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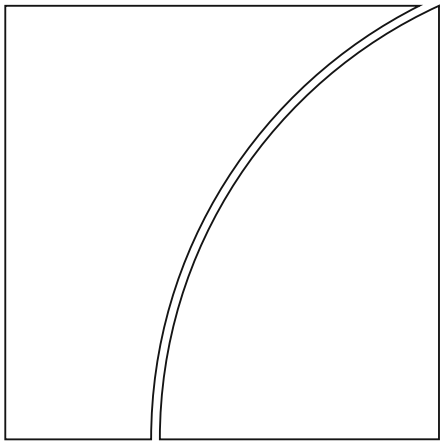

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by Sebastian Doerr, Magdalena Erdem, Guido Franco, Leonardo Gambacorta and Anamaria Illes

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Keywords: Covid-19, pandemic, information technology, crisis, recovery.

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Technological capacity and firms' recovery from Covid-19

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Abstract

Can higher technological capacity help firms to recover quicker from recessions? Analyzing the effects of the Covid-19 pandemic on firm revenues in several countries, we find that firms headquartered in jurisdictions with better digital infrastructure generated relatively higher revenue during the shock period. Improving a country's technological capability by one standard deviation is associated with a relative increase in revenues of the average firm by around 4%. The positive effect of technology is more pronounced among smaller firms, suggesting that it could have helped the recovery of SMEs.

JEL Codes: E23, G10, G38, O30

Keywords: Covid-19, Pandemic, Information Technology, Crisis, Recovery

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1 Introduction

The Covid-19 pandemic has confronted businesses with unprecedented challenges. Restrictions on people's movements have not only led to a sharp slowdown in economic activity, but also forced firms to alter their business models. Selling goods online has become the new norm, and so has remote work. Meanwhile, supply chains have been disrupted. An open question is to what extent information technology (IT), and a better digital and technological infrastructure in general, has helped firms to withstand the Covid-19 recession and adapt to the new environment.

Recent papers highlight the impact of work from home rules (Brynjolfsson et al., 2020; Papanikolaou and Schmidt, 2020; Bai et al., 2021), managerial practices (Lamorgese et al., 2020), online platforms usage (OECD, 2020), or the role of technology more generally (Gal et al., 2019; Brynjolfsson et al., 2021). Pierri and Timmer (2020) show that areas in the US with higher IT adoption among establishments experienced a smaller increase in unemployment. Yet there exists little empirical evidence on the role of a country's digital capabilities to mitigate the effects of the pandemic on businesses.

Our paper contributes to the debate by analysing whether a country's digital capabilities have helped firms to recover from the coronavirus recession. The analysis is based on a large sample of firms in 17 major countries. We find that firms headquartered in countries with better digital capabilities, as measured by their position in the World Digital Competitiveness Ranking, compiled by the Institute for Management Development (IMD), experienced higher revenue during the pandemic, relative to their

pre-pandemic trend. Specifically, improving a country's technological capability by one standard deviation is associated with a relative increase in revenues of the average firm by around 4%.

This effect is especially pronounced among smaller firms, suggesting that technological capacity might have mitigated the adverse effect of the pandemic on relatively smaller firms. Further analyses suggest that better overall technological capacity could improve young firms' ability to adapt during the aggregate Covid-19 shock; and that it is particularly beneficial for growth firms that use intangible capital more extensively (Ai et al., 2013, 2018). In additional tests, we show that there were no differential pre-trends, and that our findings remain robust in alternative specifications. For example, controlling for alternative measures of country-level efficiency does not affect our conclusions.

2 Data and Variables

The main source of firm-level data is the S&P Capital IQ package. It contains annual consolidated financial statement data on publicly listed and large private firms, which are responsible for a significant share of an economy's total output. To ensure a balanced panel of observations, we require firms to report data in the fourth quarter in each year between 2017 and 2020. We exclude financial firms. We retain only firms that report annual balance sheet data in the fourth quarter, which ensures that we have complete data for the 2020 period. Firms' return on assets is defined as net income over total assets, and the leverage ratio is defined as total debt over total assets. The final sample covers firms in 17 major economies:

Australia, Brazil, Canada, China, France, Germany, India, Italy, South Korea, Mexico, Russia, Saudi Arabia, South Africa, Spain, Turkey, the United Kingdom and the United States

To measure digital capacity at the country level, we use the World Digital Competitiveness Ranking (IMD, 2020). The IMD index ranks 63 countries on an annual basis starting from 2016 until 2020. The main index is compiled along three dimensions. Knowledge captures the intangible infrastructure necessary for the learning and discovery dimensions of technology. Technology quantifies the environment of developing digital technologies and includes the regulatory framework. Future readiness examines the level of preparedness of an economy to assume its digital transformation and includes adaptive attitudes, business agility and IT integration. It measures the capacity and readiness of economies to adopt and explore digital technologies and is compiled from hard data, which represent 2/3 of the index, and soft data (coming from surveys) which make up the other 1/3. In terms of macroeconomic controls, we collect information on GDP per capita (current USD), the total population, real GDP growth (annual in %) and CPI inflation (annual in %).

Table 1 provides summary statistics at the firm (panel a) and country level (panel b). Our balanced panel covers 15,564 firms, located in 17 countries. The average firm had a revenue growth of 4%, a return on assets of 0.2%, and a leverage ratio of 22%. The median market-to-book ratio is 1.88. At the country-level, the IMD rank ranges from 42 to 100, with 100 being the highest value.

3 Empirical Strategy and Results

Figure 1 provides a scatter plot at the country level, with average revenue growth among sample firms in 2020 on the vertical axis and the average 2018–19 IMD rank on the horizontal axis. The positive relation between a country's IMD rank and average revenue growth during 2020 suggests that a better rank is associated with higher revenues and thus better average firm performance during the Covid-19 period.

To examine the effects of technological capacity on firm revenues in greater detail we estimate the following difference-in-differences regression at the firm-year level from 2018 to 2020:

$$\begin{aligned} log(revenue)_{f,t} = & \beta \text{ IMD index}_c \times post_t + \text{firm controls}_f \times post_t \\ & + \text{country controls}_{c,t} + \theta_f + \tau_t + \varepsilon_{f,t}. \end{aligned} \tag{1}$$

The dependent variable $log(revenue)_{f,t}$ denotes the log of total revenues of firm f in year t. The $IMD\ index_c$ denotes the average 2018–19 rank of the firm's headquarters country c in the IMD World Competitiveness Rankings. The dummy $post_t$ takes on a value of one in 2020, and a value of zero in 2018 and 2019. Firm controls include the log of total assets, leverage, return on assets (all averaged across 2018–19), and age (as of 2020). Country controls are GDP per capita, the log of total population, real GDP growth and CPI inflation. All regressions include firm fixed effects (θ_f) and year or industry*year fixed effects (τ_t). Standard errors are clustered at the firm level.

3.1 Main results

Table 2 shows that a higher IMD rank is associated with relatively higher firm revenues during the Covid-19 period. Column (1) includes firm and year fixed effects, as well as pre-crisis firm controls interacted with the post dummy (omitted). The positive and highly significant coefficient on the interaction effect $IMD\ index \times post$ indicates that revenues are higher in 2020 among firms in better-ranked countries, relative to the 2018–19 period. Adding time-varying controls at the country level in column (2) does not materially affect the estimated coefficient of interest, which suggests that the impact of the IMD index is not driven by other macro factors. As Covid-19 had different effects on different industries (Doerr and Gambacorta, 2020b; Demmou et al., 2021), column (3) includes industry*year fixed effects instead of year fixed effects and thus absorbs any differential global trends affecting firms within the same 3-digit SIC industry. The coefficient of interest slightly declines in size, but remains significant at the 1% level. In terms of economic magnitude, improving a country's IMD rank by 18 positions, i.e. one standard deviation, increases revenue of the average firm by a sizeable ($18 \times 0.212 =$) 3.82%, relative to the pre-crisis period.

Some observers worry about a 'K-shaped' recovery from Covid-19, as small firms are particularly at risk, implying that larger firms recover at faster rates (Doerr and Gambacorta, 2020a; Gourinchas et al., 2020). Column (4) thus adds interaction terms of the IMD index and post dummy with the log of total pre-crisis firm assets. The positive coefficient on $post \times log(assets)$ shows that, on average, large firms have seen a relatively stronger rise in revenues than smaller firms. Yet, the positive co-

efficient on $IMD\ index \times post$, together with and negative coefficient on $IMD\ index \times post \times log(assets)$, suggests that a higher IMD ranking is associated with higher revenue especially among smaller firms. Further adding country*year fixed effects in column (5) does not materially affect our results.[1]

Column (6) further shows that technological capacity has larger effects on revenues of younger firms. While young firms might be less responsive to changes in aggregate productivity in general (Ai et al., 2013, 2018), this finding suggests that better overall technological capacity could improve young firms' ability to adapt to aggregate shocks. Finally, column (7) shows that the effect is more pronounced among growth firms (firms with book-to-market ratios below the industry median). As growth options reflect intangible capital (Ai et al., 2013), this could imply that technological capacity is particularly beneficial for firms that use intangible capital more extensively.

Where there differential pre-trends? Figure 2 provides a binscatter plot at the country level, with average revenue growth among sample firms in 2018 and 2019 on the vertical axis and the average 2018–19 IMD rank of the firms' headquarters on the horizontal axis. The blue line denotes the linear fit. There is no significant relationship between a country's IMD rank and average revenue growth prior to the Covid-19 shock, suggesting that firms in better ranked countries did not experience systematically higher revenue growth before the treatment period, relative to firms headquartered in lower-ranked countries. Table 3 confirms this visual impression in a

[1]The positive effect of IT on the performance of small firms is in line with Ahnert et al. (2021), who show that banks' IT adoption spurs entrepreneurship.

regression setup. It shows that the IMD index has no significant effect on firm revenue growth in the pre-treatment period, irrespective of whether we add firm controls, year fixed effects or industry*year fixed effects. These findings suggest that there were no differential pre-trends in firm revenue that correlate with countries' pre-crisis ranking of technological capabilities.

3.2 Extensions and robustness

China and South Korea experienced a relatively swift rebound from the Covid-19 shock. In a first step, Table 4 excludes Chinese and South Korean firms from the sample in column (1). Yet, even in this restricted sample, higher technological capacity is associated with higher revenue growth, although the estimated coefficient drops in magnitude, as can be expected.

Second, columns (2)–(4) investigate whether controlling for the impact of alternative measures of country-level efficiency in the Covid-19 period affects the impact of the IMD index on firm revenue. For example, higher financial development, better property rights, or trade openness could affect firm performance. Column (2) thus controls for financial development, as measured by the IMF index (Svirydzenka, 2016);[2] columns (3) further adds an index on countries' strength of the legal system and property rights from the Fraser Institute (Gwartney et al., 2020); and column (4) further adds trade (the sum of imports and exports over GDP) as a control. In each column, the respective variables are interacted with the *post* dummy. As can be seen, across specifications the coefficient on the interaction effect

[2]The index summarizes how developed financial institutions and financial markets are in terms of their depth (size and liquidity), access (ability of individuals and companies to access financial services) and efficiency (ability of institutions to provide financial services at low cost and with sustainable revenues, as well as the level of activity of capital markets).

IMD index × *post* remains positive and significant at the 1% level. These results thus indicates that revenue is higher in 2020 among firms in better-ranked countries, relative to the 2018–19 period, even when we account for the level of financial development, property rights, or trade.

The IMD index varies at the country level, so an implicit assumption is that a better ranking affects firms in all industries to a similar extent. As a third test, in Table 5 we relax this assumption by allowing for heterogeneity across industries. Specifically, we use INTAN-Invest data (Corrado et al., 2016) on intangible intensity at the 1-digit NACE Rev.2 industry-level to proxy for sectors ability to harness the benefits of digital technologies; for each industry, intangible intensity is defined as the median across countries of the average ratio over the 1995-2016 period of the share of intangible investment out of total value added. By interacting industry-level intangible intensity with the country-level IMD index, we create a synthetic index of technological capacity, labelled *country-industry index*, that varies at the country-industry level. A higher value of this synthetic index indicates that a firm in a given country-industry cell has higher technological capacity. Column (1) shows that the index has a positive and highly significant effect on firm revenue – confirming results for the overall IMD index in the baseline regressions. An advantage of the more granular country-industry variation of the synthetic index is that we can add country*year fixed effects to account for any observable and unobservable trends that affects firms within the same country. Column (2) shows that higher technological capacity is still associated with higher firm revenue during 2020, relative to 2018–19, even when we account for any shocks that hit firms within the same industry or country. Columns (3) and (4) show that a

higher IMD ranking is associated with higher revenue especially among younger firms. Columns (5) and (6) further show that the positive effect of the IMD ranking on revenue is less pronounced among growth firms (the sample is restricted to public firms that report their market capitalisation).

Finally, Table 6 estimates Equation (1), but uses firms' return on assets instead of log revenues as dependent variable. Column (1) shows that a higher IMD ranking is associated with higher firm returns, in line with results for revenue. Columns (2)–(3) confirm that, also for return on assets, effects are more pronounced among smaller companies.

4 Conclusion

Technology can increase a firm's resilience to shocks by facilitating sales via e-commerce, and improving customer services, logistics and operations. It can further be helpful to identify and limit inefficiencies.

In this paper, we show that improving a country's technological capability by one standard deviation is associated with a relative increase in revenues of the average firm by around 4%. This result is more pronounced among smaller firms and robust to alternative specifications.

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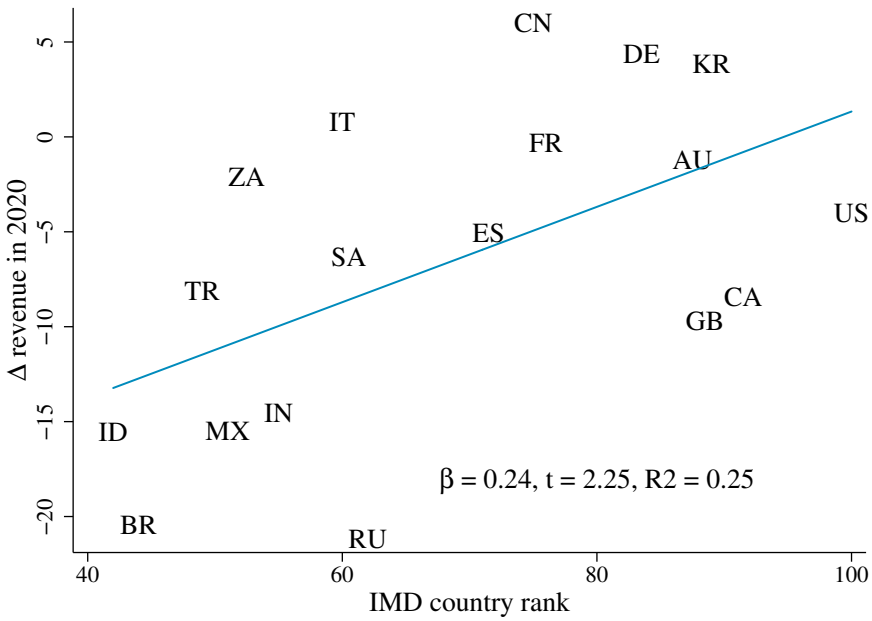
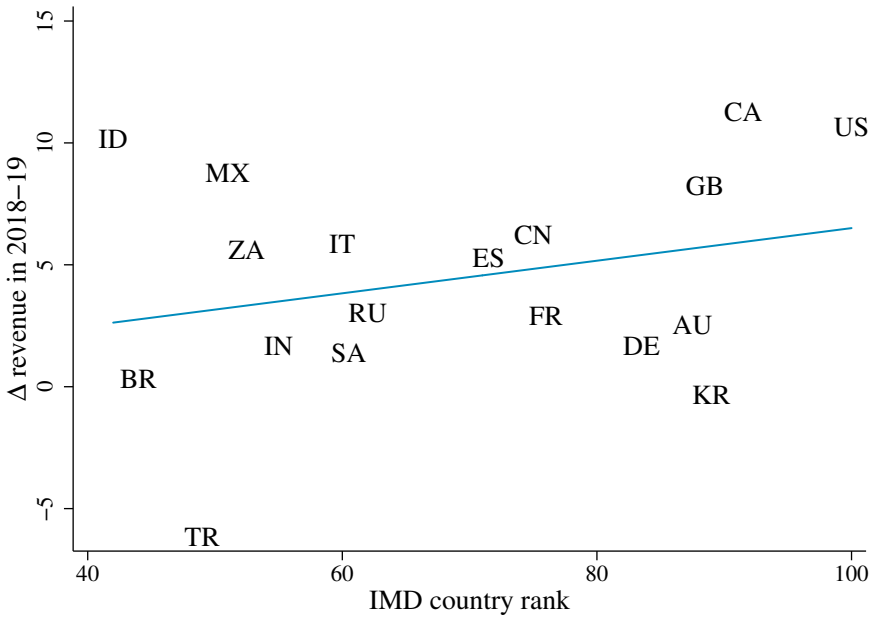
Figures and Tables

Figure 1: **Technological capacity and firm revenue during Covid-19**



This figure shows a scatter plot at the country level, with average revenue growth in 2020 on the vertical axis and the average 2018–19 IMD rank of the firm's headquarters country on the horizontal axis. Each scatter point corresponds to one of the 17 countries in the sample. The blue line denotes the linear fit.

Figure 2: **Technological capacity and firm revenue before Covid-19**



This figure shows a scatter plot at the country level, with average revenue growth in 2018–19 on the vertical axis and the average 2018–19 IMD rank of the firm's headquarters country on the horizontal axis. Each scatter point corresponds to one of the 17 countries in the sample. The blue line denotes the linear fit.

Table 1: **Summary statistics**

Panel (a): Firm-level variables

Variable	Obs	Mean	Std. Dev.	Min	Max	P25	P50	P75
log(revenue)	47415	5.21	2.21	-.12	10.56	3.69	5.17	6.69
revenue growth (in pct.)	47413	4.28	32.55	-137.15	130.58	-7.89	4.42	17.69
total assets (in mn)	47415	3976.22	18581.46	.14	603796.2	64.47	315.06	1604.88
log(total assets)	47415	5.81	2.28	-1.97	13.31	4.17	5.75	7.38
return on assets (in pct.)	47415	.17	15.98	-92.54	25.15	-.26	2.73	6.77
age	47415	14.56	8.15	4	43	8	12	21
leverage (in pct.)	47415	22.36	19.43	0	92.38	5.89	18.98	34.13
Tobin's Q	31026	3.01	3.83	.26	27.12	1.1	1.88	3.32

Panel (b): Country-level variables

Variable	Obs	Mean	Std. Dev.	Min	Max	P25	P50	P75
IMD index (rank, 100 = highest)	54	69	17.95	42	100	53	67	88
real GDP growth	54	-.02	4.25	-10.84	6.75	-2.07	1.39	2.43
GDP per capita	54	26062.6	19152.05	1900.71	65279.53	9126.59	25197.09	42354.41
population (in mn)	54	247.81	413.13	24.98	1402.11	51.71	74.87	211.05
inflation (in pct.)	54	2.88	3.27	-2.09	16.33	1.14	2.17	3.45
(imports+exports)/GDP (in pct.)	54	55.03	16.82	23.4	88.6	40.26	59.21	65.43

This table shows summary statistics for the main variables at the firm (panel a) and country level (panel b). All values are in US dollars.

Table 2: **Technological capacity and firm revenue during Covid-19**

VARIABLES	(1) log(revenue)	(2) log(revenue)	(3) log(revenue)	(4) log(revenue)	(5) log(revenue)	(6) log(revenue)	(7) log(revenue)
IMD index × post	0.252***	0.256***	0.212***	0.662***			
	(0.026)	(0.026)	(0.026)	(0.097)			
post × log(assets)				0.070***	0.073***		
				(0.011)	(0.011)		
IMD index × post × log(assets)				-0.071***	-0.074***		
				(0.013)	(0.014)		
post × age						0.024	
						(0.041)	
IMD index × post × age						-0.169***	
						(0.052)	
post × growth firm							-0.035
							(0.046)
IMD index × post × growth firm							0.137**
							(0.058)
Observations	47,415	47,415	47,415	47,415	47,415	47,415	30,996
R-squared	0.987	0.987	0.988	0.988	0.988	0.988	0.986
Firm controls	✓	✓	✓	✓	✓	✓	✓
Country controls	-	✓	✓	✓	-	-	-
Firm FE	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	-	-	-	-	-
Industry*Year FE	-	-	✓	✓	✓	✓	✓
Country*Year FE	-	-	-	-	✓	✓	✓

This table shows regression results from Equation (1) at the firm-year level over the period 2018–20. The dependent variable is the log of total firm revenues. IMD index denotes the average 2018–19 rank of the firm's headquarters country in the IMD World Competitiveness Rankings, and the dummy $post_t$ takes on a value of one in 2020, and a value of zero otherwise. Country controls include GDP per capita, the log of total population, real GDP growth and CPI inflation in country c and year t. Column (7) restricts the sample to firms with data on their market capitalisation. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1

Table 3: **Pre-trends – cross-sectional regressions**

VARIABLES	(1) Δ revenue	(2) Δ revenue	(3) Δ revenue	(4) Δ revenue
IMD index	-0.149	-0.164	-0.149	-0.151
	(0.098)	(0.123)	(0.144)	(0.125)
Observations	31,608	31,608	31,608	31,608
R-squared	0.008	0.035	0.035	0.075
Country controls	✓	✓	✓	✓
Firm controls	-	✓	✓	✓
Year FE	-	-	✓	-
Industry*Year FE	-	-	-	✓

This table shows regression results from Equation (1) at the firm-year level over the period 2018–19. The dependent variable is the log difference of total firm revenues. IMD index denotes the average 2018–19 rank of the firm's headquarters country in the IMD World Competitiveness Rankings. Firm controls include the log of total assets, leverage, return on assets, and age (as of 2020), averaged across 2018–19. Country controls include GDP per capita, the log of total population, real GDP growth and CPI inflation in country c and year t. Standard errors are clustered at the country level. *** p<0.01, ** p<0.05, * p<0.1

Table 4: **Other macro variables**

VARIABLES	(1) no CN/KR log(revenue)	(2) log(revenue)	(3) log(revenue)	(4) log(revenue)
IMD index × post	0.179***	0.202***	0.211***	0.264***
	(0.028)	(0.050)	(0.050)	(0.052)
financial development × post		0.013	0.036	0.109
		(0.056)	(0.071)	(0.073)
property rights × post			-0.005	-0.022**
			(0.008)	(0.009)
trade × post				0.001***
				(0.000)
Observations	17,370	47,415	47,415	47,415
R-squared	0.991	0.988	0.988	0.988
Firm controls	✓	✓	✓	✓
Country controls	✓	✓	✓	✓
Firm FE	✓	✓	✓	✓
Year FE	-	-	-	-
Industry*Year FE	✓	✓	✓	✓
Country*Year FE	-	-	-	-

This table shows regression results from Equation (1) at the firm-year level over the period 2018–20. The dependent variable is the log of total firm revenues. IMD index denotes the average 2018–19 rank of the firm's headquarters country in the IMD World Competitiveness Rankings, and the dummy $post_t$ takes on a value of one in 2020, and a value of zero otherwise. Firm controls include the log of total assets, leverage, return on assets, and age (as of 2020), averaged across 2018–19, interacted with the post dummy. Country controls include GDP per capita, the log of total population, real GDP growth and CPI inflation in country c and year t. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1

Table 5: **Further specifications**

VARIABLES	(1) log(revenue)	(2) log(revenue)	(3) log(revenue)	(4) log(revenue)	(5) log(revenue)	(6) log(revenue)
IMD index × post			0.594***		0.091**	
			(0.149)		(0.042)	
country-industry index × post	0.982***	0.523**				
	(0.178)	(0.266)				
post × age			-0.023	-0.019		
			(0.040)	(0.041)		
IMD index × post × age			-0.140***	-0.137***		
			(0.050)	(0.052)		
post × growth firm					-0.031	-0.035
					(0.045)	(0.046)
IMD index × post × growth firm					0.126**	0.137**
					(0.056)	(0.058)
Observations	45,546	45,546	47,415	47,415	30,996	30,996
R-squared	0.988	0.988	0.988	0.988	0.986	0.986
Firm controls	✓	✓	✓	✓	✓	✓
Country controls	✓	✓	✓	✓	✓	✓
Firm FE	✓	✓	✓	✓	✓	✓
Year FE	-	-	-	-	-	-
Industry*Year FE	✓	✓	✓	✓	✓	✓
Country*Year FE	-	✓	-	✓	-	✓

This table shows regression results from Equation (1) at the firm-year level over the period 2018–20. The dependent variable is the log of total firm revenues. IMD index denotes the average 2018–19 rank of the firm's headquarters country in the IMD World Competitiveness Rankings, and the dummy $post_t$ takes on a value of one in 2020, and a value of zero otherwise. Firm controls include the log of total assets, leverage, return on assets, and age (as of 2020), averaged across 2018–19, interacted with the post dummy. Country controls include GDP per capita, the log of total population, real GDP growth and CPI inflation in country c and year t. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1

Table 6: **Return on assets**

VARIABLES	(1) RoA	(2) RoA	(3) RoA
IMD index × post	0.028***	0.218***	
	(0.009)	(0.039)	
post × log(assets)		0.019***	0.023***
		(0.004)	(0.004)
IMD index × post × log(assets)		-0.031***	-0.035***
		(0.005)	(0.006)
Observations	47,415	47,415	47,415
R-squared	0.769	0.770	0.770
Firm controls	✓	✓	✓
Country controls	✓	✓	✓
Firm FE	✓	✓	✓
Year FE	-	-	-
Industry*Year FE	✓	✓	✓
Country*Year FE	-	-	✓

This table shows regression results from Equation (1) at the firm-year level over the period 2018–20. The dependent variable is firms' return on assets. IMD index denotes the average 2018–19 rank of the firm's headquarters country in the IMD World Competitiveness Rankings, and the dummy $post_t$ takes on a value of one in 2020, and a value of zero otherwise. Firm controls include the log of total assets and age (as of 2020), averaged across 2018–19, interacted with the post dummy. Country controls include GDP per capita, the log of total population, real GDP growth and CPI inflation in country c and year t. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1

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