Chapter 7

Regulation and ICT capital input: Empirical evidence from 10 OECD Countries

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INTRODUCTION

Over the past twenty years, European governments have clearly aimed at increasing growth by encouraging innovation, which is assumed to be positively related to product-market deregulation and resulting competition. This approach has been evident both in the Single Market program of the early 1990s that aimed to harmonize national regulations and in the so-called Lisbon Strategy (2000) that aimed at increasing the share of research and development (R&D) expenditures in GDP. Both projects have considered deregulation and market-opening reforms as means to foster innovation.

One of the assumptions that underpin the Lisbon Strategy is that economic competitiveness depends on increased investments in Information and Communication Technologies (ICT). This assumption is justified by referring to the experience of the United States, where economic growth was underpinned by high sectoral productivity gains that, in turn, were related to successful adoption of ICT. Indeed, labour productivity growth in the United States escalated from 1.1 percent in 1990-1995 to 2.5 percent in 1995-2000 while it slowed down or remained stable in most European countries (van Ark et al., 2003). This observation has generated excessive enthusiasm and often unrealistic expectations about the new economy, leading governments to assume that investments in ICT capital would raise the economic performance of Europe. The telltale story was that slower growth in Europe was linked to a comparatively small ICT diffusion at the industry level, which was due to higher levels of regulation in European countries. ICT is expected to bring substantial productivity and welfare gains as a result of lower information and search costs and simplified long-distance business services in accountancy, banking and information processing via outsourcing for example. More specifically, ICT diffusion is often used as a proxy for the “new economy” which defines a new long-term growth trajectory based on these technologies and fostered by some institutional infrastructures.

While a lot of studies link ICT investments with growth (Jorgenson and Stiroh, 1999; Oliner and Sichel, 2000), the relationship between regulation and ICT diffusion has remained a relatively under-researched issue. This is all the more important because, at the same time, many governments have been keen on implementing deregulation and ICT-increasing policies. The idea is straightforward: an efficient use of ICT generally requires firm reorganization and institutional flexibility, which can be restricted by excessively stringent regulations. In product markets, rigid regulations can reduce competitive pressure and thus lower the incentives to use the most efficient production techniques. In addition, stringent regulation hinders the performance of the labour market by reducing the skill acquisition of the work force.

Yet, the existing literature indicates that product-market regulation may have different effects on innovation depending on the distance to the technological frontier. The received argument following Aghion et al. (2005) is that the cost of product market regulation is higher the closer is an economy to the technology frontier. The aim of this chapter is to assess the validity of the argument according to which deregulation spurs investments in ICT (Bartelsman et al., 2002; Arnold et al., 2008), and that this effect is more important when economies are close to the technological frontier (Aghion et al., 2005).

We estimate an empirical model with variables for the distance to the technology frontier, regulation, as well as interaction terms between them. We estimate the model at the industry level and report evidence that the marginal effect of regulation on ICT intensity does not become more adverse even at the technological frontier. Our results show that regulation can even spur investments in ICT, especially for countries that are close to the technological frontier. Hence, we argue that deregulation policy cannot be considered as a substitute for active science and technology policies.

This chapter contributes to the literature in several ways. First, it is one of the rare empirical investigations that account for differences in ICT diffusion across countries and industries. Second, it provides an explanation for cross-country differences in ICT diffusion in 10 OECD countries, drawing attention to a positive relationship between regulation and ICT intensity when countries are close to the technology frontier. Finally, it demonstrates that the impact of regulation on ICT intensity is not uniform and depends on the distance to the technological frontier, raising doubts about the simple links established between deregulation and increase ICT intensity. The chapter is organized as follows. In the next section, we provide a brief review of the related literature. Then, we present the empirical strategy and the problems related to estimations. In the following sections, we first introduce the data used in the empirical analysis and then present the results of the baseline model. Finally, we conclude by summarizing the main findings highlight the policy implications.

RELATED LITERATURE

Although the policy discourse in the European Union tends to establish a causal link between deregulation and competition on the one hand and innovation on the other, the theoretical work on the relationship between regulation/competition and innovation does not provide a clear-cut answer to whether deregulation and competition can lead to higher innovation the microeconomic or macroeconomic levels. For example, Schumpeter (1934) argues that market concentration increases firms' incentives to innovate as it enables firms to obtain post-innovation monopoly profits as rewards for their innovatinon efforts. In other words, the monopoly deadweight loss is the price we have to pay in order to stimulate firms to undertake research and development (R&D) expenditures. Furthermore, R&D investment is a major factor driving technological change and economic growth. Therefore rising competition decreases not only innovative rents but also incentives to innovate.

On the other hand, given perfect appropriability, product market competition encourages efficiency (Arrow, 1962). Leaders would keep innovating to preserve their market power while potential entrants may hope to capture market share by surpassing the incumbents with new and better products. In this framework, competition is a necessary condition for innovation. These conflicting findings have led to a large set of empirical studies – dating back at least from Nickell (1996) - on the relationship between competition and certain measures of economic performance such as productivity or innovation.

Extensions of the Schumpeterian innovation-based endogenous growth model allow for differentiated effects from competition on to innovation. The landmark study by Aghion et al. (2005) combines the Schumpeterian and Arrow-like perspectives to derive an *inverted-U* relationship between competition and innovation. The mechanism behind this curve is the following: firms compare the expected profit of pre- and post-innovation rents. When competition is limited but increases, firms might escape competition by innovating. However, if competition is fierce, the negative Schumpeterian effect of competition on R&D dominates the positive escape-competition effect. The positive effect of competition on innovation and R&D is strongest in leveled industries characterized by neck-to-neck firms with similar technological level and unit costs. The intuition is that in leveled industries, an incremental increase in productivity helps the firm to reap market shares from a large number of competitors. Hence, in leveled industries the positive escape-competition effect of competition on R&D is stronger than in unleveled industries. The authors also found robust evidence for an inverted U-shaped relation between the Lerner index and the number of patents granted in a sample of 330 UK firms between 1968 and 1997. The “Schumpeterian effect” of competition should dominate when the level of competition is high, whereas the “escape-competition effect” should be prominent at low levels of product market competition. Moreover, following the prediction of the theoretical model, the inverted U-shaped relationship was found to be steeper for firms that are closer to the technology frontier in their industry.

A thin literature on the relationship between regulation and innovation report a negative relationship between two and thus emphasize the positive impact of lower product-market regulation on innovation and productive efficiency. This is the case in a series of studies on the potential impact of regulation on various measures of economic performance in OECD countries. For example, Nicoletti and Scarpetta (2003) considered a sample of 23 industries for 18 OECD countries over the period 1984 - 1998. They tested a model of total factor productivity (TFP) growth, using product-market regulation indicators devised by the OECD both alone and in interaction with a technology gap variable, which is measured as the log difference between the factor productivity level of the country-industry and the factor productivity of the leader. Their results indicate that economy-wide product market regulations that curb competition have a negative effect on productivity. Even if regulation itself has a positive but non-significant impact on productivity, a statistically significant positive coefficient is found for the interacted variables. As the technology gap variable is always negative, a positive coefficient for the interaction terms means a negative regulation effect on productivity. This result is interpreted as a slow-down in the catching-up process, whereby a country with the same technological gap as another country experiences slower productivity growth as a result of higher levels of regulation.

A somewhat similar result is reported in Bartelsman et al. (2002), who provide evidence that stringent regulations in the product markets reduce competitive pressures and thereby have a negative effect on innovation and adoption of new technologies, including ICT. The authors conclude that strong regulation can lead to less-intensive ICT adoption in European industries. A more recent paper by Arnold et al. (2008) finds a similar result to that of Barteslman et al (2002) and Nicoletti and Scarpetta (2003). The authors used firm-level data for the 1998-2004 period and found that anti-competitive service regulations hamper productivity growth in ICT-using sectors, with a particularly pronounced effect on firms that are catching up with the technology frontier and on those that are close to international best practice. Their results thus show that regulation particularly hurts firms that have the potential to excel in domestic and international markets. Hence, regulation should be lowered in order to increase innovation and productivity.

Such results are also confirmed in Griffith et al (2010), who utilize the Business Entreprise Research and Development Expenditures (BERD) for 12 industries and nine countries from 1987 to 2000 and the countries' deregulation efforts within the Single Market project to demonstrate that reduced product market regulation is conducive to increased innovation, all else equal.

However, other empirical evidence suggests that regulation can have a positive impact on innovation at the industry-level. Amable et al. (2010) devised a model similar to that of Aghion et al. (2005) but include the possibility that leaders carry out R&D; and by so doing, complicate the laggards' catching up process. It is assumed that the engagement of the "leader" in a new discovery induces a change in the technological paradigm: even if the quality difference is still one step, the leader's innovation makes this last step harder to climb for the follower. This model takes into account firms' strategies. There are asymmetries between the leader and its potential competitors: the former uses a relative advantage to bias the technological paradigm while the competitive fringe anticipates their investment in R&D as non-profitable. Thus, market regulation can have a positive impact on the competitive fringe's innovation by making the leader's position less profitable. The impact of regulation can also be positive and growing in high-tech industries. The empirical test, based on a panel of manufacturing industries in 17 OECD countries over the period 1979 – 2003, shows that regulation has an increasing positive impact on industries' efficiency when getting closer to the technological frontier.

A different strand of the literature on the relationship between environmental regulations and eco-innovations (see Demirel and Kesidou in chapter 6 of this volume) also indicates that both prescriptive and incentive-based environmental regulations can be conducive to eco-innovation. For example, whilst Milliman and Prince (1989), Requate and Unold (2003) and Requate (2005) report that incentive-based instruments are superior to prescriptive regulation, Hart (2004), Popp (2005) and Rothfels (2002) demonstrate that compliance with prescriptive environmental regulations can drive firms to become leaders in "green markets" and thus, become more competitive compared to their foreign peers. These findings can be explained by the presence of market imperfections that prescriptive or incentive-based regulation can address to a certain extent (Goulder and Parry, 2008).

EMPIRICAL STRATEGY

The purpose of this chapter is to test the impact of regulation on innovation with a time series cross-section data at the industry level for ten OECD countries. This leads us to consider a variable *panelvar*, which combines industries and countries that are considered as individual cases. We also consider year dummies to take into account fixed time effect, i.e. macroeconomic shocks that are homogeneous through individuals, and thus make the results more robust. The following Within-group regression is considered:

$$ICT_{it}= \beta_1 REG_{it} + \beta_2 FRONT_{it} + \beta_3 REG*FRONT+ \beta_4 REG^2 + \gamma_0 X_{it} +\lambda_t+ \varepsilon_{it} \quad (1)$$

Here ICT_{it} is ICT capital intensity in a given industry-country *i* at time *t*; REG_{it} is the value of the regulation indicator; $FRONT_{it}$ tis the extent of closeness to the technology frontier and X_{it} is a set of control variables that include the capital/labor ratio, externalities, and import penetration This is a non-linear model that include the squared values of regulation to strengthen the concavity of my model and test whether there is a non-linear relationship between regulation and ICT capital input. We estimate the model four times, using four different measures of regulation as described below.

As we included an interaction term in the model and a squared variable of the market regulation, the marginal effect of regulation on ICT capital intensity depends on the value of market regulation itself and of the closeness to the frontier. The tables of regression will be followed with computed marginal effects of the regulation on innovation and its significance at the mean value of REG_{it} for different values of $FRONT_{it}$. The marginal effect of regulation takes the form of $\beta_2 + \beta_3 FRONT + 2\beta_4 REG$.

To measure *ICT intensity*, we use industry-country-level ICT capital input (ICT_{it}), computed by the Groningen Growth and Development Center (GGDC) in the EU *Klems Database*. This variable is available from 1980 to 2005 for 10 OECD countries (Austria, Denmark, Finland, Germany, Italy, Netherlands, Portugal, Sweden, UK, US) and 11 manufacturing industries (Food products, Textiles, Wood products, Paper, Chemicals and chemical products, Rubber and plastics, Other non-metallic mineral products, Metals and fabricated metals, Machinery and equipments, Electronic and optical machinery, and Motor vehicles – see, Table A7.1 in the Appendix).

Here, we consider the ICT capital input share in the value-added to measure ICT capital intensity. Value-added is taken from the GGDC-ICOP database for each country and each industry. All nominal series were deflated to 1997 in their national currency and then "cross-section" deflated using the industry purchasing power parities provided by Timmer, Ympa and van Ark (2006). The authors considered a mix between purchasing power parities based on two points of the productive process: consumer expenditure and production. This method allows to obtain transitivity in multilateral comparisons.

Closeness to the frontier ($FRONT_{it}$) is calculated using productivity levels for each industry in each country from 1980 until 2005. Closeness to the productivity frontier is measured as the ratio between the productivity in industry *i* in country *j* at time *t* and the highest productivity level in the same industry *i* at the same time *t*. For example, in 1980, the closeness to the frontier for Germany in the Paper industry (ISIC-REV 21) is the ratio between German productivity in the paper industry in 1980 and Finland productivity in the paper industry the same year as Finland is the more productive country in the industry of paper in 1980. Hence, the lower the value of $FRONT_{it}$ the closer is the industry/country is to the technological frontier.

As proxies for *regulation* (REG_{it}), we use *four regulation indicators* provided by the OECD, which allow for comparing different regulatory environments on a long-time basis. The regulatory environment indicator for non-manufacturing sectors (*REGREF)* is available for the whole period at the national level. It gives us information about the degree of regulation in network industries (telecoms, electricity, gas, post, rail, air passenger transport, road freight) that are highly related to manufacturing sectors. It is documented by Conway and Nicoletti (2006). The higher the value of the indicator, the higher is the level of regulation.

The impact of *REGREF* on the manufacturing sector is measured by *REGIMP*, which is available from 1980 until 2003 at the industrial level for the OECD countries. This indicator measures the extent to which industries are constrained by administrative burdens, entry regulation and other market barriers in key non-manufacturing sectors such as network services, retail distribution, financial services and professional business services. The underlying idea is that these sectors are in constant interaction with manufacturing so that their regulation also constraints the operation of manufacturing firms. The OECD connects the regulatory practices in these input sectors using input-output matrices, showing their role as suppliers for the whole industry.

The *product market regulation, PMR,* is provided by the OECD and documented by Conway, Janod and Nicoletti (2005). It provides an estimation of barriers to entry for each country. This indicator has been calculated for two years, 1998 and 2003. We consider the value of 1998 for the period 1980 - 1999 and the value of 2003 for the period 2000-2005. Finally, *the size of the public enterprise sector*, *PMRP*, is a component of *PMR* that focuses on state control in the product markets. This measure can capture the differences of R&D investments in the private and the public sectors. It is also available for 1998 and 2003 and we apply the same method as for the *PMR*.

The regressions also include explanatory variables capturing alternative mechanisms influencing the intensity of ICT capital input. The main control variable is the capital/labor ratio KL_{it}, measured as the ratio of capital stock to the number of hours worked, calculated using investment series provided by the GGDC's *EU Klems Database*. Externalities, EXT_{it}, is measured as the international intensity of the ICT capital input, i.e. as the ratio of ICT capital input to value-added for the rest of the world. We use EXT_{it} as a proxy to measure spill-over effects of the ICT intensity. We also include the import penetration, *MPEN*, which is provided by the OECD and available at the industry level in the *OECD-STAN Database*. This is an indicator of import product penetration and can be a proxy for "openness" at the industry level. The summary statistics for all variables are given in Table A7.2 in the Appendix.

RESULTS

Table 7.1 below reports the results for within-group regressions, where the dependent variable is ICT intensity regressed on four different measures of regulation: *REGREF(1), REGIMP(2), PMR(3)* and *PMRP(4)*. For each regression, we report in a sub-table the marginal effects of regulation on innovation for different levels of the closeness to the technology frontier. The first line presents the marginal effect of regulation on ICT intensity at the technology frontier – i.e., when closeness to the frontier is maximum. The third line reports the marginal effect of regulation on ICT intensity when closeness to the frontier is at mean value of the closeness in the panel. The last line shows the marginal effect when the closeness to frontier is at its minimum. This, the bottom half of Table 7.1 enables us to follow how the marginal effects of regulation on ICT intensity evolve when *distance to the frontier* is increasing.

We comment briefly on the results of the regressions. Considering all models, we find that the coefficients on the dependent variables are stable in the different specifications. Regulation has a significant negative effects on ICT intensity in models (1) and (2) and a negative but insignificant effect in models (3) and (4). This result is somewhat similar to the conventional wisdom that regulations curbing competition are responsible for the low intensity of ICT capital input in OECD industries and countries. Furthermore, closeness to the technological frontier enters negatively and is significant at conventional levels in all specifications, suggesting that, within each industry, countries that are further behind the technological frontier have relatively higher levels of ICT capital input to catch up with their peers.

Insert Table 7.1 here

The interaction of regulation and closeness to the frontier (*REG*FRONT)* has a significant positive effect in all models except model (3). It means that for a given level of closeness to the technological frontier, within a given industry, increasing the level of regulation increases the relative investment in ICT capital input. This finding indicates that regulation may have negative partial effects on ICT intensity, but it also offsets the negative effects of the closeness to the frontier. Stated differently, regulation is more likely to slow down the catching-up process when industries are far from the technology frontier, but it is less likely to do so when industries are close to the technology frontier. This finding has an important policy implication in that policy prescriptions that assume a uniform effect from regulation on to innovation are likely to be counterproductive – especially when industries are close to the frontier.

The signs for the capital/labour ratio (*KL*) and import penetration (*MPEN*) are positive and significant in all models, but the magnitude of the openness coefficient is small. These results indicate that capital-intensive industries and industries with higher levels of import penetration tend to invest more in ICT, all else being equal. The sign of externalities is positive but insignificant, indicating absence of spill-over effects.

According to Aghion et al. (2005), the marginal effects of *competition* on innovation should be negative far from the technological frontier but it should positive close to the frontier. If we accept the received interpretation of regulation as a measure of low competition, their findings would imply that the effects of *regulation* on innovation (which we measure by ICT intensity here) should be negative closer to the technological frontier but positive when industries are far from the technological frontier. The marginal effects we report in Table 7.1 do not support the findings of Aghion et al (2005). The marginal effect of regulation on ICT intensity is positive and significant in all regressions except (4) when closeness to the frontier is maximum. The marginal effect is negative only when closeness to the frontier is minimum and it is significant only when *REGREF* and *REGIMP* measures of regulation are used (estimation 1 and 2).

Therefore, far from obtaining an increasingly negative effect of regulation on innovation as one approaches the technological frontier, we obtain the opposite. Even if regulation can have a negative effect on the laggards, it has a significant positive effect on the level of ICT capital input when industries are at the technological frontier. This result is all the more important as it is quite robust and similar in magnitude of the marginal effect of regulation measured by *REGREF*, *REGIMP* and *PMR*. We thus conclude regulation is a significant driver of innovation when the industry is close to the technology frontier.

Our results can be compared with those obtained in the previous empirical literature linking regulation policy, technology gap and a measure of economic performance at the industry level. The results presented in this chapter are similar to Amable et al. (2010), who used a similar dataset but another measure of innovation – namely, the number of patents per hours worked. They are also compatible with the results reported by Nicoletti and Scarpetta (2003) and Arnold et al. (2008) , who decompose the effects of regulation at different level of the technology gap. Lack of evidence for a negative relationship between regulation and productivity is also reported in Griffith and Harisson (2003), who investigate the effect of the Single Market Program on innovation, measured as expenditures in R&D. The authors find that regulatory reforms that have reduced the level of economic rents are associated with a reduction in R&D and growth rates when looking at changes over time within countries. Cross-countries' differences support the opposite – countries with lower average levels of rents are those that have higher productivity and R&D investments. Such a result can be linked to the lack of support to the negative effect of regulation.

CONCLUSIONS

In this chapter, we have investigated the relationship between different measures of regulation and industry-level ICT intensity as a measure of innovation in 10 OECD countries. In line with the literature on the relationship between competition/regulation and innovation, we have examined the relationship between regulation and ICT intensity paying attention to the non-linear nature of the competition-innovation relationship and the closeness to the technology frontier. Unlike Aghion et al. (2005), we have found that the marginal effect of regulation on innovation tends to be negative only when industries are further away from the technology frontier. Regulation tends to have a positive marginal effect when industries closest to the frontier and have no significant effects when industries are characterized by distance to the frontier that is between the two extremes. The reasons for these results lie in the fact that market regulation does not limit competition but makes it more difficult for firms to use competitive strategies as alternative to product innovation.

Our results contradict some findings on the existence of an *inverted-U* curve between competition and innovation, but they are compatible with theoretical work and micro empirical studies that report the existence of a Schumpeterian effect in the relationship between market structure and innovation. Policy prescriptions in Europe where industries are close to or at the technological frontier, should take into account the positive effects of regulation on innovation, at least in the form of ICT intensity. “Big Bang” strategies suggested by some recommendations of the Lisbon Agenda are not substitutes for an ambitious science and technology policy coupled with product market regulation.

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Table 7.1: Effects of regulation on ICT intensity in OECD countries

	(1)	(2)	(3)	(4)
REGULATION PROXY	*REGREF*	*REGIMP*	*PMR*	*PMRP*
REG	-0.109**	-8.149**	-0.281	-0.394
	(0.0433)	(3.770)	(0.457)	(0.266)
FRONT	-0.657**	-0.647**	-0.524**	-0.610**
	(0.283)	(0.262)	(0.253)	(0.275)
*REG*FRONT*	**0.114***	**3.719****	0.193	**0.159***
	(0.0607)	(1.838)	(0.119)	(0.0902)
REG^2	0.00341	25.18**	0.0853	0.0518
	(0.00309)	(11.71)	(0.0896)	(0.0314)
KL	1.315***	1.370**	1.514**	1.462**
	(0.489)	(0.556)	(0.604)	(0.570)
EXT	0.00111	0.00178	0.000815	0.000835
	(0.00120)	(0.00147)	(0.00121)	(0.00120)
MPEN	0.000997**	0.000899**	0.00103***	0.00103**
	(0.000425)	(0.000436)	(0.000366)	(0.000424)
Constant	0.441**	0.608**	0.230	0.678
	(0.185)	(0.252)	(0.497)	(0.447)
Time Fixed Effects	Yes	Yes	Yes	Yes
Within R-squared	0.407	0.381	0.367	0.385
Number of Cases	110	110	110	110
Marginal Impact of Regulation on ICT Capital				
Value of Closeness:				
Maximum	0.0311*	1.6558*	0.2128***	0.0419
	(0.0165)	(0.8770)	(0.0737)	(0.0346)
0.75	0.0027	0.7259	0.1645*	0.0022
	(0.0097)	(0.5169)	(0.0850)	(0.0441)
Mean	-0.2564	-0.204	0.1161	-0.0376
	(0.01943)	(0.4333)	(0.1039)	(0.0608)
0.25	-0.0540	-1.1337	0.0678	-0.0774
	(0.0335)	(0.7286)	(0.1270)	(0.0805)
Minimum	-0.0824*	-2.0635*	0.0195	-0.1172
	(0.0482)	(1.1386)	(0.1524)	(0.1013)

Note: The dependent variable is the ICT capital intensity. All models are estimated as Within Fixed Effects regressions. Industry-country-clustered robust standard errors are reported in parentheses with ***p<0.01, **p<0.05 and *p<0.10. The marginal impact of regulation on ICT intensity is reported in the second part of the table for different levels of closeness to the technology frontier.

Appendix

Table A7.1: List of industries

ISIC-REV Classification	Industries
15-16	Food products, beverages and tobacco
17-19	Textiles, textile products, leather and footwear
20	Wood and products of wood and cork
21-22	Pulp, paper, paper products, printing and publishing
24	Chemicals and chemicals products
25	Rubber and plastic products
26	Other non-metallic
27	Basic metals
28	Fabricated metal products, except machinery and equipment
29	Machinery and equipment, n.e.c
30	Office, accounting and computing machinery
31	Electrical machinery and apparitus, n.e.c.
32	Radio, television and communication equipment
33	Medical, precision and optical instruments, watches and clocks
34	Motor vehicles, trailers and semi-trailers

Table A7.2: Descriptive statistics

Variable	Observations	Mean	Stand. Dev.	Min	Max
ICT	2552	0.1103	0.2166	0.0003	2.8358
REGREF	2860	3.8099	1.4270	0.9385	5.9214
REGIMP	2640	0.1234	0.0377	0.0484	0.2220
PMR	2860	1.7612	0.4636	0.8243	2.5940
PMRP	2860	2.6978	0.9140	1.1926	4.2001
FRONT	2841	0.5326	0.2670	0.0042	1
KL	2567	0.0431	0.0271	0	0.1793
EXT	2552	0.0849	0.0711	0.0075	0.4509
MPEN	2613	40.1517	29.9851	2.37	400.48

Note: This table gives the descriptive statistics for the ten countries/eleven industries over twenty-five years. The number of observations in the regressions differs because of some missing observations for some years.