are nevertheless trading intermediate products with embodied technology to be related. To give an example of sector relatedness, the manufacturing sector of plastic and rubber products provides on average 11% of its products to the computer, electronic and optical products manufacturing sectors and 12% to the manufacturing of motor vehicles.

Figure 13-3 shows the differences, in 2016, between the trade-weighted and non-weighted distributions of the distance to the technological frontier. Since both measures are based on TFP gaps, observations closer to 0 identify companies with the smaller gap with respect to the frontier. The traditional, non-weighted distribution is more dispersed, with more companies on the two extremes, i.e. both closer (on the left) and farther (on the right) from the frontier.

5 Data on the use of intermediate inputs is extracted by the World Input-Output Tables from the World Input-Output Database: http://www.wiod.org/home

Figure 13-3 Weighted vs. traditional distance to the frontier, 2016



Source: Authors' own calculations
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/partii/chapter13/figure_13-3.xlsx

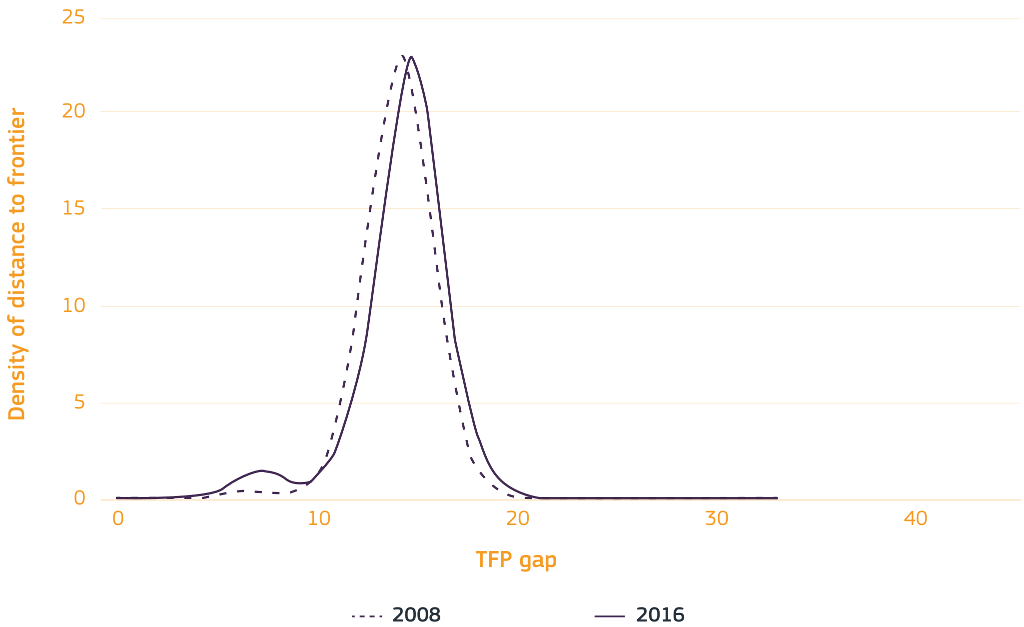
On the other hand, a distinguishing feature of our trade-weighted measure is the presence of a 'bump' of companies closer to the frontier than the rest.

While the unweighted and weighted distances to the frontier have similar overall averages (14.54 versus 14.6), the traditional distances are more dispersed (higher standard deviation and inter-quartile range) than the trade-weighted ones, with variations across sectors. Furthermore, the less the frontier's sector exports intermediate inputs to the other sectors, the smaller the difference between the traditional and the trade-weighted distances.

The evolution of the distribution of trade-weighted distance from 2008 to 2016 is shown in Figure 13-4. Two main features characterise the latest distribution. First, the main mode moves to the right, revealing an increase in the average distance to the TFP frontier. This finding is consistent with recent firm-level studies highlighting the rising gap between frontier companies and laggards which began at the beginning of the 2000s (Andrews et al., 2015). Second, in 2016, the density is characterised by a bump' emerging close to the bottom of the distribution. This new group of companies is getting closer to the frontier, despite the fact that the average economy-wide trend, i.e. the rest of the population, is falling behind. Such a trend may reveal the emergence of a new group of companies able to exploit and put into production cross-cutting technologies produced elsewhere, notably in related sectors or industry[6].

It is worth noting that this distinguishing feature can only be captured when considering the measure of distance with intermediate input trade correction (see also Figure 13-3).

Figure 13-4 Evolution of distances from the frontier



Source: Authors' own calculations
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/partii/chapter13/figure_13-4.xlsx

A first channel through which product, labour and capital market reforms may have an impact on firms' productivity and the process of technology diffusion is companies' dynamics (entry and exit). The latter is often associated with economic growth, as it facilitates the reallocation of resources from less-productive (and eventually exiting) firms to more productive ones. Adverse framework conditions may prevent the entry of adopters of superior technology, hindering innovation diffusion and productivity growth.

To investigate the mediating role of business churning and thus the direct and indirect effects of markets regulations on technology diffusion, we use a mediated regression analysis (Baron and Kenny, 1986; Preacher and Hayes, 2008) which consists of the estimation of two separate regression models:

$$TT_{it} = \beta_0 + \beta_1 TT_{it-1} + \beta_2 Churn_{jt-1} + Reg'_{jct-1}\beta^*_R + \beta_3 HC + e_{it} \quad (3)$$

$$Churn_{jt} = Reg'_{jct-1}\beta_R + u_{jt} \quad (4)$$

6 See, for instance, Xiao et al., (2018) for the concept of relatedness.

Where *TT* is the measure of potential for technology diffusion defined above, *Reg* includes the three indicators of labour, capital and product market regulation (*LabFlex, CapMkt, ProdMarkReg*), and *HC* is the growth rate of human capital. Both regression equations include sector, year, and *country* dummies.

Such an approach allows for identification of both the indirect (via the mediating effect of business dynamism, i.e. the churn rate in equation 4) and the direct effect of regulations on technology diffusion. The indirect effect is given by $\beta_2\beta_R$, while the direct effect is given by β^*_R. The sum of the two components gives the total effect[7].

4.3 Results

Figure 13-5 reports the results from the main mediated model (first column), and from a moderating model (second and third column). For the moderating model, we split the sample into firms in low-churn rate sectors and high-churn sectors in order to gauge the effects of regulation at different levels of business dynamism.

Our results suggest that framework conditions have both direct and indirect effects on innovation diffusion.

Labour-market flexibility is found to have a negative direct impact on our measure of technology diffusion: a unit increase in the value of the composite indicator of labour-market flexibility corresponds to a 3.3% decrease in technology diffusion. The indirect effect is slightly positive, meaning the increased flexibility in the wage-setting regimes and fewer restrictions on hiring and firing are positively related to business dynamism. However, the indirect effect is quite small, leading to a 0.1% increase in technology diffusion, hence the total relationship is still negative (-3.2%), being dominated by the direct effect.

The relationship between product market regulation and innovation diffusion is found to be negative. This holds for both its direct and indirect effect, the former being the most relevant channel. Results suggest that a 10% increase in the indicator corresponds to a 1.58%, to which the indirect channel contributes only 0.01%.

Improved conditions for accessing finance in the capital market have a considerably positive and direct effect on technology diffusion, leading to a 10.9% rise following a unit increase in the indicator. Even in this case, the direct channel is barely affected by the small negative indirect effect of capital accessibility on the churn rate. The weak relationship between access to finance and the churn rate is not surprising, as although easy access to venture, equity or debt financing are related to higher entry rates, they are also negatively related to exit rates. Indeed, if we consider the correlation coefficients relating access to capital markets with entry rate and exit rate separately, the latter is higher (-0.13) in absolute value than the former (0.008). This suggests that, while access to capital is moderately associated with the entry of new firms, it corresponds to a lower churn rate as it increases the probability of survival, hence decreasing the overall churn rate.

7 We estimate a system of simultaneous equations with a 3-stage least squares (3SLS), where the error terms e_{it} and u_{jt} are assumed to be correlated.

Figure 13-5 Results of estimations

Dep. var. innovation diffusion (TT)	Main model	Low churn rate	High churn rate
TT, t-1	0.713*** (0.001)	0.564*** (0.002)	0.642*** (0.002)
Labour Market Flexibility Index	-0.033*** (0.001)	-0.041*** (0.002)	0.010*** (0.002)
Product Market Regulation	-0.157*** (0.023)	2.700*** (0.124)	-1.153*** (0.060)
Access to capital markets	0.109*** (0.001)	0.131*** (0.002)	0.217*** (0.002)
Churn rate	0.139*** (0.002)		
Human capital growth	0.009*** (0.001)	0.053*** (0.001)	0.011*** (0.001)
Indirect effects			
Labour Market Flexibility Index	0.001*** (0.000)		
Product Market Regulation	-0.001*** (0.000)		
Access to capital markets	-0.001*** (0.000)		
Number of observations	3 260 637	1 952 775	1 171 121
R-sq	0.57/0.93	0.58	0.63

Science, research and innovation performance of the EU 2020

Source: Authors' own calculations
Note: Significance codes: p<0.001 ***, p<0.01 **, p<0.05 *. Robust standard error in parenthesis. All explanatory variables are lagged by one year. All econometric specifications include year, sector and country dummies.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/partii/chapter13/figure_13-5.xlsx

Finally, business dynamism and human capital growth positively affect the diffusion of technology: a 10% increase in the churn rate or in the human capital growth rate correspond to a 1.39% or a 0.9% increase in technology diffusion, respectively.

How do the above results vary if we consider sectors with different rates of churn rates? Columns 2 and 3 report the results from an alternative specification estimated for two sub-samples: firms in sectors (and countries) with both low churn rates (below the median value) and with high churn rates. The two separate regressions highlight the moderating role of the firm dynamics[8].

For low levels of churn rate, the elasticity of past technology diffusion is smaller, and firms drift away faster from the technological frontier, as suggested by the lower elasticity of current-to-past innovation diffusion. Furthermore, greater

8 We obtain similar results from a classical interaction effect between each regulation indicator and the churn rate.

absorption capacity, as measured by the growth rate of human capital, is a more relevant factor for technology diffusion in the context of a low churn rate than in high-churning ones (a 10 % higher growth rate in human capital corresponds to a 0.5 % and 0.1% increase in the dependent variable, respectively).

We also find that more regulated labour and product markets help the diffusion process. Indeed, more regulated labour markets may favour investments in human capital, as:

'...labour flexibility impacts on training and human capital accumulation. If labour relationships are expected to be short-lived, there is little incentive for firms to invest in both the general and specific training of their workforces [..] Workers, for their part, will be reluctant to acquire firm-specific skills if they do not feel a long-term commitment to their employers' (Lucidi, 2012, p. 266).

In addition, a more regulated product market can stimulate innovation in sectors where technology may be lacking altogether (e.g. environmental technologies) or in sectors that are dominated by a few firms, perhaps due to high entry costs (low-churning sectors tend to be characterised by higher employment costs) or larger economies of agglomeration.

Conversely, the results for firms in high-churning sectors are in line with a more traditional view. Less-regulated product, labour and capital markets increase technology diffusion, especially product and capital markets regulation.

Overall, the results on product (but also labour) market regulation relate to the theoretical framework linking competition and innovation in a non-linear inverted-U-shaped relationship (Aghion et al., 2005). Our findings for product market regulation in the low and high churn rate suggest that when business dynamism is high, markets may be characterised by stronger competition. In this case, more regulation in the product market discourages competition and has a negative effect on innovation diffusion (column 3 in Figure 13-5). On the other hand, when the churn rate is low, a Schumpeterian effect dominates, as the rents appropriable by entrants are low. Therefore, more regulation has a positive effect on technology diffusion (column 2 in Figure 13-2) as the innovation process is mainly driven by incumbent firms.

Finally, more accessible financial markets are always associated with more potential for technological diffusion, independently of the churn rate or the specification used.

5. Discussion and policy implications

In an era of increasing globalisation and new digital technologies that could allow faster-than-ever international knowledge diffusion and technology transfers, the gap in productivity between frontier and other firms is widening, stimulating policy and academic debates on the underlying causes, most notably on those behind the stalling technology diffusion process.

While most of the policy initiatives are aimed at improving technological capabilities and absorption capacity, there are a few which are specifically aimed at changing the speed of technology diffusion, such as the European Research Area, as innovation and knowledge diffusion are strongly affected by public policy (Stoneman and Diederen, 1994).

This chapter investigates the role of labour, capital, and product market regulatory frameworks in technology diffusion, and also accounting for the role of business dynamism in mediating and moderating the impact of regulation on technology diffusion. Under a standard empirical framework with no intermediate role for business dynamics, results match the general findings in the literature: more stringent regulations are associated with lower productivity and less technology diffusion[9] (Scarpetta and Tressel, 2003; Tressel and Scarpetta, 2004). However, the European Central Bank highlights the causal link between business churning, framework conditions and technology adoption/diffusion:

'Market competition and business churning (i.e. the rate of entry and exit of firms) – which are affected by country-specific framework conditions – influence the incentives and costs for firms to invest in new technology or adapt existing technologies' (Masuch et al., 2018, p. 110).

Therefore, accounting for both framework conditions and business dynamism, the results of this chapter suggest that greater flexibility in the labour market regulation may benefit technology diffusion as it promotes the creation of new innovative firms and facilitates the restructuring or exit of unproductive ones. However, the direct (and total) effect of labour-market flexibility is negative, suggesting that a more regulated labour market might create incentives for firms to position their absorption capacity and human capital as key elements in their ability to adopt innovations, such as, for instance, by investing in their workers with, for example, on-the-job training (Lucidi, 2012; Egert, 2016). In addition, from a Schumpeterian perspective, given that a more stringent regulatory framework leads to higher fixed costs, this could increase the entry requirements and make competition tougher, igniting the process of creative destruction and favouring the adoption of innovations by firms.

Conversely, access to capital markets has a positive direct impact on technology diffusion, which is offset by the negative indirect effect via business churning. Indeed, while access to sources of finance has been widely recognised as fostering entrepreneurship, it also increases firms' survival rates, perhaps that of less-productive ones as well, resulting in a slower reallocation of resources, thereby offsetting the positive impact on technology diffusion.

When considering the moderating role of business churning (we estimate a separate model for a low and high level of churning), we find that firms in high-churning sectors catch up faster than in low-churning ones. A faster human capital growth rate is associated with faster technology diffusion for all firms, but particularly for those in low-churning sectors, where human capital may be relatively more important than in high-churning sectors, and where less flexible labour-market regulation may create a favourable environment to invest more in human capital. Furthermore, in line with Andrews et al. (2015) and Aghion et al. (2005), we find that more stringent product market regulation is associated with less technology diffusion for firms in high-churning industries, while this is not the case for low-churning ones. A similar pattern is observed when considering labour-market flexibility, even though the magnitude of the effect is much less prominent, especially when considering greater flexibility in markets with a high churn rate. These results come somewhat in-between the traditional view supporting deregulation of labour relationships in order to boost investment and the alternative argument, which suggests that more secure and regulated labour markets boost investment in skills, innovation and absorptive capacity.

9 This estimation has been performed but is not included because of a lack of space.

Overall, this analysis offers an additional perspective to understand the uneven process of technological diffusion and the framework conditions needed to boost the pace of such diffusion. Of course, some caution is needed in interpreting the results as we do not fully control for several factors – such as capital deepening, or the technological or competition level of sectors – which are left for future avenues of research to deepen the understanding of these channels.

In terms of policy implications, our results suggest that:

- a one-size-fits-all regulatory model does not lead to faster technology diffusion, but the specific characteristics in the market and sectoral structure need to be accounted for;
- while excessive product market regulation tends to hinder technology diffusion, this only holds true in industries with vivid business dynamism and high rates of churn rates, where innovation is driven by new entrants;
- a similar argument holds for labour-market regulation, suggesting a more prudent view than merely advocating tout-court deregulation of labour-market relationships;
- human capital and access to finance are confirmed as horizontal drivers of technology catch-up and diffusion. While policies in this domain do not specifically address diffusion directly, they are key in increasing the adoption rate of innovations, enabling local (research and) innovation systems to produce, absorb and implement new knowledge, to keep pace with global technological change.

6. References

Abramovitz, M. (1986), Catching up, forging ahead, and falling behind, *The Journal of Economic History*, 46(2), 385-406.

Acemoglu, D., Johnson, S. and Robinson, J.A. (2005), Institutions as a fundamental cause of long-run growth, *Handbook of economic growth*, 1, 385-472.

Acs, Z.J., Braunerhjelm, P., Audretsch, D.B. and Carlsson, B. (2009), The knowledge spillover theory of entrepreneurship, *Small Business Economics*, 32(1), 15-30.

Agénor, P.R. and Canuto, O. (2017), Access to finance, product innovation and middle-income traps, *Research in Economics*, 71(2), 337-355.

Aghion, P., Bloom, N., Blundell, R., Griffith, R. and Howitt, P. (2005), Competition and innovation: An inverted-U relationship, The *Quarterly Journal of Economics*, 120(2), 701-728.

Andrews, D., Criscuolo, C. and Gal, P.N. (2015), *Frontier Firms, Technology Diffusion and Public Policy: Micro Evidence from OECD Countries* (No. 2), OECD Publishing.

Andrews, D., Criscuolo, C. and Gal, P.N. (2016), *The best versus the rest: the global productivity slowdown, divergence across firms and the role of public policy* (No. 5), OECD Publishing.

Archibugi, D. and Filippetti, A. (2018), The retreat of public research and its adverse consequences on innovation, *Technological Forecasting and Social Change*, 127, 97-111.

Bahar, D., Hausmann, R. and Hidalgo, C.A. (2014), Neighbors and the evolution of the comparative advantage of nations: Evidence of international knowledge diffusion?, *Journal of International Economics*, 92(1), 111-123.

Balta, N. and Mohl, P. (2014), The drivers of total factor productivity in catching-up economies, *Quarterly Report on the Euro Area* (QREA), 13(1), 7-19.

Baron, R.M. and Kenny, D.A. (1986), The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations, *Journal of Personality and Social Psychology*, 51(6), 1173.

Bartelsman, E.J., Haskel, J. and Martin, R. (2008), *Distance to Which Frontier? Evidence on Productivity Convergence from International Firm-level Data*, CEPR Discussion Papers, 7032.

Benhabib, J. and Spiegel, M.M. (2005), Human capital and technology diffusion, *Handbook of economic growth*, 1, 935-966.

Blanchard, O. (2004), The economic future of Europe, *Journal of Economic Perspectives*, 18(4), 3-26.

Brown, J.R., Martinsson, G. and Petersen, B.C. (2012), Do financing constraints matter for R&D?, *European Economic Review*, 56(8), 1512-1529.

Brynjolfsson, E. and McAfee, A. (2011), Race against the machine: How the digital revolution is accelerating innovation, driving productivity, and irreversibly transforming employment and the economy, Digital Frontier Press, Lexington, MA.

Buccirossi, P., Ciari, L., Duso, T., Spagnolo, G. and Vitale, C. (2013), Competition policy and productivity growth: An empirical assessment, *Review of Economics and Statistics*, 95(4), 1324-1336.

Caselli, F. and Coleman, W.J. (2001), Cross-country technology diffusion: The case of computers, *American Economic Review*, 91(2), 328-335.

Cassiman, B. and Veugelers, R. (2002), R&D cooperation and spillovers: some empirical evidence from Belgium, *American Economic Review*, 92(4), 1169-1184.

Castellacci, F. (2007), Technological regimes and sectoral differences in productivity growth, *Industrial and corporate change*, 16(6), 1105-1145.

Coe, D.T. and Helpman, E. (1995), International R&D spillovers, *European Economic Review*, 39(5), 859-887.

Comin, D. and Mestieri, M. (2014), Technology diffusion: Measurement, causes, and consequences, In *Handbook of economic growth* (Vol. 2, pp. 565-622), Elsevier.

Correia, H. and Fontoura Gouveia, A. (2017), *Is deregulation of product and labour markets promoting employment and productivity? a difference-in-differences approach* (No. 0084), Gabinete de Estratégia e Estudos, Ministério da Economia.

Crafts, N. (2006), Regulation and productivity performance, *Oxford Review of Economic Policy*, 22(2), 186-202.

d'Aspremont, C. and Jacquemin, A. (1988), Cooperative and noncooperative R&D in duopoly with spillovers, *The American Economic Review*, 78(5), 1133-1137.

De Haan, J. and Parlevliet, J. (2018), *Structural Reforms*, Springer.

Dosi, G. (1982), Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change, *Research Policy*, 11(3), 147-162.

Dosi, G., Pereira, M.C., Roventini, A. and Virgillito, M.E. (2017), The effects of labour market reforms upon unemployment and income inequalities: an agent-based model, *Socio-Economic Review*, 16(4), 687-720.

Eaton, J. and Kortum, S. (1999), International technology diffusion: Theory and measurement, *International Economic Review*, 40(3), 537-570.

Eaton, J. and Kortum, S. (2001), Technology, trade, and growth: a unified framework. *European Economic Review*, 45(4-6), 742-755.

Égert, B. (2016), Regulation, institutions, and productivity: new macroeconomic evidence from OECD countries, *American Economic Review*, 106(5), 109-13.

Égert, B. and Wanner, I. (2016), Regulations in services sectors and their impact on downstream industries: the OECD 2013 REGIMPACT Indicator, OECD Economic Department Working Papers, 1303, 0-1.

European Commission (2018), Science, Research and Innovation Performance of the EU 2018, Luxembourg: Publications Office of the European Union: ISBN 9789279697456.

European Commission (2019), ERA progress report 2018.

Falvey, R., Foster, N. and Greenaway, D. (2007), Relative backwardness, absorptive capacity and knowledge spillovers, *Economics Letters*, 97(3), 230-234.

Foster, L., Haltiwanger, J. and Krizan, C.J. (2006), Market selection, reallocation, and restructuring in the US retail trade sector in the 1990s, *The Review of Economics and Statistics*, 88(4), 748-758.

Fu, X., Pietrobelli, C. and Soete, L. (2011), The role of foreign technology and indigenous innovation in the emerging economies: technological change and catching-up, *World Development*, 39(7), 1204-1212.

Fuentelsaz, L., Garrido, E. and Maicas, J.P. (2015), Incumbents, technological change and institutions: How the value of complementary resources varies across markets, *Strategic Management Journal*, 36(12), 1778-1801.

Gordon, R.J. (2012), *Is US economic growth over? Faltering innovation confronts the six headwinds* (No. w18315), National Bureau of Economic Research.

Gorodnichenko, Y. and Schnitzer, M. (2013), Financial constraints and innovation: Why poor countries don't catch up, *Journal of the European Economic Association*, 11(5), 1115-1152.

Grossman, G.M. and Helpman, E. (1991), *Innovation and growth in the global economy*, MIT press.

Hall, B.H. and Lerner, J. (2010), The financing of R&D and innovation. In *Handbook of the Economics of Innovation* (Vol. 1, pp. 609-639), North Holland.

Iammarino, S., Rodríguez-Pose, A. and Storper, M. (2018), Regional inequality in Europe: evidence, theory and policy implications, *Journal of Economic Geography*, 19(2), 273-298.

Jaffe, A.B., Trajtenberg, M. and Henderson, R. (1993), Geographic localization of knowledge spillovers as evidenced by patent citations, *Quarterly Journal of Economics*, 108(3), 577-598.

Jaumotte F. and Buitron, C. (2015), Inequality and Labor Market Institutions, *IMF Staff Discussion Note*, International Monetary Fund.

Jung, M. and Lee, K. (2010), Sectoral systems of innovation and productivity catch-up: determinants of the productivity gap between Korean and Japanese firms, *Industrial and Corporate Change*, 19(4), 1037-1069.

Keller, W. (2002), Geographic localization of international technology diffusion, *American Economic Review*, 92(1), 120-142.

Keller, W. (2004), International technology diffusion, *Journal of Economic Literature*, 42(3), 752-782.

Lucidi, F. (2012), Is There a Trade-off Between Labour Flexibility and Productivity Growth? Some Evidence from Italian Firms, *AIEL Series in Labour Economics*, 261-285.

Lynn, L.H., Reddy, N.M. and Aram, J.D. (1996), Linking technology and institutions: the innovation community framework, *Research Policy*, 25(1), 91-106.

Malerba, F. (2002), Sectoral systems of innovation and production. *Research Policy*, 31(2), 247-264.

Mancusi, M.L. (2008), International spillovers and absorptive capacity: a cross-country cross-sector analysis based on patents and citations, *Journal of International Economics*, 76(2), 155-165.

Martin, J.P. and Scarpetta, S. (2012), Setting it right: Employment protection, labour reallocation and productivity, *De Economist*, 160(2), 89-116.

Mazzucato, M. (2013), Financing innovation: creative destruction vs. destructive creation, *Industrial and Corporate Change*, 22(4), 851-867.

McGowan, M.A. and Andrews, D. (2015), Labour Market Mismatch and Labour Productivity: Evidence from PIAAC data, OECD Economic Department Working Papers, (1209), 0_1.

McGowan, M.A., Andrews, D. and Millot, V. (2017), The walking dead?: Zombie firms and productivity performance in OECD countries, OECD Economic Department Working Papers, (1372), 0_1.

Nadiri, M.I. (1993), Innovations and technological spillovers, NBR papers.

Nelson, R.R. and Phelps, E.S. (1966), Investment in humans, technological diffusion, and economic growth, The *American Economic Review*, 56(1/2), 69-75.

Nickell, S. (1997), Unemployment and labor market rigidities: Europe versus North America, *Journal of Economic Perspectives*, 11(3), 55-74.

Nicoletti, G. and Scarpetta, S. (2003), Regulation, productivity and growth: OECD evidence. *Economic Policy*, 18(36), 9-72.

Nieto, M.J. and Santamaría, L. (2010), Technological collaboration: Bridging the innovation gap between small and large firms, *Journal of Small Business Management*, 48(1), 44-69.

Preacher, K.J. and Hayes, A.F. (2008), Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models, *Behavior Research Methods*, 40(3), 879-891.

Rivera-Batiz, L.A. and Romer, P.M. (1991), Economic integration and endogenous growth, *Quarterly Journal of Economics*, 106(2), 531-555.

Sadik, J. (2008), Technology adoption, convergence, and divergence, *European Economic Review*, 52(2), 338-355.

Santacreu, A.M. (2015), Innovation, diffusion, and trade: Theory and measurement, *Journal of Monetary Economics*, 75, 1-20.

Santacreu, A.M. (2017), Convergence in Productivity, R&D Intensity, and Technology Adoption, *Economic Synopses*, (11), 1-2.

Scarpetta, S. and Tressel, T. (2002), Productivity and Convergence in a Panel of OECD Industries: Do Regulations and Institutions Matter? (No. 342), OECD Publishing.

Scarpetta, S., Hemmings, P., Tressel, T. and Woo, J. (2002), The role of policy and institutions for productivity and firm dynamics: evidence from micro and industry data.

Stoneman, P. and Diederen, P. (1994), Technology diffusion and public policy, The Economic Journal, 104(425), 918-930.

Thum-Thysen, A. and Raciborski, R. (2017), Determinants of trend TFP growth and key policies that influence it, *Quarterly Report on the Euro Area* (QREA), 16(2), 31-41.

Tressel, T. and Scarpetta, S. (2004), Boosting productivity via innovation and adoption of new technologies: any role for labor market institutions?, The World Bank.

Verspagen, B. (1997), Measuring intersectoral technology spillovers: estimates from the European and US patent office databases, *Economic Systems Research*, 9(1), 47-65.

Von Hippel, E. (1994), 'Sticky information' and the locus of problem-solving: implications for innovation, *Management Science*, 40(4), 429-439.

Xiao, J., Boschma, R. and Andersson, M. (2018), Industrial diversification in Europe: The differentiated role of relatedness, *Economic Geography*, 94(5), 514-549.