Financial Development and Technology Diffusion*

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Abstract

We examine the extent to which financial market development impacts the diffusion of 16 major technologies, looking across 17 countries, from 1870 to 2000. We find that greater depth in financial markets leads to faster technology diffusion for more capital-intensive technologies, but only in periods closer to the invention of the technology. In fact, we find no differential effect of financial depth on the diffusion of capital-intensive technologies in the late stages of diffusion or in late adopters. Our results are consistent with a view that local financial markets play a critical role in facilitating the process of experimentation that is required for the initial commercialization and diffusion of technologies.

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1 Introduction

A central issue in the economics and finance literature is the extent to which financial market development drives economic growth (e.g., Beck et al. 2000; Levine 1997; Levine et al. 2000; Laeven et al 2015). There is increasing evidence that better financing environments lead to higher economic growth because they reduce financing constraints for entrepreneurs (Rajan and Zingales 1998; Guiso, Sapienza and Zingales 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 (Aghion and Howitt, 1992), 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, 2010).[1]

In this paper, we examine whether, and if so how, financial markets contribute to technology diffusion. Examining this question requires data that both span a long period of time and are also comparable across countries. We combine a cross-country panel dataset spanning 16 general purpose technologies (such as electricity, railways, telephones and motor cars) over 17 countries and 130 years with data on financial market development over the same extended period of time.[2] The long time span and extensive coverage across

[1]There is a related theoretical literature that links financial to economic development. See for example, Greenwood and Jovanovic (1990) and Acemoglu and Zilibotti (1997) for models where financial markets reduce the risks associated with modern technologies inducing faster capital accumulation. These models do not capture technology diffusion and innovation. Jovanovic and MacDonald (1994) model the risks faced by entrepreneurs while the market settles in the final shape of innovations. Michalopoulos, Laeven and Levine (2015) develop a model of growth through innovation with a financial sector that screens new projects. Unlike the focus of our paper, this paper emphasizes teh screening role of financiers instead of its risk pooling role.

[2]Our core estimations focus on 17 countries with the most comprehensive data over this period, but we also show the consistency of our results with a broader set of 55 countries where we have less

countries and technologies allows us to examine the diffusion of technology both within and across countries. A key challenge with such an analysis is untangling the extent to which an observed correlation between financial market development and technology diffusion is in fact causal. Our identification strategy therefore focuses on two types of cross sectional variation to understand the causal impact of financial development on technology diffusion. First, some of these technologies (such as the railroads or electricity generation) are significantly more capital intensive to commercialize than others (such as the ring spindles or radios) and hence more reliant on financial markets for their commercialization. By exploiting cross-technology variation in the reliance on financial markets, we therefore examine whether the *relative* rate of diffusion for more vs. less capital intensive technologies is greater in countries with deeper financial markets than in countries with less-well developed financial markets. Second, as we point out in greater detail below, commercializing technologies at their birth requires extensive experimentation by entrepreneurs, as the customers, business models, and even the way the technology will be used is often unknown. Indeed, there tends to be a consistent pattern of hundreds of new entrants into these nascent markets that is then followed by a shakeout as the technology matures and industry leaders emerge (Klepper, 1996, Klepper and Simons 2005). We exploit the fact that the governance required to commercialize new ventures in these early periods is much higher (and hence the need for well-developed local financial markets is much greater), compared to later stages of an industry's development when commercialization can more easily take place through arms length financing of larger well-established corporations. We therefore also examine the relative importance of *local* financial development on the diffusion of technologies closer to their date of invention compared to when they are more established.

We find that deeper financial markets in a country accelerate technology diffusion of more capital intensive technologies. Importantly, however, this benefit of financial mar-

comprehensive data.

ket depth is only present in the early stages of a technology's commercialization. These results are robust to the inclusion of important control variables as well as a stringent set of fixed effects. The difference in the importance of financial development for technology diffusion in the early and late stages of the technology's lifecycle is important in two respects. From an econometric standpoint, it reduces concerns about unobserved heterogeneity driving the results, as this would likely have a consistent effect at all stages of a technology's life. From a substantive perspective, these results highlight the important role of *domestic* capital markets in the diffusion of technologies in a country, particularly in the early stages of the technology's lifecycle. They are consistent with a view that in addition to reducing frictions, deeper financial markets play a critical role in facilitating the process of experimentation that is required for the adoption and diffusion 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; Samila and Sorenson, 2010; Nanda and Rhodes-Kropf 2010, 2011; Kerr, Nanda and Rhodes-Kropf, 2014), it has not been examined in a larger cross-country setting and points to a potentially important channel through which financial development affects economic growth Beck et al. 2000; Levine 1997; Levine et al. 2000; Laeven et al 2015).

The rest of the paper is structured as follows. In Section 2, we use historical examples to outline the mechanisms through which we believe financial market development impacts the commercialization, and diffusion of new technologies. Section 3 relates these examples to the data and identification strategy used in our empirical analysis. Section 4 presents our main findings and robustness checks and Section 5 concludes.

2 Finance and the Commercialization of New Technologies

Startup firms play a central role in the commercialization of new technologies (Akcigit and Kerr, 2012). While the role of startups in the emergence of more recent industries such as semiconductors, the internet and biotechnology is well known, historical accounts of the commercialization of the railways, motor cars and other new technologies also illustrate the important role of new firms. Indeed, Lamoreaux and Sokoloff (2007), writing about US innovation from the 1870s to the present day, highlight that startups have played a critical role in the development of cutting edge technologies for over a century. They point out that while individual inventors played a disproportionate role in commercializing their own innovations in the early and mid-1800s, the greater complexity and capital intensity of new technologies being commercialized from the late 1800s onwards drove an increasing amount of innovation to happen within the boundaries of new firms. For example, they write that "most of the firms that invested heavily in R&D facilities in the early twentieth century originated as entrepreneurial companies formed to exploit the discoveries of particular inventors. Perhaps the most famous [example of such an occurrence is the case of] General Electric, formed from a merger of two core enterprises that had been organized by investors with the aim of commercializing the innovations of Thomas Edison and Elihu Thompson."

The increasing complexity and capital intensity of new technologies being developed across the world from the late 1800s onwards created a key role for the financial markets in helping to fund the commercialization of these innovations. In the context of the US economy, Lamoreaux and Sokoloff (2007) point out that: "by the late nineteenth century, it was clear to observers that technological change was a permanent feature of the industrial economy and that substantial returns could be obtained through investing in the development of frontier technologies. Railroads and telegraphy were perhaps the first grand-scale examples of industries created or revolutionalized by important inventions, but others such as electricity, telephones, steel, chemicals and automobiles soon followed. An interest in these sorts of opportunities grew, technologically creative entrepreneurs increasingly sought out investors (and vice versa) because the greater technical complexity and capital intensity of new technologies meant that effective programs of inventive activity and commercial exploration required more financial backing than before."

As is still true to this day with early stage investors, much of the initial financing for these startups "typically was raised informally from local backers, many of whom were personally acquainted with the inventors involved" (p.14) For example, Lowell was a hot bed of economic activity in the early nineteenth century and its growth, based on the textile industry and immigrant labor, was extraordinary. The Boston Associates (a group of rich investors who made their money in trade) provided finance for investment in the mills and they are often considered to be the pre-history of venture capital. Lamoreaux, Levenstein and Sokoloff (2007) provide a detailed study of Cleveland, Ohio, "a center of inventive activity in a remarkable number of important industries, including electric light and power, steel, petroleum, chemicals and automobiles". They found that financing and active involvement by wealthy angel investors often played an important role in the success of these ventures. For example, George Eastman, the founder of the Eastman Kodak Company first founded the Eastman Dry Plate Company in 1881, with the backing of angel investor, Henry Strong, while the Ford Motor Company was founded in 1903 with investments from twelve local angel investors.

The active role played in the governance of new ventures seems particularly important early in the life of industries, when hundreds of new entrants are typically experimenting with the way in which the technology will be put to use. Gort and Klepper (1982) and Klepper and Simons (2005) have documented these patterns of entry across a wide range of industries, including in televisions and automobiles. For example, Klepper (2007) notes that while the motor car industry was dominated by just 9 firms by 1940, the industry was characterized by widespread experimentation in its early years, with over 270 automobile startups in the 1909. Klepper notes that "the growth of the industry was spurred by tremendous technological change. The original automobiles had low-power steam, electric or gasoline engines. They were buggy-like contraptions with engines under the body, tiller steering, chain transmissions, open bodies and hand-cranked starters". Some were designed for urban use while others were meant for rural settings. In fact, in many instances early in the life on a new technology, it was even unclear what the technology would be used for. Janeway (2012) notes that one of the early application of the telephone was to broadcast entertainment to the home. He writes that "in the first years of the 1890s, the Electrophone Company in London was offering concerts, opera, music hall variety and even church services by subscription; the entertainments were delivered to homes, hospitals and other venues via telephone". On the other hand, "point-to-point communication by wireless telegraphy served as the principal application of radio communications until the introduction of public broadcasting after the First World War"! Relatedly, Nye (1992) documents the several decade long search for commercially viable applications of electric power.

Our hypothesis is that the depth of local financial markets and the ability of local financiers to help commercialize these innovations was central to the rate and trajectory of technology diffusion. While the importance of financial markets in the commercialization and diffusion of new technologies over the past century has been documented in these detailed accounts of particular industries, regions or periods of time, it has not been studied in terms of a systematic role it might play in the rate of technology diffusion across countries. In this paper, therefore, we address this issue by asking the following question: Do cross-country differences in financial market development help to explain differences in the degree to which new technologies are commercialized and diffuse across countries? This question is of particular relevance, as technology adoption is increasingly viewed as a key channel through which countries achieve economic growth, and hence, may be an important (under-explored) mechanism linking financial market development to subsequent economic growth.

3 Data and Empirical Strategy

A key challenge to such a study is the availability of the relevant data. We overcome this challenge by combining three distinct types of data. First, we use measures of technology diffusion from the CHAT data set introduced in Comin and Hobijn (2004, 2009, 2010). This data set contains historical data on the diffusion of several major technologies over the last 200 years across a large set of countries. We construct panel data at the technology-country-year level, measuring the intensity with which each technology is used in each country over time. Table 1 lists the technologies we use. As can be seen from Table 1, the set of technologies cover a wide span of sectors. This broad coverage should inform us about the relevance of the mechanism explored in the economy. The heterogeneous nature of the technologies explored is also reflected in their measures. Some technologies embodied in capital goods (e.g., cars, computers, MRI machines) are measured by the number of units in operation. Some technologies that capture the ability to produce something (e.g., electric arc steel, electricity, telegraphic services) are measured by the total production or by the number of users (e.g., cellphones). All measures are scaled by population. We deal with the heterogeneity of measures in two ways. First, we take logarithms of the per capita technology measures. This removes the units of the analysis which go to the constant term. Second, we introduce a full set of technology-specific time dummies that captures the average diffusion path for each technology. In addition, since we are interested in understanding the diffusion of new technologies along the transition path, we censor the data for each technology at the year when the level of technology diffusion across countries becomes stable.

The second variable that is necessary for our analysis is a measure of domestic financial development. Our primary measure of financial development comes from the Jorda-Schularick-Taylor [J-S-T] Macrohistory database (Jorda et. al, 2017). We use the measure of total loans to non-financial private sector (in nominal currency), scaled by GDP (in nominal currency) in each year as our measure of financial development. These data are available for only 17 countries, however, so we also use the ratio of deposits in commercial and savings banks divided by GDP as a measure of financial development for a larger sample of 55 countries to show the robustness of these results to a broader set of countries. The source for data on bank deposits is Mitchell (2000).

Table 2 provides descriptive statistics on our measures of financial market depth for the 17 countries in our core sample. In addition to the two measures thatw e use in our analysis, we also presnet for comparison purposes a measure of credit to GDP provided by Beck et. al (2001) which is available for 1960 onwards. All three measures are positively correlated, with the two credit measures in particularly correlated at 0.56. This gives us confidence in our measure of financial market depth. Aside from the practical advantage of bank credit data being available for such a long time period, we believe that the depth of the banking sector is also a substantively useful proxy for several of the functions that financial markets provide (Levine, 1997). At the most basic level, the banking sector depth measures the degree to which savings are mobilized towards the availability of funds for credit, which, as was outlined above, was a key way through which startups were funded, either through angel investments or through institutionalized sources of finance. Better developed financial markets also reduce intermediation costs, facilitate risk management, as well as play a role in governance, all of which are critical factors for helping to commercialize new technologies.[3]

[3]We see bank credit and deposits as a proxy for the overall level of financial development, not just that of the banking sector. Nevertheless, it is also worth noting that there is growing evidence that banks play a (surprisingly) large role in directly financing innovation(e.g. Mann (2014), Chava et al (2013),

The third variable we need to conduct our analysis is the classification of technologies based on their capital intensity. In our analysis, we exploit the fact that some technologies are more capital intensive than others and hence will need to depend more on external finance for their commercialization. Because of that, the financial market development will accelerate the diffusion of capital-intensive technologies to a greater degree than those that are less capital-intensive. Note that, measuring the capital intensity of technologies, rather than industries, facilitates our analysis, since the capital intensity of technologies is a truly technological attribute and therefore it is likely to be more stable over time and across countries than the capital needs of the companies in an industry.

The classification of technologies according to their capital intensity is outlined in Table 1. Appendix 1 provides detail on the sources, measures and coverage of the different technologies. Despite our efforts, it is impossible to obtain precise estimates about the costs of these technologies that apply universally to all countries and time periods. However, we believe that the differences in the costs of acquiring the capital intensive vs. less capital intensive technologies are large enough that they dominate the potential measurement error that the exercise is bound to have. We consider that the more capital intensive technologies are railways, telegraphy, telephones, electricity production, the production of steel with electric arc and blast oxygen furnaces, and cell-phone communications. The less capital intensive technologies are technologies that are embodied in smaller machines and in consumer durables such as ring spindles, automatic looms, cars, trucks, tractors, radios, TVs, computers and MRI machines.

Our baseline econometric specification therefore takes the form:

$$y_{ict} = \eta_{it} + \phi_c \ + \beta_1 \mathbf{X}_{ct} + \beta_2 FIN_{ct} + \beta_3 (FIN_{ct} * DEP_i) + \varepsilon_{ict}. \quad (1)$$

where y_{ict} denotes our measure of the adoption of technology i in country c at time

Nanda and Nicholas (2014)). See Kerr and Nanda (2015) for a review.

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. Many of the concerns related to confounding factors in cross-country econometric studies are country–specific (and, to a first order, symmetrically affect the adoption of all kind of technologies). We therefore include country-fixed effects, denoted by ϕ_c, 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 also impact technology diffusion. FIN_{ct} is our time-varying measure of financial market depth (i.e., loans to GDP ratio) across countries. Hence β_2 measures the relationship between financial market depth and country's relative rate of adoption of technologies.

Given concerns about endogeneity and omitted variables that may bias this relationship, our main coefficient of interest is β_3, which 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 commercialization 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.

More specifically, three assumptions are necessary for the validity of our identification strategy. (i) Loans to GDP ratio is a good measure of financial market development;

(ii) any factor that differentially affects the diffusion of capital-intensive (vs. non-capital-intensive) technologies is not correlated with financial market development, and (iii) our classification of technologies truly captures their capital intensity and not something else that correlates with capital-intensity. Below we discuss the validity of these assumptions.

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.

4 Empirical Results

4.1 Basic Results

Table 3 reports the results from our baseline regression. As can be seen from column 1 of Table 3, the level of financial development (second row) is insignificantly correlated with the speed of technology diffusion. More importantly, the association between financial market development and technology diffusion is larger for capital intensive technologies.

To understand the economic magnitude of these coefficients, we conduct the following exercise. We first run our baseline regression in column 1 of Table 3, but only including the set of Technology x Year and Country Fixed Effects as explanatory variables. We compute the standard deviation of the residuals from this regression, to understand variation remaining in our dependent variable, once we account for fixed effects in our analyses. We next run the a regression with $FIN_{ct} * DEP_i$ as dependent variable on the same set of dummies. We compute the standard deviation of the residuals from this regression and interact them with β_3, the coefficient on $FIN_{ct} * DEP_i$ in Table 3. Dividing this interaction by the standard deviation of the residuals from the first regression provides us with an estimate of the share of one standard deviation in technology diffusion that is explained by a one standard deviation change in $FIN_{ct} * DEP_i$. This calculation yields an estimate of 14%, suggesting that the size of the relationship is non-trivial.

Thus far, we have shown that there is a significant positive association between the level of financial development and the differential diffusion of technologies that are capital intensive and that the economic magnitudes are not trivial. We now discuss various hypotheses about the origin of this association with the hope that the discussion brings us closer to uncovering a causal link between financial development and technology diffusion. One concern that typically arises in cross-country empirical analysis is that of reverse causality. In our context, this means that our baseline results may not indicate that financial development fosters technology adoption but rather that technology adoption leads to the development of financial institutions. One formulation of this reversed mechanism is that technology adoption increases income, and in richer societies there is a higher supply of financial resources (in this case more credit relative to GDP).

Alternatively, the adoption of capital-intensive technologies could lead to an increase in investment (for a given income) and that could in turn spur financial development. However, the total amount of investment involved in the adoption of our technologies is not necessarily correlated with their capital intensity. Take for example computers since the 1990s or cars since the 1920s. Though not very capital-intensive, investment in these capital goods represented a significant portion of total investment in the economy during these time periods. Hence, there is little reason to believe that it is precisely the adoption of capital intensive technologies what stimulates investment and, through this channel, the development of financial markets.

One way to study this reverse causality hypothesis more systematically is to control for per capital income and by allowing per capita income to affect differentially the diffusion of capital intensive technologies. The rationale for this strategy stems from the fact that investment-output ratios are highly correlated with income at high and medium term frequencies (see, e.g., Prescott, 1984 , and Klenow and Rodriguez-Clare, 1997). If this correlation is driven by the expansion of capital intensive industries, allowing for a differential effect of income on the diffusion of technologies in capital intensive industries should capture the reverse channel of technology diffusion on financial market development. Column 2 of Table 3 implements this exercise. While GDP per capita is associated with technology diffusion, we find that per capita income is not differentially associated with the diffusion of capital intensive technologies. Furthermore, allowing for a differential effect of income on capital intensive technologies does not affect the significance of the differential association between financial development and the diffusion of capital intensive technologies.[4]

Another variable variable that may impact the estimates of β_3 is human capital. If financial marketd evelopment favors the accumulation of human capital and human capital is more relevant for the diffusion of capital-intensive technologies, we could observe a differential correlation between financial market development and the diffusion of capital-intensive technologies. To explore whether the estimates of β_3 in Table 3 reflect this mechanism, we control in column 3 for the level of human capital and the interaction between human capital and capital intensive technologies. We measure human capital by the secondary enrollment rate. This exercise yields two findings. First, we find no significant complementarity between human capital and the capital intensity of technologies. Second, we find that the estimates of β_3 are completely robust to controlling for human capital. Therefore, we do not find evidence that any potential link betwen financial market development and human capital are behind the point estimates of β_3.

In columns 4-6 of Table 3, we include country x time period fixed effects so that we now absorb any time-varying unobserved heterogeneity at the country level. Our coefficient of interest attenuates very slightly, but continues to remain statistically significant and with

[4]In Appendix 2, we also report the results from regressions where we look at lagged financial development. Our results continue to remain robust using this specification.

an equivalent economic magnitude, suggesting that our time varying control variables have addressed the relevant sources of omitted variable bias.

4.2 Late vs. Early Stage of Technology's Lifecycle

In the previous section, we have documented that the diffusion of capital-intensive technologies is more correlated with financial market development as measured by the loans to GDP ratio than the diffusion of less capital-intensive technologies. At this point, the reader may note that this finding is reminiscent of the key finding by Rajan and Zingales that financial market development favors the growth of industries where there is a greater external finance need (i.e. a greater gap between current cash flows and current investments, which may proxy for future expected cash flows). To the extent that technologies are embodied in new capital, as it is the case with some of the technologies in our dataset, and if capital inetnsity proxies for external finance need, equation (1) can capture the Rajan-Zingales mechanism.

There are, however, other mechanisms that could be consistent with the estimates in Table 3. Suppose for example that deep local credit helps adopters to lower the risk from implementing technologies early in their diffusion process where there is much uncertainty about the evolution of the technology and about the demand for the goods and servcies associated with the technology. This mechanism is also consistent with equation (1) and with the estimates from Table 3.

A natural question is whether we can empirically identify the Rajan-Zingales mechanism from the effect of financial markets in the reducing uncertainty faced by early adopters. One significant difference between these two hypotehses is that, for a given level of external finance need, the Rajan-Zingales mechanism applies to any form of capital regardless of how long ago the technology (that embeds) was invented. In contrast, the risk from uncertainty about the nature of demand and technology faced by adopters seems to be much larger early on than when the market and the technology have matured.

To obtain a better understanding of the mechanism that drives our findings, we divide our sample between the early and the late stages of technology diffusion. We implement this division using two distinct criteria. First, we split our sample into periods before and after 50 years from the invention of a technology. Thus, for each technology and country, the early adoption period comprises the periods prior to the invention year plus 50, and the late adoption, the periods afterwards. Second, we use the estimates of the adoption lags for each technology-country pair from Comin and Hobjin (2010). We define the early adoption stage as the period between the invention of the technology and the median adoption date for all the countries in sample for that technology. The late adoption stage comprises the subsequent years. Table 4 outlines the invention dates, and technology lags from Comin and Hobjin (2010). Note that, a key difference between these two classifications is that in the first the length of the early adoption stage is the same across technologies, while in the second it varies. Also note that early adopting countries will tend to have their diffusion process split in both samples, with the early stage covering the initial observations and the late stage covering diffusion once the technology is more widespread worldwide.

Table 5 presents the results for the two diffusion stages. We find that financial market development affects the diffusion of technology only in the early stages of diffusion. This is true both for splits made using a cutoff of 50 years from the invention of all technologies as well as a more nuanced split based on the median adoption lag for each technology as outlined in Table 4. In Figure 1, we report the results from dynamic specifications where we look at the relative importance of financial development in the diffusion of more capital intensive technologies, but do so for a series of time periods with successively increasing time from invention. This dynamic specification provides further evidence that the effects we measure are most important early in the life of the technology, in years closest to the invention.

The lack of association between financial market development and the diffusion of capital-intensive technologies for late adopters is hard to reconcile with the reversed causation hypothesis. If adopting capital-intensive technologies caused the development of financial markets, why don't we see a similar association between these two variables for both early and late adopters? On the other hand, the fact that the effect is much more salient in the early stages of a technology's lifecycle highlights the particularly important role of domestic capital markets in the initial diffusion of technologies. One natural interpretation of this finding is that local financial market development may facilitate the experimentation required with helping to commercialize new technologies.

4.3 Omitted Variables

Aside from reverse causality which we address through our time-varying controls, there may be concerns that an omitted variable that is correlated with our interaction term (i.e., financial development * capital intensity) may be driving technology diffusion. Next we argue that our findings are unlikely to be driven by the omission of a relevant variable and instead they are substantive. Many of the sources of omitted variable bias stem from factors that have been shown to predict long-term cross-country differences in development such as culture (Guiso, Sapienza and Zingales, 2008, and Tabellini, 2009), geography (Sachs and Warner, 1995) and the quality of institutions (Acemoglu, Johnson and Robinson, 2001). However, they typically do not have predictive power over development measures at higher frequencies once we include country-fixed effects which control for persistent country-level characteristics as we do.

For an omitted variable to drive our findings, it would have to be correlated with financial development and differentially affect the diffusion of capital intensive technologies.

While many of the channels through which an omitted country-level factor affects technology diffusion are likely symmetric across technologies, certain geographical variables could have a differential effect on the diffusion of capital intensive technologies. Take for example country size. Since the diffusion of certain capital intensive technologies such as telephone lines or railways often require large sunk costs and lead to network externalities one could argue that larger countries may be more prone to adopting intensively these technologies than small countries. Similarly the ruggedness of the terrain may also affect the costs of setting up the networks involved in the diffusion of these capital intensive technologies.

All these geographical variables are arguably constant. Therefore, we could collectively capture their effect on technology diffusion by interacting the country fixed-effects with the capital intensity indicator. This set of dummy variables also captures any differential effect of other variables that are fixed at the country-level on the diffusion of capital-intensive technologies. Therefore, the dummies capture the potential effect of certain institutional traits such as property right protection or the rule of law that are persistent but might differentially impact more capital intensive technologies.

As can be seen from Panel B of Table 5, the inclusion of the set of country-dummies interacted with our capital intensity indicator does not significantly alter our estimates of the effect of financial market development on technology diffusion. In fact, the estimated effect of financial development x capital intensity increases marginally for the early years. Overall, our results suggest that fixed country-level characteristics that affect differentially the diffusion of capital-intensive technologies do not account for our findings.

We note also that our specification include interactions between per capita income and capital intensity as well as the interaction between human capital and capital intensity. The former provides a control for many omitted variables that tend to be correlated with income. For example, suppose capital-intensive technologies had different Engel curves than less capital-intensive technologies. Allowing the log of per capita income to have a differential effect on the adoption of capital-intensive technologies addresses this concern. The robustness of our results to including the interaction between income and capital intensity suggests that the differential effect of financial depth we identify is distinct from other channels that operate through proxies of development. The interaction between this measure and capital intensity controls for the possibility that more capital intensive technologies may systematically depend on more, or less, on human capital, which could bias our estimates. We observe no differential effect of human capital on the diffusion of capital-intensive technologies.

Another argument that could be made in this regard is that capital-intensive technologies may also benefit more from government involvement in the economy since this involvement may be directed towards building or financing the infrastructures required for these technologies to diffuse. If government investment in infrastructures was correlated with financial market development, omitting government investment measures would bias our estimates. In Table 6, we therefore include a time varying measure of government expenditure, available from Jorda et. al (2017) and a measure of the quality of political institutions, available from the Polity IV Project and find our results are robust to the inclusion of these controls and their interaction with our measure of financial development.

One caveat of our analysis is that the sample of countries is quite limited due to constraints imposed by the data on financial market development. To explore the robustness of our findings to the sample, we adopt as measure of financial market development the deposits to GDP ratio instead of the loans to GDP ratio. Admitedly, this measure captures the liability side of banks while loans reflects the asset side of the banks which is closer to our mechanism. Note however that both side of the banks balance sheet must balance, hence deposits should be informative about the banks ability to issue loans. As a result of this change, we can extend the analysis from 17 countries to 55. Table 7 shows the estimates of regression (1). The key finding is that the estimates of β_3 do not change with the new sample and financial development measure. This suggests that our findings are more general than the limited country sample we consider in the baseline regressions.

4.4 Alternative interpretations of the classification

An assumption we have explicitly made to identify the role of financial markets on technology diffusion is that the classification of technologies according to their capital-intensity does not proxy for other classifications of technologies. That is, that there is no omitted variable in the capital intensive classification.

A possible classification that is correlated with ours is based on whether the technologies are tradable. It is easy to see that all the technologies in the less capital-intensive group are traded, while some technologies in the more capital-intensive group such as KMs of railroad tracks laid, telegrams sent, telephones installed are non-traded. Tradable technologies are directly embodied in goods whose import may be easier when importers have access to credit. Therefore, if this is the channel by which financial development affects technology diffusion, we should observe a positive differential effect of financial development on the diffusion of tradable technologies vs. non-tradable ones. To the extent that tradability is associated with less capital intensity, we find the exact opposite. Therefore, this is clearly not the mechanism we have identified in our analysis.[5]

Finally, we have observed that though human capital tended to matter in the diffusion of technology (see Table 3), but we did not find that it mattered more for the diffusion of capital intensive technologies. This suggests, a priori, that our classification based on capital intensity does not capture the degree of complementarity with human capital of the technologies. Inspection of the classification supports this conclusion.[6] Technologies whose operation require significant human capital, such as computers or MRI are in the less capital-intensive group.

The number of possible technology-classifications is extremely large and we cannot go through all of them. But given this evidence, we feel confident that our classification of

[5]Furthermore, there is no apparent reason why tradability should matter only in the initial stages of adoption.

[6]A similar argument implies that the capital-intensity classification is not proxying for whether goods/services are superior (i.e., have higher income elasticity of demand).

technologies based on their capital intensity is not proxying for alternative classifications of technology. Furthermore, we hope to have convinced the reader that the differential effect that financial development has on the diffusion of capital-intensive technologies in the early stages of technology diffusion of the leading countries, is evidence of the importance of local access to financial markets by the companies that develop new products and services that embody the specific new technologies.

5 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 cross-country panel dataset that covers the diffusion of 16 major technologies across 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. This effect operates in the early stages of diffusion and in the early adopters of technology. In contrast, we find no differential effect of financial depth on the diffusion of capital-intensive technologies in the late stages of diffusion or in late adopters.

While not conclusive, this evidence suggests that a potentially important role of finance is to facilitate the experimentation required to overcome the initial hurdles around the adoption and diffusion of new technology. This mechanism has begun to be explored more deeply in the context of financial intermediaries such as venture capital investors who facilitate technology commercialization today, but it has not been examined more broadly as a driver of technology diffusion across countries. Our evidence suggests an opportunity for further research to deepen our understanding of this potentially important mechanism relating financial development to economic growth.

References

[1] Acemoglu, Daron, Simon Johnson and James A. Robinson, 2001. ”The Colonial Origins of Comparative Development: An Empirical Investigation,” American Economic Review, vol. 91(5), pages 1369-1401, December

[2] Acemoglu, Daron, and Fabrizio Zilibotti, 1997. “Was Prometheus Unbound by Chance? Risk, Diversification, and Growth.” Journal of Political Economy, 105(4), 709-751

[3] Aghion, P., T. Fally, and S. Scarpetta. 2007. “Credit constraints as a barrier to the entry and post-entry growth of firms.” Economic Policy, 22, pp. 731-79.

[4] Aghion, P., and P. Howitt. 1992. “A Model of Growth through Creative Destruction.” Econometrica, 60, pp. 323-51.

[5] Alcoa Inc., Alcoa’s 125 Years Company Website 2014.

[6] Archer, G, History of Radio to 1926 (New York: American Historical Society, American Book, Stratford Press, 1938).

[7] Beck, T. and R. Levine. 2002. “Industry growth and capital allocation: Does having a market - or bank - based system matter?” Journal of Financial Economics, 64:2, pp. 147-80.

[8] Beck, T., R. Levine, and N. Loayza. 2000. “Finance and the sources of growth.” Journal of Financial Economics, 58:1-2, pp. 261-300.

[9] Beemer, Rod, Chester, Peterson. Ford-N-Series-Tractors. 1997. Print

[10] Bertrand, M., A. Schoar, and D. Thesmar. 2007. “Banking deregulation and industry

structure: Evidence from the French banking reforms of 1985." Journal of Finance, 62:2, pp. 597-628.

[11] Cetorelli, N. and P. E. Strahan. 2006. "Finance as a barrier to entry: Bank competition and industry structure in local U.S. markets." Journal of Finance, 61:1, pp. 437-61.

[12] Chapman, S. D., and J. Butt. 1988. "The Cotton Industry, 1775–1856." In *Studies in Capital Formation in the United Kingdom, 1750–1920*, edited by Charles H. Feinstein and Sidney Pollard, 105–25. Oxford: Clarendon Press, 1988.

[13] Chava, S, A. Oettl, A. Subramanian and K Subramanian 2013. "Banking Deregulation and Innovation." Journal of Financial Economics, 109, pp. 759-774.

[14] Comin, D. and B. Hobjin 2004 "Cross-Country Technology Adoption: Making the Theories Face the Facts." Journal of Monetary Economics, 51(1), pp. 39-83

[15] Comin, D. and B. Hobjin 2009 "The CHAT Dataset." HBS WP 10-035.

[16] Comin, D. and B. Hobjin 2009 "Lobbies and Technology Diffusion." The Review of Economics and Statistics, 91(2), pp. 229-244

[17] Comin, D. and B. Hobjin 2010 "An Exploration of Technology Diffusion." American Economic Review, 100(5), pp.2031-59.

[18] Demirguc-Kunt, A. and R. Levine 2001 "Financial Structure and Economic Growth: A Cross-Country Comparison of Banks, Markets, and Development, " MIT Press.

[19] Dodge, Grenville, How We Built the Union Pacific Railway and other Railway Papers and Addresses presented by the author to the New York Public Library on 24 October, 1910

[20] Duncan, Geoff. Ed Roberts, Maker of First Successful Personal Computer, Dies at 68. Digital Trends April 2, 2010. Web Article.

[21] Douglas, A. 1995. *Radio Manufacturers of the 1920's: Vol. 2* Sonoran Pub.

[22] Galloway, John D. The First Transcontinental Railroad: Central Pacific, Union Pacific (New York: Simmons-Boardman, 1950).

[23] Genova, T. 2001. "Television History – The First 75 Years." April 9, 2001. Web Article.

[24] Gort, M. and S. Klepper. 1982. "Time Paths in the Diffusion of Product Innovations " Economic Journal, 92, pp.630-53.

[25] Greenwood, Jeremy, and Boyan Jovanovic. 1990. Financial Development, Growth, and the Distribution of Income. Journal of Political Economy, vol. 98, no. 5, pp. 10761107.

[26] Guiso, L., Sapienza, P., and L. Zingales. 2004. "Does local financial development matter?" Quarterly Journal of Economics, 119:3, pp.929-69.

[27] Guiso, L., Sapienza, P., and L. Zingales. 2006. "Does Culture Affect Economic Outcomes?" Journal of Economic Perspectives, 20:2, pp.23-48.

[28] Hamilton, Robert. Hospitals to Share Costly Equipment. The New York Times. July 31, 1988. Web Article.

[29] French, Gilbert, The Life and Times of Samuel Crompton of Hall-in-the Woods, Inventor of the Spinning Machine Called the Mule (Manchester: Charles Simms and Co, 1862).

[30] Ichino, A and G. Maggi. 2000. "Work Environment and Individual Background: Explaining Regional Shirking Differentials in a Large Italian Firm" Quarterly Journal of Economics, 115:3, 1057-90.

[31] Janeway, W. 2012. "Doing Capitalism in the Innovation Economy " Cambridge University Press, Cambridge, UK.

[32] Jayaratne, J. and P. E. Strahan. 1996. "The finance-growth nexus: Evidence from bank branch deregulation." Quarterly Journal of Economics, 111:3, pp. 639-70.

[33] Jordà, O, M. Schularick, and A. M. Taylor. 2017. "Macrofinancial History and the New Business Cycle Facts."in NBER Macroeconomics Annual 2016, volume 31, edited by Martin Eichenbaum and Jonathan A. Parker. Chicago: University of Chicago Press.

[34] Jovanovic, Boyan and Glenn M. MacDonald, 1994. "The Life Cycle of a Competitive Industry," Journal of Political Economy, University of Chicago Press, vol. 102(2), pages 322-347, April.

[35] Kerr, W.R., R. Nanda and M. Rhodes-Kropf. 2014 "Financing Innovation" Annual Review of Financial Economics 7 (November 2015): 445â€"462.

[36] Kerr, W.R., R. Nanda and M. Rhodes-Kropf. 2014 "Entrepreneurship as Experimentation" Journal of Economic Perspectives, 23(3), pp.25-48.

[37] King, R. G. and R. Levine. 1993a. "Finance and growth - Schumpeter might be right." Quarterly Journal of Economics, 108:3, pp. 717-37.

[38] King, R. G. and R. Levine. 1993b. "Finance, entrepreneurship, and growth - Theory and evidence." Journal of Monetary Economics, 32:3, pp. 513-42.

[39] Klenow, P.J. and A. Rodriguez-Clare. 1997."Economic Growth: A Review Essay" Journal of Monetary Economics, 40:3, pp.597-617.

[40] Klepper, S. 1996. "Entry, Exit, Growth, and Innovation over the Product Life Cycle," American Economic Review, 86(3), pp 562-83.

[41] Klepper, S. 2007. "The Organization and Financing of Innovative Companies in the Evolution of the US Automobile Industry " Chapter 2 in Financing Innovation in the United States, 1870 to the Present, edited by Naomi Lamoreaux and Kenneth L. Sokoloff, MIT Press, Cambridge, MA.

[42] Klepper, S. and Kenneth L. Simons, 2005. 'Industry shakeouts and technological change', International Journal of Industrial Organization, 23(1-2), pp. 23-43.

[43] Kornblum, Richard J. The Design of an Endpoint Control System for the Basic Oxygen Steel Furnace. , 1968. Print

[44] Kortum, S. and J. Lerner, 2000. "Assessing the Contribution of Venture Capital to Innovation."RAND Journal of Economics, 31(4), pp. 674-692.

[45] Laeven, L, S. Michalopoulos and R. Levine, 2015 "Financial Innovation and Endogenous Growth."Journal of Financial Intermediation, January, 24(1):1–24.

[46] Lamoreaux, N., M. Levenstein and K. L. Sokoloff 2007. "Financing Invention during the Second Industrial Revolution: Cleveland, Ohio 1870-1920" Chapter 1 in Financing Innovation in the United States, 1870 to the Present, edited by Naomi Lamoreaux and Kenneth L. Sokoloff, MIT Press, Cambridge, MA.

[47] Lamoreaux, N. and K. L. Sokoloff 2007. "The Organization and Finance of Innovation in American History" Introduction to Financing Innovation in the United States, 1870 to the Present, edited by Naomi Lamoreaux and Kenneth L. Sokoloff, MIT Press, Cambridge, MA.

[48] Levine, R. 1997. "Financial development and economic growth: Views and agenda." Journal of Economic Literature, 35:2, pp. 688-726.

[49] Levine, R., N. Loayza, and T. Beck. 2000. "Financial intermediation and growth: Causality and causes." Journal of Monetary Economics, 46:1, pp. 31-77.

[50] Mann, W. 2014. "Creditor Rights and Innovation: Evidence from Patent Collateral " working paper.

[51] Metals consulting international Limited, 2008 "Capital investment costs for plant & equipment in iron & steelmaking"

[52] Meyer, D. E. 2009. "The First Century of GMC Truck History". web article.

[53] Mims, F. M. 1984. "The Altair story; early days at MITS". *Creative Computing* 10 (11): p. 17.

[54] Mitchell, B. 2003. "International Historical Statistics 1750-2000: Africa, Asia and Oceania" Palgrave Macmillan.

[55] Mitchell, B. 2003. "International Historical Statistics 1750-2000: Europe" Palgrave Macmillan.

[56] Mitchell, B. 2003. "International Historical Statistics 1750-2000: The Americas" Palgrave Macmillan.

[57] Nanda, R. and T. Nicholas. 2014. "Did Bank Distress Stifle Innovation During the Great Depression?" Journal of Financial Economics, 114:2, 273-292.

[58] Nanda, R. and M. Rhodes-Kropf. 2010. "Financing Risk and Innovation." Harvard Business School Working Paper 10-013.

[59] Nye, J. 1992. "Electrifying America: Social Meanings of a New Technology." MIT Press, Cambridge, MA.

[60] Perez, C. 2002. "Technological Revolutions and Financial Capital." Edward Elgar, Cheltenham, UK.

[61] Phelps, Christina, The Persian Gulf Submarine Telegraph of 1864 The Geographical Journal 135:2 (1969), 169–190.

[62] Price, D., I. Delakis, C. Renaud, and R. Dickinson. 2008. "MRI Scanners: A Buyers'guide", web article, accessed 11-2-2014

[63] Pripps, Robert N.; Morland, Andrew Farmall Tractors: History of International McCormick-Deering Farmall Tractors. Farm Tractor Color History Series. 1993

[64] Radcliffe, W. 1974 *Origin of the New System of Manufacture Commonly Called Power-Loom Weaving: Fully Explained in a Narrative Containing William Radcliffe's Struggles Through Life* A.M. Kelley, Clifton, N.J.

[65] Rajan, R. G. and L. Zingales. 1998. "Financial dependence and growth." American Economic Review, 88:3, pp. 559-86.

[66] Rajan, R. G. and L. Zingales. 2003. "The great reversals: The politics of financial development in the twentieth century." Journal of Financial Economics, 69:1, pp. 5-50.

[67] Rhodes, Frederick, Beginnings of Telephony (New York and London: Harper & Brothers, 1929).

[68] Rodrigue, J. P., C. Comtois, and B. Slack. 2013. *The Geography of Transport Systems* Routledge

[69] Sachs, J. and A. Warner. 1995. "Economic Reform and the Process of Global Integration." Brookings Papers on Economic Activity, 1995:1, pp. 1-118

[70] Samila, S. and O. Sorenson. 2011. "Venture Capital, Entrepreneurship and Economic Growth." The Review of Economics and Statistics, 93:1, pp. 338-349.

[71] Sulzberger, Carl. The Pearl Street Generating Station, 1882. IEEE Global History Network. 2014. Web Article.

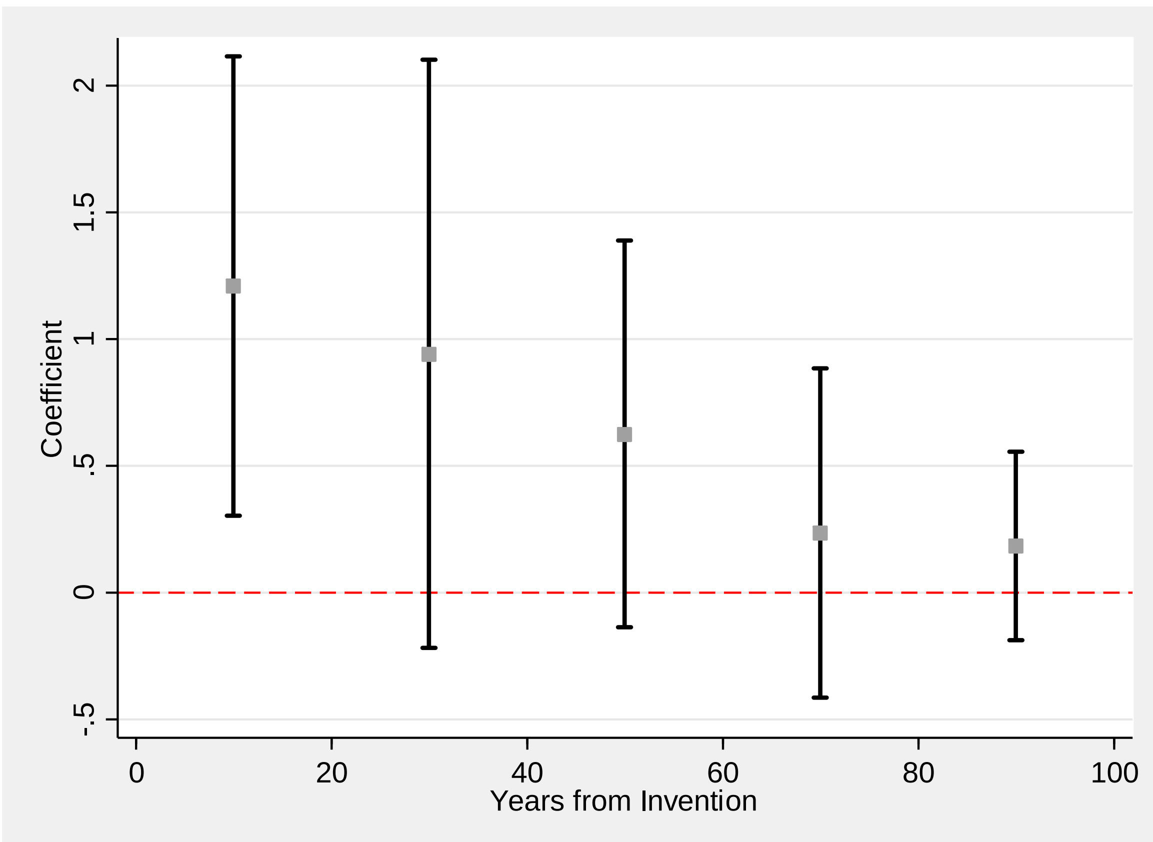
[72] Thompson, Robert, Wiring a Continent: The History of the Telegraph Industry in the United States, 1832–1866 (Princeton, NJ: Princeton University Press, 1947).

[73] Walton, P. 1925 *The Story of Textiles* Walton Advertising and Printing Co, Boston.

[74] Wolpin, S. 2014 "The First Cellphone went on Sale 30 Years Ago for $4,000", March 13. Web Article.

Figure 1: Relative Effect of Financial Development on Diffusion of More Capital Intensive Technology, by years from Invention

Notes: This figure plots the coefficients from triple interactions between our measure of financial development, an indicator for more capital intensive technologies and indicators for the time since invention. Each coefficient represents the mid-point for 20-year blocks of time since invention, so for example, the first coefficient represents the coefficient for the time period representing the first 20 years since invention, the next coefficient represents years 21-40 since invention and so on. The specification includes technology-year fixed effects and country fixed effects. Standard error bars represent 95% confidence intervals.



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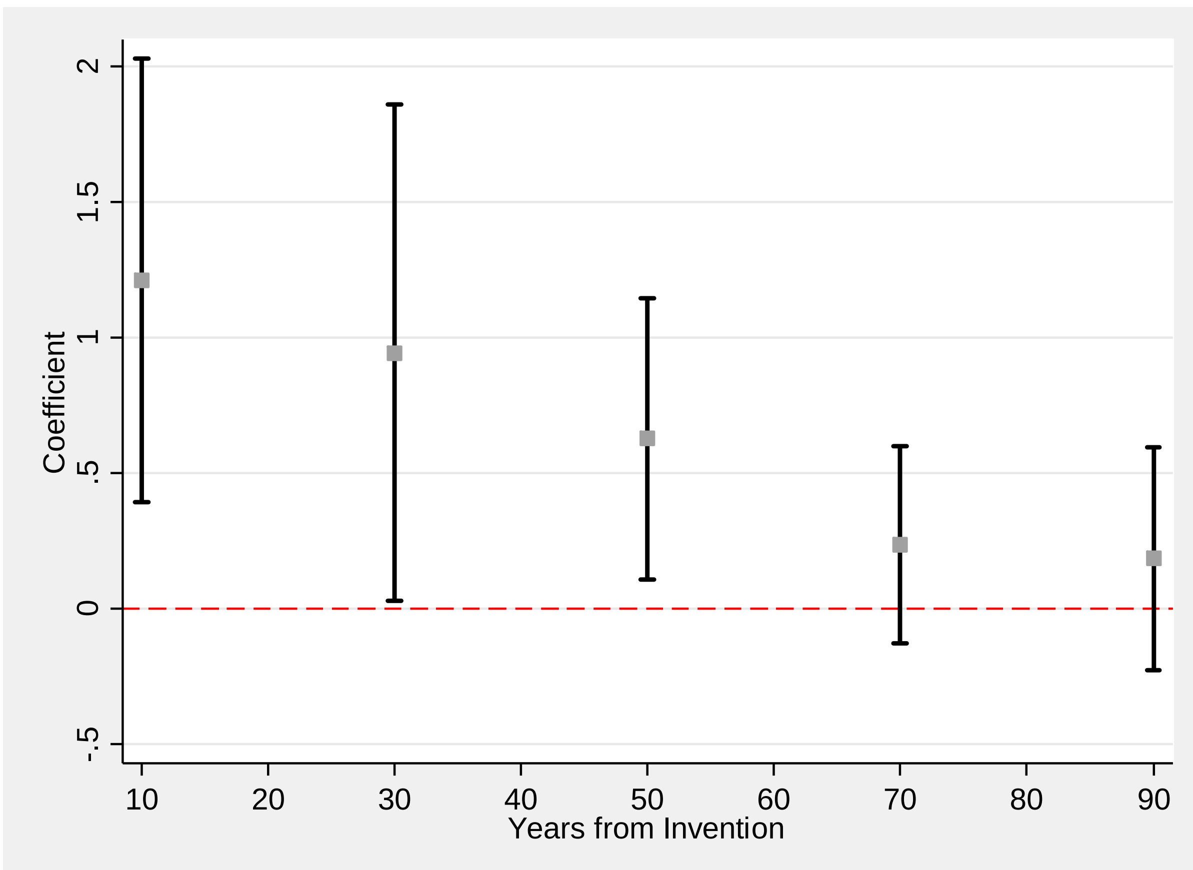

Table 1: Description of Technologies Used

	Technology	Measure	Capital Intensity	Countries covered		Country-Years per technology	
				Core Sample	*Extended Sample*	*Core Sample*	*Extended Sample*
1	Railroad	Km of track installed	High	15	34	125	183
2	Telegram	Telegrams sent	High	17	35	148	275
3	Telephone	Number connected	High	17	54	310	631
4	Electricity Production	KwHr produced	High	17	53	284	628
5	Electric Arc Steel	Tons produced	High	17	47	162	291
6	Blast Furnace Steel	Tons produced	High	16	35	84	156
7	Cell Phones	Number of users	High	17	53	56	137
8	Ring Spindle	Number in operation	Low	10	32	59	170
9	Loom	Number in operation	Low	17	46	20	81
10	Passenger Cars	Number in operation	Low	17	54	269	599
11	Commercial Vehicles	Number in operation	Low	17	53	261	575
12	Tractors	Number in operation	Low	17	52	91	263
13	Radio	Number in operation	Low	17	54	206	518
14	TV	Number in operation	Low	17	55	158	422
15	Computers	Number in operation	Low	17	53	50	138
16	MRI machines	Number in operation	Low	17	23	48	59
	Total					2,331	5,126

Note: All measures are scaled by population and expressed in logarithms.

Table 2: Financial Development for Core Sample

Notes: This table reports three measures of financial development, averaged across the following 17 countries in the core sample AUS, BEL, CAN, CHE, DEU, DNK, ESP, FIN, FRA, GBR, ITA, JPN, NLD, NOR, PRT, SWE & USA. All data is aggregated to 26 5 year time periods for each country spanning 1870-1999. J-S-T Data refers "total loans/GDP" in the Jorda-Schularick-Taylor Macrohistory Database and D-L Data refers to "Private Credit by Deposit Money Banks and Other Financial Institutions to GDP" in the Financial Structure Database provided by Demirguc-Kunt and Levine. Deposits/ GDP is the ratio of deposits in Savings and Commercial banks, taken from Mitchell, as a share of GDP. This table reports average values across all countries for the three variables. At the country-year level, the pairwise correlation between Credit/GDP from J-S-T and Credit/GDP from D-L is 0.56 and the pairwise correlation between Credit/GDP from J-S-T and Deposits / GDP is 0.48

Year	Loans/GDP [J-S-T Data]	Credit/GDP [D-L Data]	Deposits/GDP
1870 - 1874	0.19		0.16
1875 - 1879	0.25		0.22
1880 -1884	0.27		0.20
1885 - 1889	0.35		0.25
1890 - 1894	0.35		0.26
1895 - 1899	0.40		0.32
1900 - 1904	0.44		0.34
1905 - 1909	0.54		0.40
1910 - 1914	0.62		0.42
1915 - 1919	0.49		0.38
1920 - 1924	0.53		0.40
1925 - 1929	0.55		0.42
1930 - 1934	0.63		0.51
1935 - 1939	0.52		0.46
1940 - 1944	0.44		0.48
1945 - 1949	0.35		0.45
1950 - 1954	0.36		0.36
1955 - 1959	0.40		0.34
1960 - 1964	0.48	0.44	0.33
1965 - 1969	0.54	0.50	0.33
1970 - 1974	0.61	0.57	0.33
1975 - 1979	0.66	0.63	0.31
1980 - 1984	0.69	0.69	0.29
1985 - 1989	0.78	0.80	0.32
1990 - 1994	0.87	0.97	0.34
1995 - 1999	0.85	0.97	0.37

Table 3: Financial Development and Technology Diffusion

1870-1999: Dependent Variable: Log Technology Diffusion per capita

	Country Fixed Effects			Country-Year Fixed Effects		
	(1)	(2)	(3)	(4)	(5)	(6)
Loans/GDP X capital intensity	0.541**	0.658**	0.655**	0.503*	0.601**	0.602**
	(0.253)	(0.267)	(0.271)	(0.263)	(0.255)	(0.255)
Loans/GDP	-0.0382	-0.0438	-0.0468			
	(0.290)	(0.195)	(0.205)			
GDP per capita x capital intensity		-0.478	-0.498		-0.510	-0.520
		(0.386)	(0.382)		(0.408)	(0.393)
GDP per Capita		1.646***	1.680***			
		(0.432)	(0.441)			
Human Capital x capital intensity			0.144			0.088
			(0.345)			(0.387)
Human Capital			0.285**			
			(0.117)			
Technology X Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	No	No	No	Yes	Yes	Yes
Observations	2,331	2,331	2,331	2,331	2,331	2,331

Robust standard errors in parentheses, clustered by technology and country

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

Notes: (1) All data is aggregated to 26 5year time periods spanning 1870-1999.
(2) Main effect for capital intensity is absorbed by the technology-year fixed effects and main effects for loans/GDP, GDP per Capita and Human Capital absorbed by country-year fixed effects

Table 4: Invention Dates and Diffusion Lags across Technologies

	Technology	Invention Date	Median diffusion Lag (in yrs) from Comin and Hobjin 2010
1	Railroad track	1825	66
2	Telegram	1835	23
3	Telephone	1875	9
4	Electricity Production	1882	19
5	Electric Arc Steel	1907	29
6	Blast Furnace Steel	1950	10
7	Cell Phones	1973	10
8	Ring Spindle	1779	81
9	Loom	1785	168
10	Passenger Cars	1885	25
11	Trucks	1885	25
12	Tractors	1903	89
13	Radio	1920	9
14	TV	1927	23
15	Personal Computers	1973	12
16	MRI machines	1977	4

Table 5: Early vs. Late in Technology's Lifecycle

1870-1999: Dependent Variable: Log Technology Diffusion per capita

Panel A: Country-Year Fixed Effects

	Early defined as below Median Adoption Lag from Comin and Hobjin		Early defined as less than 50 Years from Invention	
	Early	*Late*	*Early*	*Late*
Loans/GDP X capital intensity	0.894***	0.056	0.816***	0.548
	(0.254)	(0.417)	(0.245)	(0.337)
GDP per capita x capital intensity	-0.978***	-0.120	-1.136**	-0.263
	(0.190)	(0.184)	(0.499)	(0.374)
Human Capital x capital intensity	-0.498***	0.811*	-0.045	0.183
	(0.0937)	(0.449)	(0.653)	(0.346)
Technology X Year FE	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes
Observations	1,013	1,318	885	1,446

Panel B: Country-Capital Intensity Fixed Effects

	Early defined as below Median Adoption Lag from Comin and Hobjin		Early defined as less than 50 Years from Invention	
	Early	*Late*	*Early*	*Late*
Loans/GDP X capital intensity	1.009**	0.047	1.052**	0.153
	(0.393)	(0.378)	(0.394)	(0.391)
Loans/GDP	-0.133	-0.025	-0.198	-0.052
	(0.168)	(0.258)	(0.180)	(0.122)
GDP per capita x capital intensity	-0.091	-0.327	-1.423**	-0.192
	(0.235)	(0.424)	(0.513)	(0.550)
GDP per capita	1.455***	1.403***	1.985***	1.831***
	(0.294)	(0.320)	(0.572)	(0.480)
Human Capital x capital intensity	-0.718	0.474	-0.507	0.043
	(0.419)	(0.282)	(0.690)	(0.155)
Human Capital	0.638*	-0.082	0.895	0.278**
	(0.332)	(0.172)	(0.509)	(0.104)
Technology X Year FE	Yes	Yes	Yes	Yes
Country X Capital Intensity FE	Yes	Yes	Yes	Yes
Observations	1,013	1,318	885	1,446

Robust standard errors in parentheses, clustered by technology and country

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

Notes: (1) All data is aggregated to 26 5year time periods spanning 1870-1999.

(2) Main effect for capital intensity is absorbed by the technology-year fixed effects and main effects for loans/GDP, GDP per Capita and Human Capital absorbed by country-year fixed effects

Table 6: Robustness: Quality of Institutions and Government Expenditure

1870-1999: Dependent Variable: Log Technology Diffusion per capita

Panel A: Country-Year Fixed Effects

	Early defined as below Median Adoption Lag from Comin and Hobjin		Early defined as less than 50 Years from Invention	
	Early	*Late*	*Early*	*Late*
Loans/GDP X capital intensity	0.975***	0.008	0.875***	0.598
	(0.270)	(0.470)	(0.263)	(0.394)
Institutions x capital Intensity	0.017	0.010	0.041*	0.031
	(0.077)	(0.019)	(0.021)	(0.020)
Gov. Exp x capital intensity	0.431	-0.603	0.438	-0.427
	(0.623)	(1.098)	(1.183)	(0.832)
GDP per capita x capital intensity	-0.907	-0.168	-1.469	-0.448
	(0.625)	(0.313)	(1.106)	(0.463)
Human Capital x capital intensity	-0.561	0.703	-0.131	-0.044
	(3.506)	(0.626)	(14.361)	(0.274)
Technology X Year FE	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes
Observations	951	1,276	839	1,388

Panel B: Country-Capital Intensity Fixed Effects

	Early defined as below Median Adoption Lag from Comin and Hobjin		Early defined as less than 50 Years from Invention	
	Early	*Late*	*Early*	*Late*
Loans/GDP X capital intensity	1.164**	0.381	1.351**	0.293
	(0.401)	(0.362)	(0.579)	(0.450)
Loans/GDP	-0.278*	-0.295	-0.523***	-0.227
	(0.138)	(0.242)	(0.156)	(0.234)
Institutions x capital Intensity	-0.009	-0.028*	-0.013	0.020
	(0.036)	(0.014)	(0.016)	(0.021)
Institutional Quality	0.053**	0.015	0.037*	-0.008
	(0.022)	(0.009)	(0.018)	(0.017)
Gov. Exp x capital intensity	-0.830	2.383***	1.635	-0.944
	(1.226)	(0.200)	(1.095)	(0.709)
Gov Expenditure/ GDP	-0.347	-1.561***	-1.832**	0.429
	(0.791)	(0.408)	(0.807)	(0.600)
GDP per capita x capital intensity	-0.173	0.006	-1.390**	-0.243
	(0.182)	(0.422)	(0.483)	(0.540)
GDP per capita	1.230***	1.177***	1.696***	1.786***
	(0.300)	(0.290)	(0.464)	(0.516)
Human Capital x capital intensity	-0.569	0.503*	-0.579	0.015
	(0.332)	(0.245)	(0.781)	(0.165)
Human Capital	0.646**	-0.073	0.974	0.303**
	(0.299)	(0.223)	(0.598)	(0.124)
Technology X Year FE	Yes	Yes	Yes	Yes
Country X Capital Intensity FE	Yes	Yes	Yes	Yes
Observations	951	1,276	839	1,388

Robust standard errors in parentheses, clustered by technology and 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 and main effects for loans/GDP, GDP per Capita and Human Capital absorbed by country-year fixed effects

Table 7: Extended Sample of 55 Countries

1870-1999: Dependent Variable: Log Technology Diffusion per capita

	Early defined as below Median Adoption Lag from Comin and Hobjin		Early defined as less than 50 Years from Invention	
	Early	*Late*	*Early*	*Late*
Deposits/GDP X capital intensity	0.995***	-0.320	0.999***	-0.130
	(0.274)	(0.517)	(0.289)	(0.388)
Deposits/GDP	-0.113	0.529*	-0.0767	0.437
	(0.176)	(0.260)	(0.152)	(0.288)
GDP per capita x capital intensity	-0.300	0.198	-0.178	0.233
	(0.320)	(0.158)	(0.335)	(0.214)
GDP per capita	1.251**	1.109***	1.401***	1.046***
	(0.436)	(0.172)	(0.288)	(0.227)
Human Capital x capital intensity	0.440	0.0741	0.547	0.193
	(0.349)	(0.425)	(0.479)	(0.363)
Human Capital	-0.085	-0.047	0.104	0.022
	(0.265)	(0.463)	(0.394)	(0.346)
Technology X Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Observations	2,366	2,760	1,562	3,564

Robust standard errors in parentheses, clustered by technology

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

Notes: (1) All data is aggregated to 26 5year time periods spanning 1870-1999.

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

Appendix 1: Capital Intensity measures by technology

	Technology	Capital Intensity	Approximate Nominal Cost	Year	Cost in 2010 dollars	Reference
1	Railroad	High	$32,000 per mile of track	1860s	$657,000 per mile	Dodge (1910)
2	Telegram	High	$1.2 million, first transatlantic cable.	1859	$24.6 million	Thompson (1947)
3	Telephone	High	$2.2 million, cost of wiring for American Bell Company in 1888	1888	$45.2 million	Rhodes (1929)
4	Electricity Production	High	$300,000 Constructing Pearl St. station	1882	$5.5 million	Janeway (2012)
5	Electric Arc Steel	High	$24 million, cost of installing mini-mill lower bound	2010	$24 million	Metal Consulting International (2010)
6	Blast Furnace Steel	High	$2 billion, cost of installing integrated mill	2010	$2 billion	Metal Consulting International (2010)
7	Cell Phones	High	$100 million, creation of first network	1983	$188 million	Wolpin (2014)
8	Spindle	Low	£7, price of a cotton jenny with 60-80 spindles	1780s	$230	Chapman and Butt (1988)
9	Loom	Low	£20, per loom	1828	$611	Radcliffe (1974)
10	Passenger Cars	Low	$950, Price of Model T	1908	$17,817	Rodrigue et al. (2013)
11	Trucks	Low	$1250, Rapid Model B	1905	$24,904	Meyer (2009)
12	Tractors	Low	$750, price for the first commercial tractor, the Fordson	1917	$8,783	Pripps and Morland (1993)
13	Radio	Low	$120, price of new Kolster 6D	1927	$1,240	Douglas (1995)
14	TV	Low	$600, price of RCA Victor console	1939	$7,545	Genova (2001)
15	Computers	Low	$397, Altair 8800, first PC	1974	$1,397	Mims (1984)
16	MRI machines	Low	$300,000, price of entry level MRI scanner	2014	$288,738	info.blockimaging.com

Note: The units of measurement for each technology are outlined in Table 1. The country-level diffusion of a technology in a given year is scaled by the population and measured in logarithms.

Table Appendix 2: Lagged Financial Development and Technology Diffusion

1870-1999: Dependent Variable: Log Technology Diffusion per capita

	Without Lag in Loans to GDP			Loans to GDP Lagged 5 years		
	(1)	(2)	(3)	(4)	(5)	(6)
Loans/GDP X capital intensity	0.541**	0.658**	0.655**	0.563**	0.680**	0.678**
	(0.253)	(0.267)	(0.271)	(0.244)	(0.249)	(0.251)
Loans/GDP	-0.0382	-0.0438	-0.0468	-0.0278	-0.0578	-0.0343
	(0.290)	(0.195)	(0.205)	(0.237)	(0.217)	(0.214)
GDP per capita x capital intensity		-0.478	-0.498		-0.516	-0.540
		(0.386)	(0.382)		(0.438)	(0.461)
GDP per Capita		1.646***	1.680***		1.667***	1.709***
		(0.432)	(0.441)		(0.480)	(0.497)
Human Capital x capital intensity			0.144			0.142
			(0.345)			(0.349)
Human Capital			0.285**			0.309
			(0.117)			(0.230)
Technology X Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,331	2,331	2,331	2,212	2,212	2,212

Robust standard errors in parentheses, clustered by technology

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

Notes: (1) All data is aggregated to 26 5year time periods spanning 1870-1999.
(2) Main effect for capital intensity is absorbed by the technology-year fixed effects and main effects for loans/GDP, GDP per Capita and Human Capital absorbed by country-year fixed effects