Finance and the Diffusion of New Technologies*

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Abstract

Do frictions in the capital markets contribute to the significant differences in the diffusion of new technologies across countries? We examine whether financial market depth impacts the diffusion of 20 major technologies, looking across 60 countries, from 1870 to 2000. We find that greater depth in the banking sector leads to faster technology diffusion for more capital extensive technologies, but only for countries above a certain threshold level of banking sector development. Deeper financial markets also lead to faster diffusion in periods closer to the invention of new technologies. These results highlight the key role of domestic capital markets in technology diffusion, as well as point to an important mechanism relating financial market development to economic growth.

Key Words: banking, technology diffusion, growth.

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1 Introduction

A central issue in the finance literature is the extent to which financial market development drives economic growth across countries (e.g., Beck et al. 2000; Levine 1997; Levine et al. 2000). There is increasing evidence that better financing environments are associated with higher economic growth because they reduce financing constraints for entrepreneurs (Rajan and Zinglaes 1998; Gusio, Sapienza and Zinglaes 2004) and facilitate more efficient allocation of capital across investment opportunities in the real economy (e.g., King and Levine 1993a,b; Jayaratne and Strahan 1996; Rajan and Zingales 2003; Bertrand et al 2007).

While the relationship between financial development and product market efficiency is well-documented, far less attention has been paid to the specific role that capital markets might play in the faster adoption and diffusion of new technologies. Technology adoption is believed to be a key channel through which productivity growth is achieved, and differences in the diffusion of new technologies has been found to explain a significant portion of the large cross-country differences in total factor productivity (Comin and Hobjin, 2009).

Do frictions in the capital markets also contribute to the significant differences in the adoption of new technologies across countries? We address this question by examining whether deeper financial markets drive the faster diffusion of 20 major technologies (such as telephones, railroads, and computers), using a cross-country panel dataset spanning 60 countries and 130 years. Following Rajan and Zingales (1998), our identification strategy focuses on the fact that some of these technologies (such as the railroads) are significantly more capital intensive to commercialize than others (such as the computers). We therefore examine whether the *relative* rate of diffusion for more vs. less capital intensive technologies is greater in countries with deeper financial markets.

Our proxy for financial market depth is the ratio of bank deposits to GDP. We find that greater depth in the banking sector leads to faster technology diffusion of more capital extensive technologies. Moreover, financial market depth is particularly beneficial for the diffusion of technologies in periods closer to their invention. Interestingly, however, the importance of greater financial development for technology diffusion is only true for countries above a certain threshold. These results are robust to controlling for GDP per capita and human capital, as well as the inclusion of country- and technology-year fixed effects.

Our results highlight the important role of domestic capital markets in technology diffusion, as well as suggest that financial markets play in key role in the process of experimentation that is required for the adoption of new technologies close to their date of invention. While this mechanism has been explored in the context of venture capital (Kortum and Lerner, 2000;

Nanda and Rhodes-Kropf 2009), it has not been examined in a larger cross-country setting and points to an important, under-explored mechanism relating financial development to economic growth.

2 Data

We use the ratio of deposits in commercial and savings banks divided by GDP as our measure of financial market depth. The source for these data are Mitchell (2000). Table I provides a summary of the ratio of deposits to GDP over time across the different continents in our dataset.

The technology diffusion measures come from Historical Cross-Country Technology Adoption (HCCTA) data set introduced in Comin and Hobijn (2004). This data set contains historical data on the adoption of several major technologies over the last 200 years across a large set of countries. We therefore construct panel data at the technology-country-year level, measuring the intensive margin of diffusion for each technology across each country over time. Table II lists the technologies we use and how we measure them. Because of data availability constraints, we use different measures for different technologies. Some technologies are measured as the share of capital that embodies the new technology (e.g. fraction of ring spindles). Other production technologies are measured either by the number of equipment units of the technology scaled by real GDP or by the output produced with the technology over real GDP.

In addition, we collect data on the cost of commercializing each technologies in order to classify the technologies as being high or low capital intensity. Our data appendix provides more detail on the sources, measures and coverage of the different technologies.

Since we are interested in understanding the determinants of the speed of diffusion of new technologies along the transition path, we censor the data for each technology at the year when the level of technologies across countries becomes stable. The truncation of the sample for a given technology is the same for all countries as the plateauing of a technology in any given country is likely to be endogenous. The year of truncation for each technology is outlined in Table 1.

For all the variables used in our analysis, we compute five-year averages and use non-overlapping data in our regressions. Taking these five year averages increases the signal-to-noise ratio of our variables and, a priori, does not reduce much of the relevant variation in the data since both technology diffusion and financial market depth are relatively low frequency phenomena. Next we implement our identification strategy and present our estimates.

3 Empirical Results

Our baseline regression has the following form:

$$y_{ict} = \eta_{it} + \phi_i \ + \beta_1^{'}\mathbf{X}_{ct} + \beta_2^{'}FIN_{ct} + \beta_3^{'}(FIN_{ct} * DEP_i) + \varepsilon_{ict}.$$

y_{ict} denotes our measure of the adoption of technology i in country c at time t. To allow for the fact that technologies follow different diffusion paths as well as to account for the fact that we measure different technologies using different units, we include a full set of technology-times-year fixed effects, denoted by η_{it} in our regression specification. Effectively these fixed effects imply that our dependent variable is the deviation of a country's adoption of a technology from the average adoption of that technology across countries in each period. In addition, we include country-fixed effects, denoted by ϕ_i, to control for other country-specific factors that might impact the rate of diffusion of technologies. $\mathbf{X}_{ct}$ is a vector of time-varying control variables such as income per capita, a country's stock of human capital, and the adoption of complementary technologies, that are also impact technology diffusion.

FIN_{ct} is our time-varying measure of financial market depth across countries. Hence $\beta_2^{'}$ measures the relationship between financial market depth and country's relative rate of adoption of technologies. Given concerns about endogeneity in this relationship, however, our main coefficient of interest is $\beta_3^{'}$. $\beta_3^{'}$ is the coefficient on the interaction between financial market depth and an indicator variable for whether a given technology is highly capital intensive to commercialize. It therefore measures a country's relative rate of adoption of more vs. less capital intensive technologies.

Our identification hinges on the assumption that our indicator variable creates a substantive distinction between the capital needs required for the diffusion of new technologies, and furthermore, does not confound any other mechanism that may also cause these technologies to be grouped together and that happens to be the true driver of faster technology diffusion in deeper capital markets. We now turn to our empirical results.

In Tables III to VIII we document the consistent pattern that financial market depth leads to the faster relative adoption of capital intensive technologies relative to those that are less capital intensive. Our results are robust to the inclusion of several control variables, sub-samples of time periods (not yet reported) and a placebo test where the technologies are randomly assigned a level of capital intensity. They also show that it is countries above a threshold level of a deposit to GDP ratio of 25% (about the 30 percentile in Europe and the mean level of banking sector development for the entire sample) that drive this effect. The effect is zero for countries below this threshold.

4 Conclusions

Prior work looking at the role of financial market development in productivity and economic growth has largely focused on the role of better developed financial markets in allocating capital efficiently across investment opportunities. In this paper, we provide evidence for another key role played by well-developed financial markets: reducing the frictions associated with the adoption and the diffusion of new technologies. We use a novel panel dataset on 20 major technologies across 60 countries and 130 years to examine whether greater depth in the banking sector leads to faster diffusion of these new technologies. Our results provide compelling evidence that banking sector depth facilitates the faster diffusion of more capital intensive technologies and that this is particularly true in periods closer to the date of invention, when the greater depth in the capital markets might help with the experimentation required to overcome the initial hurdles of adoption and diffusion. While this mechanism has been explored in the context of venture capital, it has not been examined in a larger cross-country setting and points to an important, under-explored mechanism relating financial development to economic growth.

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Table I: Bank Deposits / GDP

Year	Europe and N. America	Asia	South America	Africa
1870	0.15	0.26		
1875	0.22	0.24		
1880	0.20	0.30		
1885	0.28	0.13		
1890	0.29	0.14		
1895	0.37	0.23		
1900	0.39	0.17	0.20	
1905	0.46	0.16	0.48	
1910	0.48	0.14	0.38	0.10
1915	0.44	0.18	0.53	
1920	0.42	0.15	0.69	
1925	0.43	0.13	0.30	
1930	0.52	0.20	0.32	
1935	0.47	0.20	0.45	
1940	0.51	0.32	0.36	
1945	0.41	0.27	0.35	
1950	0.31	0.17	0.25	0.12
1955	0.30	0.15	0.27	0.09
1960	0.31	0.12	0.21	0.10
1965	0.30	0.14	0.23	0.12
1970	0.30	0.14	0.26	0.13
1975	0.30	0.14	0.29	0.15
1980	0.28	0.15	0.21	0.16
1985	0.32	0.15	0.14	0.18
1990	0.34	0.18	0.12	0.18
1995	0.36	0.28	0.25	0.19

Notes: (1) All data is aggregated to 26 5year time periods spanning 1870-2000.

Europe & N. Am includes AUT, BEL, CAN, CHE, DEU, DNK, ESP, FIN, FRA, GBR, GRC, ITA, NLD, NOR, POL, PRT, RUS, SWE and USA

Asia includes AUS, CHN, IDN, IND, IRN, IRQ, ISR, JOR, JPN, KOR, LBY, MYS, NZL, PHL, SAU, THA and TUR

South America includes ARG, BRA, CHL, COL, MEX, URY and VEN

Africa includes BEN, COG, DZA, EGY, ETH, GHA, KEN, MAR, MUS, NGA, SDN, TUN, UGA, ZAF, ZAR, ZAM, ZMB and ZWE

Table II: Description of Technologies Used

	Technology	Capital Intensity	Countries covered		Country-Years per technology	
			Full Sample	*Europe & N. Am*	*Full Sample*	*Europe & N. Am*
1	Electricity Production	High	58	18	652	285
2	Railroad track	High	35	18	181	131
3	Motor-powered ships	High	7	7	74	74
4	Steam-powered ships	High	14	14	155	155
5	Blast Furnace Steel	High	36	17	160	87
6	Electric Arc Steel	High	49	18	293	165
7	Telegram	High	38	17	288	156
8	Telephone	Medium	59	19	654	318
9	Passenger Cars	Medium	59	19	620	277
10	Trucks	Medium	58	18	594	268
11	Tractors	Medium	57	18	287	103
12	Cell Phones	Low	58	19	145	59
13	Computers	Low	57	19	144	56
14	Internet	Low	58	19	102	38
15	Loom	Low	51	18	108	30
16	MRI machines	Low	23	18	59	51
17	Pesticides	Low	52	19	69	26
18	Radio	Low	59	18	553	212
19	Ring Spindle	Low	34	12	175	63
20	TV	Low	60	19	456	167

Table III: Financial Depth and Technology Diffusion: Full Sample

1870-2000: Dependent Variable: Log Technology Diffusion per capita

	Full Sample			
	(1)	*(2)*	*(3)*	*(4)*
Deposits/GDP X capital intensity	0.254**	0.396***	0.324**	0.556***
	(0.120)	(0.120)	(0.130)	(0.130)
Deposits/GDP	0.488***	0.236**	0.271**	0.835***
	(0.120)	(0.110)	(0.120)	(0.140)
Human Capital		0.280**	0.084	0.048
		(0.110)	(0.130)	(0.130)
GDP per Capita		1.179***	1.221***	1.217***
		(0.052)	(0.055)	(0.054)
Human Capital x capital intensity			0.550***	0.588***
			(0.150)	(0.150)
GDP per capita x capital intensity			-0.0784*	(0.071)
			(0.046)	(0.046)
Number of years since invention				-0.142***
				(0.029)
Deposits/ GDP x years since invention				-0.0157***
				(0.002)
Technology X Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Observations	3187	3187	3187	3187

Robust standard errors in parentheses, clustered by country

*** p<0.01, ** p<0.05, * p<0.1

Notes: (1) All data is aggregated to 26 5year time periods spanning 1870-2000.

(2) Main effect for capital intensity is absorbed by the technology-year fixed effects

Table IV: Financial Depth and Technology Diffusion: Full Sample

1870-2000: Dependent Variable: Log Technology Diffusion per capita

	Countries with Average Deposits / GDP >=25%			
	(1)	*(2)*	*(3)*	*(4)*
Deposits/GDP X capital intensity	0.476***	0.507***	0.635***	0.692***
	(0.160)	(0.160)	(0.160)	(0.160)
Deposits/GDP	0.269**	0.013	-0.0624	0.098
	(0.130)	(0.130)	(0.130)	(0.170)
Human Capital		0.394***	0.140	0.134
		(0.130)	(0.160)	(0.160)
GDP per Capita		1.132***	1.263***	1.273***
		(0.087)	(0.097)	(0.097)
Human Capital x capital intensity			0.661***	0.657***
			(0.210)	(0.210)
GDP per capita x capital intensity			-0.230***	-0.231***
			(0.079)	(0.079)
Number of years since invention				-0.164***
				(0.038)
Deposits/ GDP x years since invention				-0.004
				(0.003)
Technology X Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Observations	5769	5769	5769	5769

Robust standard errors in parentheses, clustered by country

*** p<0.01, ** p<0.05, * p<0.1

Notes: (1) All data is aggregated to 26 5year time periods spanning 1870-2000.

(2) Main effect for capital intensity is absorbed by the technology-year fixed effects

Table V: Financial Depth and Technology Diffusion: Full Sample

1870-2000: Dependent Variable: Log Technology Diffusion per capita

	Countries with Average Deposits / GDP < 25%			
	(1)	*(2)*	*(3)*	*(4)*
Deposits/GDP X capital intensity	-0.231	0.265	-0.155	0.639
	(0.470)	(0.440)	(0.460)	(0.500)
Deposits/GDP	0.616*	0.607*	0.797**	2.059***
	(0.360)	(0.340)	(0.340)	(0.440)
Human Capital		0.089	(0.131)	(0.173)
		(0.200)	(0.210)	(0.210)
GDP per Capita		1.225***	1.252***	1.245***
		(0.071)	(0.073)	(0.072)
Human Capital x capital intensity			0.668***	0.719***
			(0.220)	(0.220)
GDP per capita x capital intensity			(0.024)	(0.031)
			(0.058)	(0.057)
Number of years since invention				-0.105**
				(0.043)
Deposits/ GDP x years since invention				-0.0318***
				(0.007)
Technology X Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Observations	5769	5769	5769	5769

Robust standard errors in parentheses, clustered by country

*** p<0.01, ** p<0.05, * p<0.1

Notes: (1) All data is aggregated to 26 5year time periods spanning 1870-2000.

(2) Main effect for capital intensity is absorbed by the technology-year fixed effects

Table VI : Financial Depth and Technology Diffusion: Europe and North America

1870-2000: Dependent Variable: Log Technology Diffusion per capita

	Europe and North America			
	(1)	*(2)*	*(3)*	*(4)*
Deposits/GDP X capital intensity	0.624***	0.573***	0.817***	0.864***
	(0.140)	(0.130)	(0.140)	(0.140)
Deposits/GDP	0.0406	0.154	0.061	0.294*
	(0.120)	(0.120)	(0.120)	(0.150)
Human Capital		0.668***	0.542***	0.547***
		(0.130)	(0.150)	(0.150)
GDP per Capita		1.019***	1.322***	1.291***
		(0.091)	(0.110)	(0.110)
Human Capital x capital intensity			0.287	0.274
			(0.220)	(0.220)
GDP per capita x capital intensity			-0.470***	-0.437***
			(0.090)	(0.090)
Number of years since invention				-0.133***
				(0.037)
Deposits/ GDP x years since invention				-0.006**
				(0.002)
Technology X Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Observations	2721	2721	2721	2721

Robust standard errors in parentheses, clustered by country

*** p<0.01, ** p<0.05, * p<0.1

Notes: (1) All data is aggregated to 26 5year time periods spanning 1870-2000.

(2) Main effect for capital intensity is absorbed by the technology-year fixed effects

Table VII : Financial Depth and Technology Diffusion: Europe and North America

1870-2000: Dependent Variable: Log Technology Diffusion per capita

	Countries in Europe and North America with Average GDP >=25%			Deposits /
	(1)	*(2)*	*(3)*	*(4)*
Deposits/GDP X capital intensity	1.114***	1.067***	1.177***	1.224***
	(0.170)	(0.170)	(0.170)	(0.170)
Deposits/GDP	-0.236*	-0.181	-0.211	-0.030
	(0.140)	(0.130)	(0.130)	(0.180)
Human Capital		0.655***	0.546***	0.545***
		(0.140)	(0.170)	(0.170)
GDP per Capita		0.806***	1.176***	1.154***
		(0.110)	(0.140)	(0.140)
Human Capital x capital intensity			0.272	0.257
			(0.250)	(0.250)
GDP per capita x capital intensity			-0.548***	-0.517***
			(0.130)	(0.130)
Number of years since invention				-0.162***
				(0.045)
Deposits/ GDP x years since invention				-0.005
				(0.003)
Technology X Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Observations	1869	1869	1869	1869

Robust standard errors in parentheses, clustered by country

*** p<0.01, ** p<0.05, * p<0.1

Notes: (1) All data is aggregated to 26 5year time periods spanning 1870-2000.

(2) Main effect for capital intensity is absorbed by the technology-year fixed effects

Table VIII : Financial Depth and Technology Diffusion: Europe and North America

1870-2000: Dependent Variable: Log Technology Diffusion per capita

	Countries in Europe and North America with Average GDP < 25%			Deposits /
	(1)	*(2)*	*(3)*	*(4)*
Deposits/GDP X capital intensity	-0.404	-0.243	-0.181	-0.018
	(0.620)	(0.600)	(0.610)	(0.640)
Deposits/GDP	-0.144	0.175	0.19	0.500
	(0.420)	(0.400)	(0.410)	(0.560)
Human Capital		0.214	0.058	0.042
		(0.320)	(0.370)	(0.370)
GDP per Capita		1.230***	1.297***	1.299***
		(0.190)	(0.210)	(0.210)
Human Capital x capital intensity			0.468	0.497
			(0.490)	(0.490)
GDP per capita x capital intensity			(0.135)	(0.129)
			(0.150)	(0.150)
Number of years since invention				(0.018)
				(0.078)
Deposits/ GDP x years since invention				-0.008
				(0.010)
Technology X Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Observations	852	852	852	852

Robust standard errors in parentheses, clustered by country

*** p<0.01, ** p<0.05, * p<0.1

Notes: (1) All data is aggregated to 26 5year time periods spanning 1870-2000.

(2) Main effect for capital intensity is absorbed by the technology-year fixed effects