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LOBBIES AND TECHNOLOGY DIFFUSION

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Abstract—This paper explores whether lobbies slow down technology diffusion. To answer this question, we exploit the differential effect of various institutional attributes that should affect the costs of erecting barriers when the new technology has a technologically close predecessor but not otherwise. We implement this test using a data set that covers the diffusion of twenty technologies for 23 countries over the past two centuries. We find that each of the relevant institutional variables that affect the costs of erecting barriers has a significantly larger effect on the diffusion of technologies with a competing predecessor technology than when no such technology exists. These effects are quantitatively important. Thus, we conclude that lobbies are an important barrier to technology adoption and to development.

I. Introduction

CROSS-COUNTRY differences in the degree of adoption of technologies are enormous (Comin, Hobijn, & Rovito, 2006). They are so large that they have been pointed to as the main factor causing the large cross-country differences in income per capita (Hsieh & Klenow, 2003, for example). The fundamental question for growth theorists is what frictions generate these cross-country differences in technology adoption. In this paper we assess the role of one such friction on the adoption of new technologies. Namely, the political barriers erected as a result of the lobbying efforts of the producers of incumbent technologies.

Political barriers have long been believed to be an important deterrent to technology diffusion.[1] Until now, however, this belief has only been founded in a few anecdotes.[2] The lack of a systematic effort to prove this belief is the consequence of three difficulties. First, it is very hard to obtain direct measures of political barriers. Second, indirect measures of barriers are problematic because they typically are endogenous. Third, to explore the effects of lobbies on technology adoption, it is necessary to have a comprehensive data set on technology adoption, which, until recently, did not exist.

In this paper, we overcome these difficulties by using a new data set that we compiled and a new identification strategy. Our Historical Cross-Country Technology Adoption data set contains historical data on the adoption of twenty major technologies (such as railroads, telephones, and computers) over the last 215 years for 23 of the world's leading industrial economies.

Our identification strategy hinges on two arguments. First, as shown both theoretically (Myerson, 1993; Ferejohn, 1986; Persson, Roland, & Tabellini, 2000) and empirically (Kunicova & Rose-Ackerman, 2002; Persson, Tabellini, & Trebbi, 2003; Besley & Case, 1995), certain institutional attributes affect the political cost the legislature faces when raising barriers to the diffusion of a new technology. In particular, the cost lobbies must incur to induce legislators to raise diffusion barriers are higher when legislators are not independent, the judicial system is effective, and the regime is democratic and nonmilitary.

Second, the benefits old technology producers enjoy from raising barriers against the diffusion of a new technology depend on certain attributes of the new and old technologies. Some new technologies are so superior to the old technology that, even with political barriers, consumers prefer the new technology to the old one, so old technology producers receive no benefit from lobbying for barriers. In these cases, the new technology will diffuse quickly regardless of the institutional environment and the associated costs of lobbying.

In other cases, however, the productivity differential between the old and new technologies is relatively small, and old technology producers may be able to use political barriers to convince consumers to use their technology. Then, the old producers' ability to raise barriers and slow the diffusion of the new technology depends on the cost of inducing the legislative authority to heavily regulate the new technology's production. When the cost of raising barriers is low, the legislative authority accepts the old technology's lobbying bribes and raises barriers that slow down the diffusion of the new technology. Conversely, when the legislative authority faces a large cost of passing regulations, barriers are not raised, and new technologies diffuse quickly.

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[1] For example, Olson (1984) and Parente and Prescott (2000).

[2] See Mokyr (1990) for examples.

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It follows that, if lobbies are a relevant concern, the speed of diffusion of new technologies with technologically close predecessors will be affected by the institutional attributes that affect the political cost of erecting barriers. These institutional attributes should have no effect, however, on the diffusion of technologies without technologically close predecessors. This differential effect of institutions on the diffusion of technologies with different kinds of predecessors is the basis for our identification strategy of the effect of lobbies on the speed of diffusion of technologies.[3]

Our analysis suggests a significant negative effect of lobbying on technology diffusion. In particular, we find that, in countries where the legislative authorities have more flexibility, the judicial system is not effective, the regime is not very democratic, or there is a military regime, new technologies with technologically close predecessors diffuse more slowly than technologies without such predecessor technologies. These results are robust to controlling for human capital, GDP per capita, electricity production, geographical variables, differential effect of controls for each group, country fixed effects, and country fixed effects interacted with the technology classification. Further, our results are not only significant, but also quantitatively important to understanding technology diffusion. In particular, the institutional variables interacted with the technology classification generate 50% of the variance in technology diffusion.

Our empirical approach avoids traditional identification problems. First, it focuses on the details of the mechanism by which lobbying affects technology diffusion, thus providing a stronger test of causality. Second, as shown in section III C, while it may be relatively easy to think of omitted correlates of the institutional variables that may have an independent effect on the diffusion of technologies, it is much less easy to find reasons why these correlates should have an effect on the group of technologies with a predecessor technology above and beyond the effect they have on the technologies without one. Similar arguments also apply to the reverse causality interpretation of our results.

Finally, by showing that institutions affect the speed of diffusion of technologies through their effect on lobbying, we make a contribution to the literature on development and institutions. Contrary to existing approaches, we do not rely on instrumental variables. Our approach consists in focusing on one particular mechanism by which institutions may affect growth (that is, technology diffusion). This allows us to use multiple left-hand-side variables and have much more variation which allows us to identify the effect of specific institutional traits.

II. The Model

Production: Output (Y) is produced competitively using one of two technologies: the old (o) and the new (n). More formally, output is given by

$$Y = \max\{x_o^\alpha, dx_n^\alpha\},$$

where d is the relative productivity of the new technology and x_o and x_n denote the number of units of old and new technology intermediate good used, respectively. Each intermediate good is produced by one producer. The marginal cost of production is equal to $\bar{a}$ for both old and new technologies. At some point (made precise below), the producer of the new technology intermediate good learns how to produce it efficiently, and the marginal cost of production for the new technology intermediate good becomes $a < \bar{a}$.[4] Intermediate good producers may also make transfers to the legislative authority in exchange for regulations that affect the marginal cost of producing the new intermediate good.

Institutions: The legislative authority (L) determines the level of regulation (τ) the producer of new technology goods faces. There are two possible levels of regulation.[5] Heavy regulation increases the marginal cost of producing new intermediate goods by $\bar{\tau}$, while no regulation (that is, $\tau = 0$) leaves the marginal cost of new intermediate goods unchanged. The per-period payoff of the legislative institution is equal to the sum of three terms: a private value of being in power (b), the contributions received (C) minus the costs of bending the political constraints imposed by other institutions (S). The cost of passing regulations depend on the actions taken by L and on the institutional setting (that is, $S(\tau,r)$). It is costless for L to set $\tau = 0$ (that is, $S(0) = 0$). The cost of implementing $\bar{\tau}$ declines with L's independence and is also lower in military and/or nondemocratic regimes than in democratic regimes.

Timing: Without loss of generality, we consider a three-period economy. The old technology intermediate good arrives in period 1. The old technology intermediate good is produced and the producer decides whether to make a conditional contribution to the legislative authority. L decides whether to regulate the production of new technology intermediate goods in period 2. At the beginning of period 2, the new technology arrives. Period 2 is symmetric to period 1, with the only difference that now production and contributions can be undertaken by both the old and new technology producers. At the beginning of period 3, the marginal cost of producing new

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[3] Rajan and Zingales (1998) use a similar strategy to identify the effect of capital markets development on economic development. One important methodological difference, though, is that while they have various measures of capital market development (the exogenous variable in their test), we do not have any direct measure of lobbying intensity.

[4] All costs are indexed in terms of output, which is taken as the numeraire.

[5] The feasibility of only two tax rates may be completely general if, as in Acemoglu and Robinson (2000a), there is an informal sector where producers can avoid the sales taxes but operate at lower productivity. $\bar{\tau}$ would then be the rate that makes the producer indifferent between operating in the two sectors.

technology intermediate goods declines to a. Otherwise, period 3 is identical to period 2.

Analysis: Each period, the final output producer selects the technology that yields higher profits. Let $\pi(x)$ denote the profits of the output producer when using technology x. The relative profit ratio is then defined as

$$\frac{\pi(n)}{\pi(o)} = \left[d\left(\frac{p_o}{p_n}\right)^{\alpha} \right]^{1/(1-a)},$$

where p_o and p_n denote, respectively, the prices of the old and new intermediate good. Therefore, the final output producer uses the new technology if $d\left(\frac{p_o}{p_n}\right)^{a} > 1$. If instead, $d\left(\frac{p_o}{p_n}\right)^{\alpha} < 1$, he uses the old technology. This decision rule introduces Bertrand competition between the old and new intermediate good producers. The result of this competition is that the producer that supplies the intermediate goods charges a price equal to the minimum between the monopolist price and the marginal cost of production of the other producer (when he is around).

Empirically, political barriers do not stop new technologies from diffusing forever. We ensure this occurs in the model by assuming the following throughout:

Condition 1. $d\left(\frac{\bar{a}}{a + \bar{\tau}}\right)^{\alpha} > 1.$

Condition 1 implies that, if both intermediate good producers charge their marginal cost of production in period 3, the final output producer uses the new technology even in the presence of heavy regulations on the production of new intermediate goods. Given this outcome at period 3, we can proceed solving for the political contributions each producer makes using backwards induction.

In period 3, intermediate good producers make no contribution to L because the game finishes in that period. In addition, nobody will make contributions in period 2 because the outcome in the next period—that the new technology is demanded—occurs regardless of the contributions made.

The technology demanded at time 2 depends on the technological distance between the new and the old technology, d, and on whether, at period 1, the old technology producer can induce L to set $\tau = \bar{\tau}$ for period 2. In particular, if d is sufficiently large, $\pi(n)/\pi(o)$ is larger than 1 even in the presence of barriers to the diffusion of the new technology. In this event, the new technology diffuses upon arrival. The following condition and proposition 1 formalize this intuition.

Condition 2. $d\left(\frac{\bar{a}}{\bar{a} + \bar{\tau}}\right)^{\alpha} \geq 1$

Proposition 1. *If condition 2 holds, new technologies diffuse immediately regardless of the institutional setting.*

Alternatively, if condition 2 does not hold (that is, the new technology is not sufficiently superior to the old one), the final output producer may demand the old technology in the presence of diffusion barriers. This alone, however, is not sufficient to slow the diffusion of the new technology. The old technology lobby must also induce L, at $t = 1$, to pass heavy regulations.

L's payoff if he does not regulate is 0. Regulating heavily yields L a payoff of $C(\bar{\tau}) - S(\bar{\tau}, r)$, where $C(\bar{\tau})$ is the conditional contribution made by the producer of the old technology intermediate good if $\tau = \bar{\tau}$. Therefore, L sets $\tau = \bar{\tau}$ at time 1 if and only if

$$C(\bar{\tau}) \geq S(\bar{\tau}, r). \tag{1}$$

Is it feasible for the old technology producer to make such a contribution to L? The most he is willing to contribute to induce heavy regulations are the profits to be made at time 2, since at time 3 the new technology diffuses. If the old technology producer supplies intermediate goods at time 2, he sets a price p_{o2} given by the following expression:

$$p_{o2} = \min\{(\bar{a} + \bar{\tau})d^{-1/\alpha}, \bar{a}/\alpha\}.$$

The first term in p_{o2} is the price that makes the final output producer indifferent between using the new and the old technology. Whenever this constraint is not binding, the old technology producer will set the monopolistic price, $\bar{a}/\alpha$.

Given this optimal pricing rule, the profits accrued by the old technology producer in period 2 are

$$\prod_{o2} = (p_{o2} - \bar{a})(\alpha/p_{o2})^{1/(1-\alpha)}.$$

Condition 3 and proposition 2 characterize the environment in which the new technology diffuses slowly.

Condition 3. $\prod_{o2} = (p_{o2} - \bar{a})(\alpha/p_{o2})^{1/(1-\alpha)} \geq S(\bar{\tau}).$

Proposition 2. *If condition 2 does not hold and condition 3 holds, new technologies diffuse slowly (that is, they diffuse in period 3).*

Intuitively, since only the old technology producer is around at $t = 1$, it can take advantage of this incumbency to bribe L to raise barriers to the adoption of the new technology when it arrives at period 2. Condition 3 ensures the feasibility of inducing L to regulate. Since condition 2 does not hold, the final output producer prefers the old technology when the new technology is regulated, and therefore the old technology producer keeps the market in period 2.[6]

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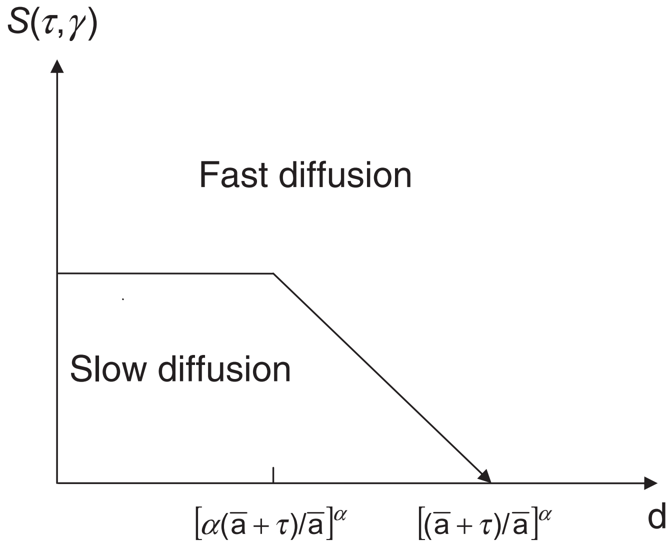
[6] One interesting issue is whether it is possible for the new technology producer to compensate the old technology producer in exchange for not inducing L to raise barriers against the diffusion of the new technology. This arrangement would increase social welfare, but would be hard to

FIGURE 1.—SPEED OF DIFFUSION



Identification: Propositions 1 and 2 yield exclusion restrictions that allow us to identify the importance of lobbying for technology diffusion. For expositional purposes, these are plotted in figures 1 and 2. Figure 1 represents the speed of diffusion of technology as a function of S and d. When d is large, the new technology diffuses fast regardless of S and the institutions that determine it. When d is small, however, new technologies diffuse fast only if the institutions are such that the cost of raising barriers, S, is large. Otherwise, they shall diffuse slowly. Hence, we can identify the effect of lobbying on technology diffusion by estimating the differential effect of the institutional attributes that affect the cost of raising barriers on the diffusion of technologies with technologically close predecessor technologies (low d) versus those without (high d).

This argument is done for a given Π_{o2}. Figure 2 shows that, as we increase the elasticity of demand, α, the rents that the old technology producer is willing to invest in lobbying decline, and the region of the (d,S) space where there is slow diffusion shrinks. Further, as α tends to 1 this region disappears. This provides us with a second identification scheme. Namely, we can infer the effect of lobbies on technology diffusion by estimating the differential effect of the institutional attributes that affect the cost of raising barriers on the diffusion of technologies with technologically close predecessor technologies and high α versus the rest.

Tirole (1988) and Aghion and Howitt (1998) relate α to the size of the sunk costs, F, necessary for a producer (in this case, of the old technology) to begin operating. Intuitively, a higher F reduces the number of old technology producers and, therefore, the elasticity of substitution between different intermediate goods associated with the old technology. Hence, a higher sunk cost, F, is equivalent to a smaller α. Since it is easier to measure the size of sunk costs of historical technologies than their demand elasticity, we will take advantage of this theoretical work in our empirical implementation.

III. Empirical Exploration

In this section we describe the data used in the empirical analysis. Then we present the econometric implementation of our identification strategy. Finally, we present the estimates of the effect of lobbies on technology diffusion and argue in favor of the causal interpretation of the estimates.

A. Data

Technologies: The technology diffusion measures come from our Historical Cross-Country Technology Adoption (HCCTA) data set introduced in Comin and Hobijn (2004). This data set contains historical data on the adoption of twenty major technologies over the last 215 years for 23 of the world's leading industrial economies.[7] Column 1 of table 1 lists the technologies we use and how we measure them. Our technologies cover seven sectors of economic activity.[8] 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 (such as fraction of ring spindles). Other production technologies are measured either by the number of equipment units of the technology (such as robots) scaled by real GDP or by the output produced with the technology (such as tons of Bessemer steel) over real GDP. Finally, consumption technologies are scaled by population rather than by real GDP.[9]

Since we are interested in understanding the determinants of the speed of diffusion of new technologies along the transition path, for each technology we censor the data at a certain year determined by one of two criteria: the distribution of the level of technologies across countries becomes stable; for technologies that become dominated by even newer technologies, it corresponds to the year in which the level of technology starts declining. In either case, the truncation of the sample for a given technology is the same for all countries.

Classifications: We classify technologies according to two criteria. First we classify them according to whether they have a previous competing technology. There are two senses in which a new technology may be very superior to the existing technologies, and thus not have a previous

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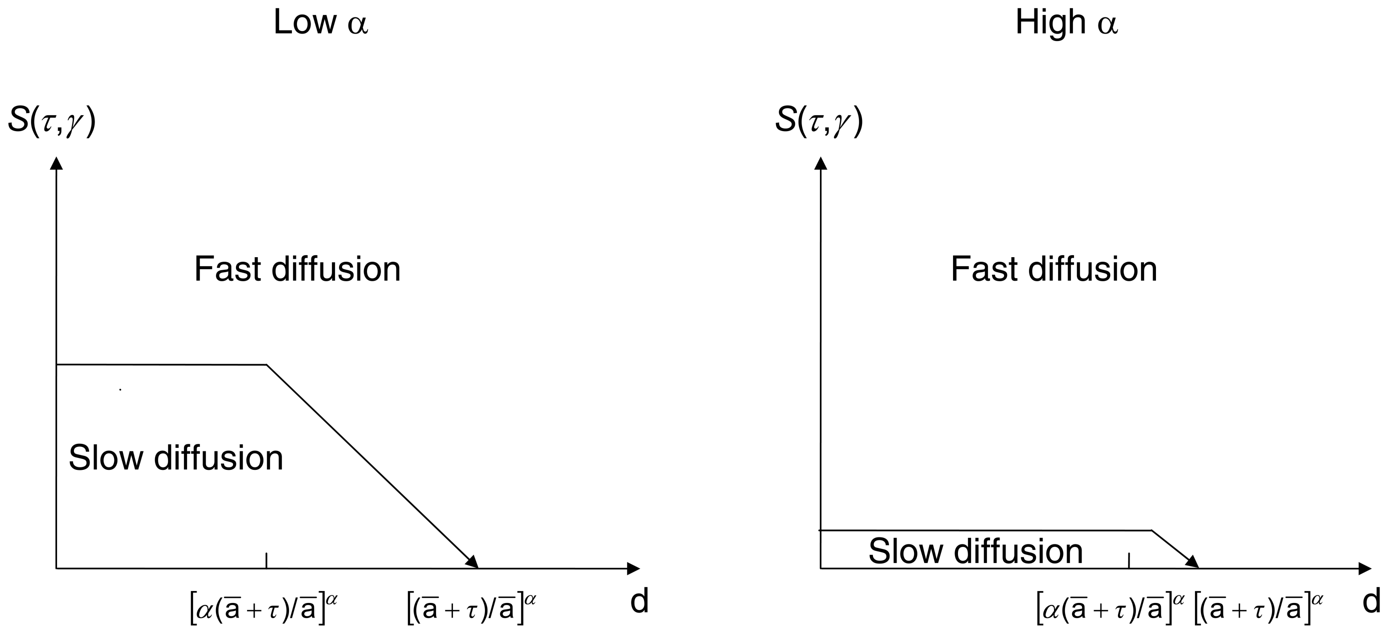
enforce. For a discussion of some of the difficulties in enforcing this kind of contract, see Comin and Hobijn (2005).

[7] Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States.

[8] Textiles, steel, telecommunication, mass communication, information technology, transportation (rail, road, and airways), and shipping.

[9] Our findings are robust to scaling all technology adoption measures by population rather than scaling some by population and others by GDP.

FIGURE 2.—SPEED OF DIFFUSION



competing technology. In a vertical sense, a new technology does not have a competing technology if it can conduct the same tasks as the previous technology, but much more efficiently. In a horizontal sense, a new technology does not have a previous competing technology if it can perform important tasks that were previously unfeasible.

Measuring these relative productivities is not trivial for various reasons. First, the relative productivity of new technologies typically varies over time. Our measurements correspond to the relative productivities over a relatively short period (always less than thirty years) after the new technology is invented. Second, the relative productivity of the new technology may vary across countries and/or across activities (typing versus computing for PCs) or across routes (for transportation technologies). Of course, it is virtually impossible to take all these dimensions into account. However, we believe our classification is robust since the distribution of observed relative productivities can be approximated accurately by a bimodal distribution.[10] Appendix A and Comin and Hobijn (2005) discuss the relative productivities estimates for the various technologies and the references in more detail. Table 1 describes the technology predecessors (column 2), the estimates of vertical distance (column 3), and the horizontal innovations introduced by the technology (column 4).

Six of our technologies—Bessemer steel, electric arc steel, telegraphs, railroads, PCs, and robots—were significantly more productive than their predecessor technologies. Column 5 of table 1 contains the classification according to productivity distance. For the rest of the technologies in our sample, the technological distance with their predecessors, though still significant, was relatively small. Freight trains, TVs, and radios deserve some remarks. The introduction of freight trains increased the speed of cargo transportation by a factor of 2 or 3 with respect to canal transportation. Hence, whenever canals were available, cargo trains did not constitute a radical improvement in transportation. However, in countries without navigable rivers their impact was very big. Experiments have shown that advertisement recall rates are not higher for radios or TVs than for newspapers. However, the two brought image and sound to the media, and these are important horizontal improvements over newspapers and magazines. In our analysis, we will experiment by classifying radios and TVs as both revolutionary and nonrevolutionary technologies.

The second scheme by which we classify technologies recognizes the difficulty of lobbying when the production of the old technology is dispersed. As a result, a technology has a competing concentrated predecessor if (i) the production of the previous technology requires large sunk costs and (ii) the productivity gap between new and old technology is small. Our research, described in appendix B, shows large sunk costs were required to begin producing Bessemer and open hearth steel; to install telegraphs and telephone lines; to construct canals, railroads, and trains; and to begin producing cars, trucks, and sail ships. Note that, based on our first classification, the productivity gap between these and the subsequent technologies was not very large. Therefore, as listed in column 6 of table 1, the technologies with competing and concentrated predecessor technologies are open hearth and blast oxygen steel, telephones, mobile

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[10] We have checked the robustness of our results in two directions. First, we have experimented with alternative classifications that are flexible with the few technologies that are closer to the cutoff between the two groups. Second, we have eliminated one by one the technologies to make sure that the results were not driven by any single technology.

Table 1.—Technologies and Classifications

		Technology Distance		Competing Concen.	
Technologies	Predecessor Technology	Vertical (Factor of Increment)	Horizontal	Pred.	Comp. Pred.
1. Fraction of ring spindles	Mule spindles	<1 (s)		Yes	No
2. Tons of steel produced with Bessemer over GDP	Crucible steel	>500,000 (p)		No	No
3. Tons of steel produced with open hearth over GDP	Bessemer	<2.5 (p)		Yes	Yes
4. Tons of steel produced with blast oxygen over GDP	Open hearth	2.5 (p)		Yes	Yes
5. Tons of steel produced with electric arc over GDP			Produces stainless steel	No	No
6. (Log.) Telegrams per capita	Mail	>3,000 (s), >100 (c)		No	No
7. (Log.) Telephones per capita	Telegrams	3 (s)		Yes	Yes
8. (Log.) Mobile phones per capita	Telephone	1.33 (p)		Yes	Yes
9. (Log.) Newspapers per capita				No	No
10. (Log.) Radios per capita	Newspapers	<1 (r)	Transmits sound	Yes	No
11. (Log.) TVs per capita	Radio	1.3 (r)	Transmits image	Yes	No
12. (Log.) Personal computers per capita	Typewriters/ calculators/ mainframes		Fast complex computations	No	No
13. (Log.) Industrial robots over GDP	Manual labor	<6.6 (p)	Flexible manufacturing	No	No
14. (Log.) Freight traffic on railways (TKMs) over GDP*	Canals/wagons	>5 (s), 2 (p with respect to canals)		Yes/No	Yes/No
15. (Log.) Passenger traffic on railways (PKMs) over GDP	Horse transportation	10 (s)		No	No
16. (Log.) Trucks per unit of real GDP	Railways	<1 (s), 1.2 (c in short distances)		Yes	Yes
17. (Log.) Passenger cars over GDP	Railways	<1 (s)		Yes	Yes
18. (Log.) Aviation cargo (TKMs) over GDP	Trucks/railways	<4 (s)		Yes	Yes
19. (Log.) Aviation passengers (PKMs) per capita	Cars/railways	<4 (s)		Yes	Yes
20. Share of steam and motor ships in merchant fleet tonnage	Sail ships	1.2 (s)		Yes	Yes

*Yes, where canals are available. No, otherwise.
Legend of vertical measures: (s) speed, (p) productivity, (c) cost, (r) recall rates.

phones, trucks, cars, planes, steam and motor ships, and cargo transportation by train wherever canals were available. The predecessors to all the other technologies in our sample either lag very much behind the productivity of the new technology or their production required much smaller sunk costs than the technologies just listed. Therefore, ring spindles, radios, and TVs—which, according to the first classification were classified as having a competing predecessor—are now classified as not having a concentrated, competing predecessor.[11]

Institutions: The political-economy literature has identified four institutional traits that increase the cost of raising political barriers. These are the lack of independence of legislators when passing laws,[12] the effectiveness of the judicial system,[13] the degree of democracy,[14] and the absence of a military regime. The measures of legislative independence and of the existence of a military regime come from Cross-National Time-Series Data Archive (also known as the Banks data set). The degree of democracy comes from Polity IV and the effectiveness of the judiciary comes from the Business International Corporation as in La Porta et al. (1998).[15]

For all the variables used in our analysis, we compute five-year averages and use nonoverlapping 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 institutional change are relatively low-frequency phenomena. Next we implement our identification strategy, present our estimates, and discuss their interpretation.

B. Results

Our baseline regression has the following form:

$$y_{ict} = \alpha_{0c} + \alpha D_{it} + \beta_1'\mathbf{X}_{ct} + \beta_2'\mathbf{R}_{ct} + \beta_3'(I_i \times \mathbf{R}_{ct}) + \varepsilon_{ict}. \qquad (2)$$

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[11] By construction, the two classifications of technologies are correlated. Since the correlation between these classifications is less than perfect (about 75%), however, this duality provides us with a second identification scheme to estimate the effect of lobbies on the diffusion of new technologies.

[12] Independent legislators do not have to respond to superior entities for their laws.

[13] The probability of a judicial sentence when accepting conditional contributions increases with the effectiveness of the judiciary.

[14] Work by Myerson (1993), Ferejohn (1986), Persson, Roland, and Tabellini (2000), Adsera, Boix, and Payne (2003), Persson and Tabellini (2000, ch. 9), Lijphart (1994, 1999), Powell (2000), Kunicova and Rose-Ackerman (2002), Persson, Tabellini, and Trebbi (2003), and Besley and Case (1995) has shown that electoral pressure aligns officials' incentives with public interest, which consists of not slowing down the diffusion of new technologies.

[15] See Comin and Hobijn (2005) for more information on these variables and for more detail on the arguments about how these traits affect the cost of raising barriers.

TABLE 2.—EFFECT OF LOBBYING ON TECHNOLOGIES WITH COMPETING PREDECESSOR (DEPENDENT VARIABLE: TECHNOLOGY DIFFUSION (y_{ict}))

Variable	I	II	III	IV	V
Controls (Xct)					
ln(GDP/pop)	1.12	1.21	1.20	1.19	1.18
	(8.83)	(8.88)	(8.77)	(8.74)	(8.52)
Prim. enr. before 1970	0.91	1.04	1.09	1.09	1.09
	(3.84)	(4.01)	(4.12)	(4.14)	(4.13)
Sec. enr. before 1970	−0.29	−0.09	−0.08	−0.09	−0.10
	(−1.58)	(−0.45)	(−0.40)	(−0.45)	(−0.48)
Prim. enr. after 1970	−0.37	0.66	0.62	0.61	0.65
	(−0.67)	(0.81)	(0.88)	(0.87)	(0.92)
Sec. enr. after 1970	−0.73	−0.82	−0.86	−0.87	−0.86
	(−2.47)	(−2.65)	(−2.78)	(−2.82)	(−2.77)
ln(electricity production)	0.18	0.16	0.17	0.17	0.16
	(2.95)	(2.59)	(2.74)	(2.68)	(2.57)
Institutions					
Democracy		−0.06	−0.07	−0.09	−0.08
		(−3.53)	(−3.73)	(−3.36)	(−2.60)
Military regime			0.16	0.11	0.24
			(0.92)	(0.66)	(1.34)
Legislative flexibility				0.04	0.12
				(0.47)	(1.10)
Judicial effectiveness					0.11
					(1.54)
Institut. × incumb. tech.					
Democracy × incumb. tech.		0.10	0.09	0.15	0.12
		(7.85)	(7.54)	(4.68)	(3.47)
Mil. reg. × incumb. tech.			−0.65	−0.77	−1.00
			(−2.47)	(−2.86)	(−3.41)
Legislat. flex. × incumb. tech.				−0.21	−0.33
				(−2.05)	(−2.68)
Judicial. eff. × incumb. tech.					0.07
					(2.10)
No. of obs.	2,648	2,452	2,452	2,452	2,452
R^2 (within)	0.29	0.27	0.27	0.27	0.27

Note: *t*-statistics in parentheses computed using robust standard errors.
All regressions include a full set of technology-year fixed effects and country fixed effects.

y_{ict} denotes our measure of the adoption of technology i in country c at time t. α_{0c} is a country-specific constant that captures other country-specific attributes that may affect technology diffusion.[16]

As explained above, we measure different technologies using different units. Further, as shown in Comin et al. (2006), technologies follow different diffusion paths. To control for these differences in diffusion across technologies we always include a full set of time- and technology-specific fixed effects denoted by D_{it} in our regressions. This implies that, effectively, our dependent variable is the deviation of the adoption level of each technology i in country c at time t from the average adoption level in the technology and period across countries. $\mathbf{X}_{ct}$ is a set of conventional controls that have been highlighted in the technology diffusion literature. This vector includes the level of income per capita, various measures of educational enrollment,[17] and the adoption of complementary technologies captured by the production of electricity over real GDP. $\mathbf{R}_{ct}$ represents the set of institutional variables that affect the cost of lobbying. These are legislative flexibility, effectiveness of the judiciary, the democracy index, and the military regime dummy. $I_i \times \mathbf{R}_{ct}$ interacts the institutional variables ($\mathbf{R}_{ct}$) with either a dummy variable for the technologies that have a competing predecessor technology or a dummy for the technologies with concentrated *and* competing predecessors (I_i).

β_3 is the critical vector of coefficients for the identification of the role of lobbying activity on technology diffusion. Specifically, if lobbies slow down the diffusion of new technologies, we should observe that the effect of institutions that increase the cost of lobbying on technology diffusion is larger for technologies with a competing incumbent technology than for technologies without one. This implies that β_3 should be positive for institutional variables that increase the cost of lobbying—such as the degree of democracy—and negative for variables that decrease the cost of lobbying—such as the independence of the legislature and the military regime dummy.

Table 2 reports the first set of coefficient estimates from regression (2) which only explore the interactions with the competing predecessor technology dummy. Each column corresponds to a different regression. Column 1 corresponds to a basic regression with only the vector $\mathbf{X}_{ct}$ as a regressor. There we can observe that income per capita, the primary

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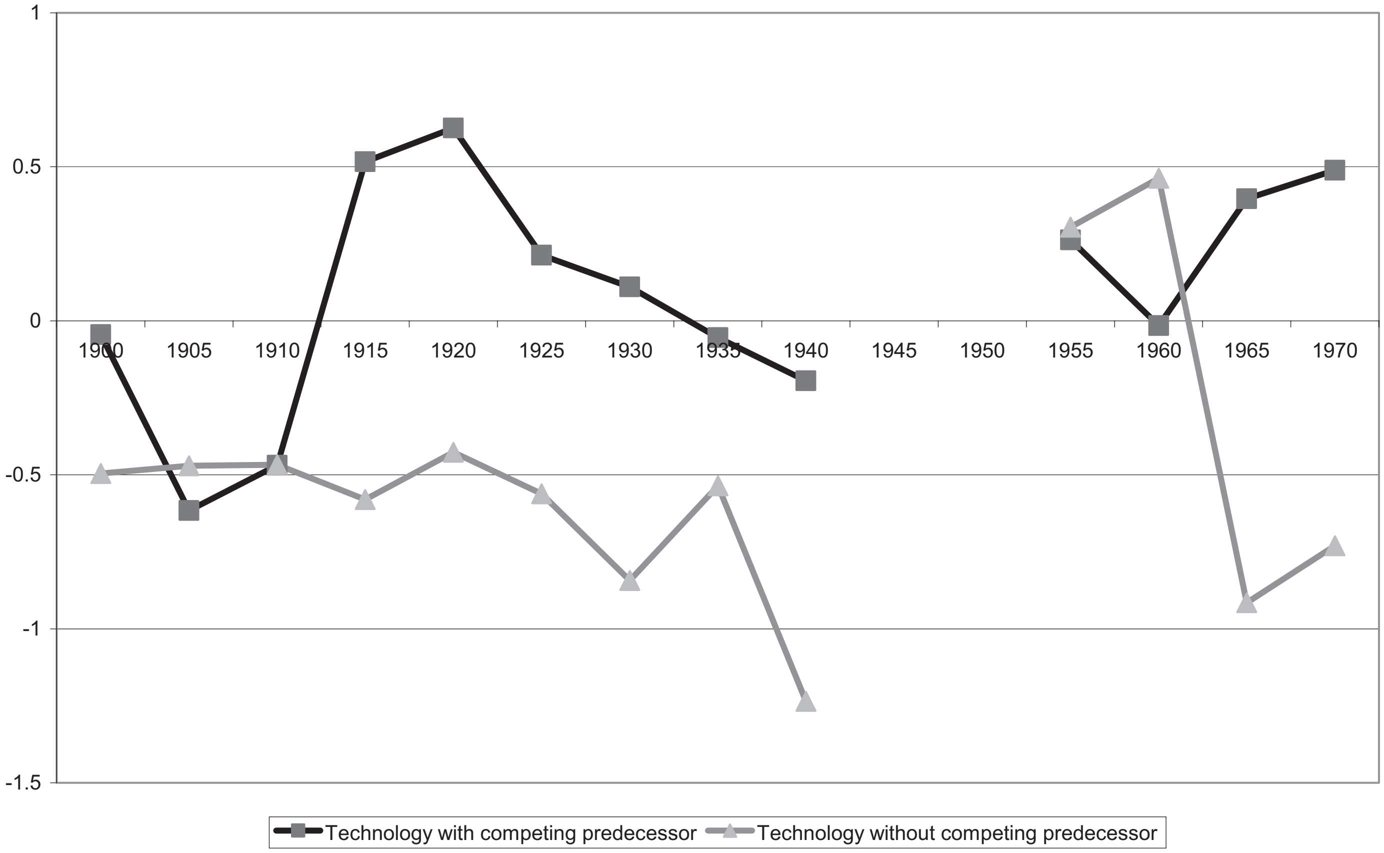
[16] In Comin and Hobijn (2005) we do not include a country fixed effect in the baseline specification. This allows us to exploit the efficiency of the judiciary (which only has cross-country variation) in our identification scheme.

[17] The enrollment rates in primary and secondary schooling before 1970 are computed by us; for the years after 1970 they are computed by the World Bank.

FIGURE 3.—INCREASE IN ADOPTION FROM HIGHER DEMOCRACY SCORE BY TECHNOLOGY GROUP



enrollment, and the intensity of electricity production are positively associated with the level of technology diffusion. The positive coefficient for enrollment, however, only holds for enrollment before 1970.

Rather than including the three institutional variables in $\mathbf{R}_{ct}$ and the associated interactions with the competing predecessor technology dummy, $I_i \times \mathbf{R}_{ct}$, at once, we find it instructive to introduce them sequentially. Since the comparative statics that motivate the identification strategy are valid keeping everything else constant, we delay the interpretation of the results until the column that includes all four institutional traits.

Column 2 starts with democracy. Democracy is associated with a lower diffusion of new technologies. This observation is orthogonal to our test. The relevant finding for our test is that democracy has a significantly larger (in other words, more positive) effect on the diffusion of those technologies with a close predecessor technology.

We illustrate this finding graphically in figure 3. This figure shows a measure of the effect of democracy in the adoption of technologies with (the line with squares) and without (the line with triangles) competing predecessor technologies for each five-year period. In particular, we take the estimates of column 2 and add the predicted effects of democracy (both the overall and the interacted with the technology classification) to the error term. Let's call this variable the modified error. Then we classify countries according to whether they have a democracy score of more than 7 in each period. Finally, we compute the average modified error for technologies with and without competing predecessors in countries with high and low democracy scores and for each period. Figure 3 plots the difference in the modified average error between observations with high and low democracy scores for the adoption of technologies with and without competing predecessors.

Figure 3 shows that in all but four five-year periods, a higher democracy score is associated with a more intensive level of adoption of technologies with competing predecessors than of technologies without a competing predecessor (in other words, the line with squares is above the line with triangles). In three of the four periods where this is not the case, the effect of democracy is very similar across technology groups. The larger effect of democracy on the adoption of technologies without competing predecessors in 1960 is entirely driven by mail in Greece. The cross-country variance of technology adoption after removing the fixed effects is approximately 0.9. The average difference in the effect of democracy between technologies with and without competing predecessors over the sample period plotted in figure 3 is 0.59. This suggests a quantitatively important role of the differential effect of democracy in explaining the cross-country variation in technology adoption.

In column 3 we consider the conditional effect of the military dummy and its interaction with the predecessor technology dummy on technology diffusion. Having a military regime does not significantly affect the diffusion of new technologies in general. However, it significantly slows down the diffusion of new technologies that have a competing predecessor technology.

In column 4 we add the independence of the legislature to the set of institutional controls R_{ct}. The degree of flexibility enjoyed by the legislature does not have a significant effect on technology diffusion in general. It, does, however, slow the diffusion of new technologies with a competing predecessor technology.

Column 5 also adds the judicial effectiveness to R_{ct}. This variable does not have a significant effect on the diffusion of new technologies in general. However, judiciary effectiveness has a significantly larger effect on the diffusion of technologies with a competing predecessor technology than on the diffusion of technologies without one. The other proxy for the static political costs to the legislative authority of raising diffusion barriers is the legislative flexibility variable. Consistent with the theory, we also observe that a high degree of legislative flexibility reduces the speed of diffusion of the technologies with a competing predecessor by more than that of the technologies that do not have a competing predecessor.

Similarly, column 5 shows that the regime variables also have a differential effect on the diffusion of technologies with competing predecessors consistent with the relevance of lobbying in slowing the speed of diffusion of technologies. Specifically, being in a military regime slows the diffusion of technologies with a competing predecessor technology by more than the diffusion of technologies without a competing predecessor technology. Finally, a higher degree of democracy is associated with faster diffusion for technologies with a competing predecessor technology than for technologies without one.

Table 3 reports the estimates for regression (2) when we classify technologies not only according to the technological gap with the predecessor, but also according to whether the production of the predecessor technology was concentrated. The differential effects of institutions in the diffusion of technologies with and without concentrated predecessors are very similar to the effect across technologies with and without competing predecessors. We find that democracy and judicial effectiveness have a significantly larger effect on the diffusion of technologies with concentrated predecessors. We also observe that legislative effectiveness and military regime have a negative and significant differential effect on the diffusion of technologies with a concentrated predecessor.

TABLE 3.—EFFECT OF LOBBYING ON TECHNOLOGIES WITH CONCENTRATED COMPETING PREDECESSOR (DEPENDENT VARIABLE: TECHNOLOGY DIFFUSION (y_{ict}))

Variable	I	II	III	IV
Controls (Xct)				
ln(GDP/pop)	1.21	1.17	1.17	1.15
	(8.83)	(8.59)	(8.61)	(8.39)
Prim. enr. before 1970	1.03	1.10	1.08	1.07
	(3.95)	(4.12)	(4.09)	(4.05)
Sec. enr. before 1970	−0.09	−0.09	−0.10	−0.11
	(−0.45)	(−0.44)	(−0.47)	(−0.54)
Prim. enr. after 1970	0.50	0.53	0.51	0.53
	(0.71)	(0.75)	(0.72)	(0.76)
Sec. enr. after 1970	−0.81	−0.84	−0.86	−0.83
	(−2.63)	(−2.74)	(−2.77)	(−2.68)
ln(electricity production)	0.16	0.16	0.16	0.15
	(2.60)	(2.60)	(2.62)	(2.39)
Institutions				
Democracy	−.055	−0.06	−0.08	−0.064
	(−3.10)	(−3.36)	(−3.55)	(−2.62)
Military regime		0.00	−0.01	0.13
		(−0.01)	(−0.09)	(0.76)
Legislative flexibility			0.05	0.12
			(0.64)	(1.41)
Judicial effectiveness				0.12
				(1.73)
Institut. × concen. pred.				
Democracy × concen. pred.	0.94	0.09	0.15	0.11
	(7.39)	(7.01)	(4.99)	(3.42)
Mil. reg. × concen. pred.		−0.49	−0.63	−0.91
		(−1.80)	(−2.27)	(−3.07)
Legislat. flex. × concen. pred.			−0.22	−0.36
			(−2.35)	(−3.29)
Judicial. eff. × concen. pred.				0.09
				(2.90)
No. of obs.	2,452	2,452	2,452	2,452
R^2 (within)	0.27	0.27	0.27	0.27

Note: *t*-statistics in parentheses computed using robust standard errors.
All regressions include a full set of technology-year fixed effects and country fixed effects.

Our model emphasizes the importance of the dynamic component to policymaking. In particular, current institutions affect the political barriers next period. Hence, in our regressions, the exogenous variables should reflect the lagged, rather than contemporaneous, institutions. In addition to being closer to the model, this variation should mitigate the possibility that our estimates are driven by reverse causality. In the first two columns of table 4, we rerun the basic regression for both classifications of technologies, replacing the institutional variables with their five-year lag. Interestingly, all the results hold, even a fortiori.

The estimated effect of lobbies on technology diffusion, in addition to being statistically significant, is quantitatively relevant. The variance of the diffusion level of the technologies with a predecessor after removing the effect of the technology-time dummies is 0.9. The dispersion induced by the estimated effect of the differential effect of institutional/policy variables on the diffusion of technologies with a predecessor is 0.46. This means that the estimated effect of lobbies on technology diffusion represents 50% of the observed variation in technology diffusion.

The validity of the standard errors used to determine the statistical significance of our estimates hinges on the assumptions made about ε_{ict}. Next, we show that our results are qualitatively and quantitatively robust to various assumptions about the error terms. We illustrate this using the specification in the first two columns of table 4. The conclusions we reach for this particular specification are representative of all the specifications run in our analysis. The odd columns in table 4 report the estimates of the interactions of the institutional

TABLE 4.—ROBUSTNESS OF STANDARD ERRORS (DEPENDENT VARIABLE: TECHNOLOGY DIFFUSION (y_{ict}))

Variable	I	II	III	IV	V	VI	VII	VIII
Lagged institut. × incumb. tech.								
Lagged democracy × incumb. tech.	0.13		0.13		0.13		0.08	
	(4.10)		(2.19)		(2.61)		(10.13)	
Lagged legislat. flex. × incumb. tech.	−1.14		−1.14		−1.14		−0.37	
	(−3.86)		(−3.1)		(−2.56)		(−4.2)	
Lagged mil. reg. × incumb. tech.	−0.40		−0.40		−0.40		−0.13	
	(−3.41)		(−2.22)		(−2.29)		(−3.7)	
Lagged judicial. eff. × incumb. tech.	0.09		0.09		0.09		0.04	
	(3.14)		(1.52)		(1.77)		(3.61)	
Lagged institut. × concen. pred.								
Lagged democracy × concen. pred.		0.12		0.12		0.12		0.07
		(4.23)		(2.26)		(2.73)		(8.21)
Lagged legislat. flex. × concen. pred.		−1.10		−1.10		−1.10		−0.37
		(−3.72)		(−2.66)		(−2.51)		(−4.45)
Lagged mil. reg. × concen. pred.		−0.43		−0.43		−0.43		−0.12
		(−3.90)		(−2.61)		(−2.76)		(−3.6)
Lagged judicial. eff. × concen. pred.		0.10		0.10		0.10		0.05
		(3.48)		(1.56)		(2.06)		(4.28)
Error term								
Cluster	No	No	Country	Country	Tech.-Coun.	Tech.-Coun.	No	No
Serial correlation	No	No	No	No	No	No	Yes	Yes
No. of obs.	2,427	2,427	2,427	2,427	2,427	2,427	2,427	2,427
R^2 (within)	0.275	0.275	0.275	0.275	0.275	0.275	—	—

Note: *t*-statistics computed using robust standad errors in parentheses. All regressions control for income per capita, enrollment in primary and secondary education, and electricity production. All regressions include a full set of technology-year and country fixed effects.

Columns III and IV cluster the error terms at the country level. Columns V and VI cluster the error terms at the technology-country level.

Columns VII and VIII allow for heteroskedastic errors with a different AR(1) process for the error terms in each technology-country cluster.

variables with the competing predecessor technology dummy. The even columns do the same for the interactions of the institutional variables with the concentrated and competing predecessor technology dummy. We consider three alternatives to our baseline robust standard errors. Columns 3 and 4 cluster the error terms at the country level. Columns 5 and 6 permit the correlation of the error term within each of the technology-country clusters. Finally, columns 7 and 8 allow for serially correlated errors. Specifically, we allow for heteroskedastic errors with a different AR(1) process for the errors in each technology-country cluster.

Comparing columns 1 and 2 with columns 3 through 6 we observe that clustering the errors does not affect the significance of the interactions of the technology classification dummies with democracy, the military regime dummy, and legislative flexibility. Clustering, however, renders the differential effect of lagged judicial effectiveness on technologies with close predecessors and/or concentrated predecessor technologies insignificant. Whether we cluster the error terms in country groups or technology-country groups does not make any difference.

In columns 7 and 8 we use a feasible generalized least squares (FGLS) estimator to allow for serial correlation and clustering in the error term. The point estimates obtained with this estimator are quite similar to the point estimates obtained with our fixed-effect estimator. The signs of the estimated differential effects of the institutional variables on technologies with concentrated and/or competing predecessor technologies are unchanged, though the absolute value of these estimates decline a little. The FGLS estimator, however, is more precise, and the *t*-statistics of the differential effect of the institutional traits on the technologies with concentrated and/or close competing predecessor technologies are even higher than those with the other estimators. The results that we present in the rest of the paper are also very robust to these variations in the specification for the error term.

C. *Interpretation and Robustness*

We believe that we can interpret the results presented so far as evidence of a causal negative effect of lobbies on technology diffusion. This interpretation of the differential correlation between institutions and diffusion for the technologies with competing and concentrated, competing predecessors is motivated by how unlikely it is to find omitted variables that drive the correlation. These variables should be correlated with the institutional controls and have a larger effect on the diffusion of technologies with a close predecessor than on technologies without one.

Good governments, climate, unmeasured factors, high TFP, and all the usual suspects that normally explain why we find a positive correlation between institutions and development levels fail to explain why the effect of the relevant institutional variables is stronger for technologies with a competing or concentrated, competing predecessor. Next, we discuss various observations that make this failure to find a relevant omitted variable more general.

Sector-specific omissions: In the sectors in our sample there is an even representation of technologies with and without competing predecessors. The same is true for technologies with and without concentrated, competing prede-

TABLE 5.—ROBUSTNESS: TECHNOLOGY DIFFUSION WITH AND WITHOUT INCUMBENT TECHNOLOGIES (DEPENDENT VARIABLE: TECHNOLOGY DIFFUSION (y_{ict}))

Variable	I	II	III	IV	V	VI
Controls × incumb. tech.						
ln(GDP/pop) × incumb. tech.			0.24			
			(1.43)			
Prim. enr. 70− × incumb. tech.			−0.02			
			(−0.04)			
Sec. enr. 70− × incumb. tech.			1.35			
			(3.24)			
Prim. enr. 70+ × incumb. tech.			−0.77			
			(−0.49)			
Sec. enr. 70+ × incumb. tech.			0.89			
			(1.41)			
ln(electricity) × incumb. tech.			0.00			
			(0.02)			
ln(area) × incumb. tech.				0.13		
				(3.51)		
ln(population) × incumb. tech.				−0.12		
				(−3.31)		
ln(GDP) × incumb. tech.					−0.03	
					(−1.10)	
Institut. × incumb. tech.						
Lagged democracy × incumb. tech.	0.13	0.16	0.11	0.12	0.16	0.05
	(4.10)	(4.60)	(3.59)	(2.94)	(3.92)	(1.27)
Lagged legislat. flex. × incumb. tech.	−1.14	−0.67	−0.36	−0.50	−0.60	−0.36
	(−3.86)	(−4.54)	(−2.61)	(−2.77)	(−3.27)	(−2.39)
Lagged mil. reg. × incumb. tech.	−0.40	−1.39	−1.10	−1.48	−1.58	−0.49
	(−3.41)	(−4.78)	(−3.38)	(−3.81)	(−4.05)	(−1.45)
Lagged judicial. eff. × incumb. tech.	0.09	0.15	0.02	0.16	0.15	0.20
	(3.14)	(4.33)	(0.59)	(4.40)	(4.06)	(3.84)
Dummies						
Country dummies	No	No	No	No	No	Yes
Country dummies × incumb. tech.	No	No	No	No	No	Yes
Sector dummies × institutional var.	No	Yes	No	No	No	No
No. of obs.	2,427	2,427	2,427	2,210	2,210	2,427
R^2 (within)	0.275	0.29	0.28	0.24	0.23	0.31

Note: *t*-statistics computed using robust standard errors in parentheses. All regressions include a full set of technology-year and country fixed effects.
All regressions control for income per capita, enrollment in primary and secondary education, and electricity production.
Regression III controls in addition for ln(area) and for ln(population). Regression IV controls in addition for ln(GDP).

cessor technologies. Thus, the omission of sector-specific variables that symmetrically affect the technologies in the sector does not rationalize our estimates.

To show this formally, we include in our baseline regression the interaction between each of the four institutional variables and each of the six sectors. In table 5, we focus on the classification of technologies based on the presence of a competing predecessor, while table 6 reports the estimates of the differential effects of institutions on technologies with concentrated, competing predecessors. For comparison purposes, column 1 in tables 5 and 6 are taken from columns 1 and 2 in table 4. As anticipated, column 2 of tables 5 and 6 show that the inclusion of sector-specific effects of the institutional traits that affect the cost of lobbying does not reduce the size and significance of the differential effects of these traits on the diffusion of technologies with competing (table 5) and with concentrated, competing predecessors (table 6).

An example can help us illustrate how much this restricts the set of omitted variables that could induce our estimates. One could think that the inverse of the productivity distance between new and old technologies is a proxy for the capital intensity of the technology—the omitted variable. Naturally, the protection of property rights is more relevant for the diffusion of more capital-intensive technologies, since capital is easier to expropriate than labor. Then, good institutions that protect better property rights should have a stronger effect on the diffusion of technologies with a close predecessor technology. Thus, the omission of the interaction between capital-intensity classification and the institutional variables would bias the estimates of the interaction we introduce in regression (2).

This argument, however, rests on the premise that there is a negative correlation between the capital intensity of a technology and its productivity advantage with respect to the predecessor technology. This premise does not hold in our sample of technologies because the capital intensity of our technologies depends mostly on the sector the technology belongs to (that is, transportation, steel, telecommunications, and IT are capital intensive while textiles and mass communications are not), and in most of the sectors we have an even distribution of technologies between those that have close predecessors and those that do not. Therefore, not controlling for the capital intensity of technologies or for any other attribute that is relatively homogeneous within the sector will not result in a bias of our estimates.[18]

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[18] Another variable that may affect the speed of diffusion of certain technologies is whether the government undertakes complementary in-

TABLE 6.—ROBUSTNESS: TECHNOLOGIES WITH COMPETING AND CONCENTRATED PREDECESSORS (DEPENDENT VARIABLE: TECHNOLOGY DIFFUSION (y_{ict}))

Variable	I	II	III	IV	V	VI
Controls × concen. pred.						
ln(GDP/pop) × concen. pred.			0.14			
			(.92)			
Prim. enr. 70− × concen. pred.			0.47			
			(1.37)			
Sec. enr. 70− × concen. pred.			0.51			
			(1.53)			
Prim. enr. 70+ × concen. pred.			0.12			
			(0.10)			
Sec. enr. 70+ × concen. pred.			0.22			
			(0.37)			
ln(electricity) × concen. pred.			0.01			
			(0.25)			
ln(area) × concen. pred.				0.13		
				(4.62)		
ln(population) × concen. pred.				−0.14		
				(−4.83)		
ln(GDP) × concen. pred.					−0.05	
					(−2.20)	
Institut. × concen. pred.						
Lagged democracy × concen. pred.	0.12	0.16	0.11	0.11	0.15	0.06
	(4.23)	(4.60)	(3.60)	(2.92)	(3.97)	(1.77)
Lagged legislat. flex. × concen. pred.	−1.10	−0.67	−0.46	−0.35	−0.46	−0.38
	(−3.72)	(−4.54)	(−3.63)	(−2.25)	(−2.85)	(−2.94)
Lagged mil. reg. × concen. pred.	−0.43	−1.39	−1.11	−1.36	−1.48	−0.62
	(−3.90)	(−4.78)	(−3.38)	(−3.38)	(−3.68)	(−1.81)
Lagged judicial. eff. × concen. pred.	0.10	0.15	0.06	0.14	0.14	0.22
	(3.48)	(4.33)	(1.61)	(4.66)	(4.37)	(4.84)
Dummies						
Country dummies	No	No	No	No	No	Yes
Country dummies × concen. pred.	No	No	No	No	No	Yes
Sector dummies × institutional var.	No	Yes	No	No	No	No
No. of obs.	2,210	2,427	2,427	2,210	2,210	2,210
R^2 (within)	0.275	0.29	0.27	0.24	0.23	0.24

Note: *t*-statistics computed using robust standard errors in parentheses. All regressions include a full set of technology-year and country fixed effects. All regressions control for income per capita, enrollment in primary and secondary education, and electricity production. Regression III controls in addition for ln(area) and for ln(population). Regression IV controls in addition for ln(GDP).

Omission of social value of technology: A second potential source of bias in our estimates of the effect of lobbies on technology diffusion might arise from the omission of controls that measure the social value of new technologies. The technology gap between a technology and its predecessor is likely to be positively correlated with the social value of the new technology. The quality of institutions may reflect the sensitivity of the government to the social value of institutions. Therefore, we should expect that countries with "good" institutions are going to adopt policies that accelerate the (relative) diffusion of technologies without a close predecessor technology. Therefore, the omission of a measure of the social value of the new technology would result in a bias in the estimate of the interaction between the technology classification and the institutional variables. In particular, it would bias the estimates toward finding lower effects of good institutions in the diffusion of technologies with close predecessors. However, as described above, we find exactly the opposite. The degree of democracy, nonmilitary regime, and the effectiveness of the judicial system have a stronger (positive) effect on the diffusion of technologies with a close predecessor than on the diffusion of those without one.[19]

Omission of differential effect of controls in X_{ct}: Another source of omitted variable bias in the estimates of the differential effects of the institutional variables on the technologies with close predecessors may be the omission of the interaction between the technology classification and the controls in X_{ct}. It could be argued that technologies with a close predecessor are more complementary to, say, human capital. Democratic institutions may be more effective in promoting human capital accumulation. Omitting the interaction between human capital measures and institutions might then generate a positive differential effect of institu-

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vestments. These investments are particularly important in transportation (roads, railroads, airports, harbors) and telecommunications. Omitting the magnitude of these government investments does not bias our estimates given the sector-specificity of the investments' importance.

[19] A similar argument could be made about the biases from the omission of measures of the willingness to accept change. It is not obvious to us how this variable would be correlated (if at all) with our institutional variables. One possibility is that, as discussed in Acemoglu and Robinson (2000b), bad institutions are more opposed to the adoption of more revolutionary technologies because these may threaten the political power of current leaders. If so, this omission would bias the estimates in favor of a larger effect of democracy, judicial effectiveness, and military on the diffusion of technologies without a close predecessor, the opposite of what we find.

tional variables on technologies with a close predecessor for reasons other than lobbies. To explore this possibility, column 3 of tables 5 and 6 allow for a differential effect of the controls in X_{ct} (income per capita, enrollment rates, and electricity production) on the diffusion of the technologies with a predecessor (table 5) and with a concentrated, competing predecessor (table 6). The differential effects of institutions on the diffusion of technologies with a competing predecessor or with a concentrated, competing predecessor are largely robust to the presence of differential controls. The only institutional variable that becomes insignificant after allowing for a differential set of controls is judicial effectiveness. Hence, the differential effect of institutions on the diffusion of technologies with competing or concentrated, competing predecessors is not driven by the interaction between the technology classification and any of the correlates in X_{ct}, including human capital measures.

Beyond good versus bad institutions: The fact that we can simultaneously identify the differential effect of all the institutional variables on the diffusion of the technologies with a competing or concentrated, competing predecessor raises the hurdle for the potential omitted variables since, to account for the estimated coefficients, they must be appropriately correlated with all the variables in R_{ct}. This is particularly difficult since we find that some measures of good institutions—democracy, judicial effectiveness, and nonmilitary regime—accelerate more the diffusion of technologies with a competing predecessor, but one variable that is usually associated with good institutions—legislative flexibility—slows more the diffusion of this same group of technologies. This finding is perfectly natural, however, if lobbies constitute an important deterrent to the adoption of technologies with a competing predecessor.

Omission of geography variables: To increase our confidence in the robustness and interpretation of the estimated differential effect of institutions across technology groups, we explore next some further omissions. For most of them, however, it is hard to argue why they should affect differentially the technology groups in a way that correlates with the differential effect that our institutional traits have.

The size of the country or its economy should have an effect on the diffusion of some of the technologies such as transportation and communication technologies. To explore whether they affect the estimated differential effects of institutions, column 4 includes as regressors the country area and population, while column 5 includes real GDP. Of course, we allow these variables to have a differential effect on the technologies with a competing predecessor (table 5) and with a concentrated, competing predecessor (table 6). Though these measures of size have a significant differential effect on the diffusion of technologies with a predecessor technology, the differential effects of institutions on the diffusion of technologies with competing or with concentrated, competing predecessors are virtually unaffected.

Source of identification: In column 6 we try to understand the source of the identification for the interaction between technologies and institutions. In particular, we explore whether we are obtaining any identification from the time-technology dimension or whether all the identification comes from the country-technology dimension. To do that, we include in the regression both country fixed effects and country fixed effects interacted with the dummy for technologies with previous competing technologies. After eliminating the country-technology dimension, the differential effects of the military dummy and of democracy on technologies that have a competing technology decline by approximately half and become insignificant. However, the differential effect of the flexibility of the legislature remains negative and significant at the 2% significance level. This means we are identifying some of the differential effects of institutions on technology diffusion by exploiting the time series variation of the institutions.

Column 6 in table 6 explores the source of the identification of the differential effect of institutions on the diffusion of technologies with concentrated, competing predecessors. As before, we do that by including, simultaneously, country fixed effects and country fixed effects interacted with the dummy for technologies with concentrated, competing predecessors. When doing that, we find that the estimate of the differential effect of legislative flexibility does not change while the estimate of the differential effects of democracy and the military dummy declines by about half. However, these differential effects of the institutional traits on technologies with close, concentrated predecessor technologies are still significant: legislative flexibility is significant at the 1% level while democracy and the military dummy are significant at the 7% level. Hence, we are identifying an important portion of the differential effects of institutions on technology diffusion through the time series variation of the institutions. This makes it even more unlikely that the estimates of the differential effects of institutions on technology diffusion are driven by omitted variables and reinforces the conclusion that lobbies are an important impediment to technology diffusion.

Reverse causality: Similar arguments lead to the conclusion that it is unlikely that reverse causality drives the observed differential correlation between diffusion for technologies with predecessor technologies and the institutional variables in R_{ct}. Namely, it is hard to argue why the speed of diffusion in the sectors with an incumbent technology, but not in the sectors without one, led to a democratic regime or to a legislative system where the authorities had no legislative independence. We believe that the previous discussion makes this argument very difficult to sustain. In addition, it is important to note that the technologies we are studying are quite micro, and therefore the effect of their diffusion (or lack thereof) in aggregate macro variables, such as GDP and the labor market, may be quite limited.

IV. Concluding Remarks

Differences in the available technology across countries are believed to be a first-order determinant of cross-country income per capita differentials. In this paper we explored the empirical relevance of one of the determinants of technology diffusion. Namely, lobbying efforts by producers of incumbent technologies. We observed that lobbies significantly slow the speed of diffusion of new technologies.

In addition, the findings of this paper also illustrate one channel by which institutions affect development. Namely, institutions affect the parties' incentives to engage in lobbying activities, lobbying slows technology diffusion, and technology crucially affects development. The empirical identification of this mechanism is a contribution to the institutions and growth literature.

This literature has followed two routes to progress. In standard regression analysis, it has tried to identify the effect of institutions on income per capita by controlling for elements other than institutions that may affect income per capita differences. This route has typically been unsuccessful because institutions become insignificant after the inclusion of common controls or country fixed effects. A second route has argued that attenuation bias is responsible for this insignificance and has tried to find good instruments of institutions. This approach has been more successful, but it is still not clear whether the proposed instruments are truly valid.[20] Further, since income per capita is highly correlated with many indicators of "good institutions," it is very hard to detect the specific institutional traits that drive income per capita differences with this instrumental variables approach.

This paper provides an alternative route to establishing the link between institutions and development, which hinges on two pillars. First, the use of measures of diffusion for various technologies as dependent variables. Second, the identification of the effect of institutions by interacting institutions to a relevant ex ante classification of technologies.

We believe that our approach has some important advantages. First, as we have argued above, it is very robust to omitted variable and reverse causality biases. Second, by using a multidimensional dependent variable with so much variation both over time and in the cross section as technology diffusion, the test of the null that lobbies have no effect on technology diffusion is more powerful. Indeed, we have identified the effect of lobbies on technology diffusion through the differential effects of institutions on technology diffusion even after introducing country fixed effects and the interaction of country fixed effects with the a priori classification of technologies. Finally, with our approach we have been able to pinpoint some specific institutional traits that strongly affect technology diffusion. This step is very important for two reasons. First and foremost, it is critical to draw specific policy recommendations from this kind of empirical analysis. Second, we have observed that not all the institutional characteristics that are usually associated with advanced economies accelerate the speed of diffusion of technologies. In particular, more flexibility of the legislative authority makes it easier for lobbies to induce it to raise political barriers to the diffusion of new technologies that ultimately slow their diffusion.

The strategy used to identify the role of lobbies on technology diffusion captures the barriers raised by incumbents that compete with new entrants in the product market. This is just one of the possible mechanisms by which interest groups (broadly understood) slow down the diffusion of new technologies. De Soto (1989), for example, claims that corrupt bureaucracies prevent the adoption of new technologies. Acemoglu and Robinson (2000a, 2000b) argue that elites block the adoption of new technologies in order to preserve their political power. Finally, various authors have claimed that interest groups such as unions or elites may block the adoption of technologies that affect their labor market outcomes. One interesting line of research that we plan on pursuing in the future is to evaluate the empirical relevance of these mechanisms. Doing so will require increasing the number of technologies in our data set.[21]

The empirical strategy used in this paper can be applied to identify mechanisms other than lobbies through which institutions affect technology diffusion and income per capita. These exercises may provide us with a better understanding of the specific institutional traits that trigger engines of development such as technology adoption. If, as this and other papers suggest, institutions are important for development, identifying the likely consequences of specific institutional traits is crucial for the advancement of poor countries.

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[20] See the debate among Acemoglu, Johnson, and Robinson (2001), Glaeser et al. (2004), and Acemoglu et al. (2005).

[21] For example, our data set only contains one labor-saving technology (industrial robots).

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APPENDIX A

Productivity Differentials

Appendix A documents the productivity differential between a given technology and its proceeding technology.

Ring spindles: In 1779, Crompton designed the spinning mule. The first ring spindles were simultaneously invented by John Thorp and Charles Danforth in 1828. The main technical difference between the ring and mule spindles is that the ring spins continuously, while the mule spins intermittently. Saxonhouse and Wright (2000) provide the average speed of new mule and ring spindles in a sample of fifteen countries for various periods up to 1920. As late as 1914, the average spinning speed of new mule spindles was 9,600 rpm, while that of ring spindles was 8,900 rpm.

Bessemer: Prior to the invention of the Bessemer process, steel was produced with crucibles. Wrought iron bars were broken up and heated in clay crucibles, each holding at most forty to fifty pounds of metal. Ten to fifteen days were then devoted to converting the iron into steel, which required large quantities of fuel. The Bessemer converter brought an unprecedented productivity improvement over the crucible. It cast five tons of steel in twenty to thirty minutes (Fisher, 1963, p. 117).

Open hearth and blast oxygen: Subsequent innovations in steel production generated much smaller productivity improvements than the Bessemer furnace did. Open hearth furnaces did not significantly improve the productivity of the Bessemer converter, while blast oxygen furnaces were 2.5 times more productive than open hearth furnaces (Adams & Dirlam, 1966).

Electric arc: The invention of the electric arc allowed for the first time the efficient production of the stainless steel used in cookware, cutlery, hardware, surgical instruments, major appliances, industrial equipment, and building materials for skyscrapers.

Telegraphs: Between 1840 and 1850, the telegraph cut costs by a factor of hundred and reduced elapsed time per word transmitted by a factor of three thousand, from ten days to five minutes for a one-page message between New York and Chicago (Sichel, 1997, p. 127).

Telephones: The productivity increase between the telephone and the telegraph depended on the task being completed. Solymar (1999) and Smith (2004) report that it took about six times longer to tap a message and translate the Morse code into words than it took to read it by telephone. Coe (1995), however, estimates that it took about the same time to dispatch trains by phone and by telegraph. Additionally, Casson (2004) cites a United Press study that estimates it also took the same time to dispatch news to ten cities by phone and by telegraph. Taking the average of these three tasks, we estimate that the telephone increased communications productivity by a factor of three.

Cell phones: In 1993, Gallup conducted a survey of cell phone users asking how much their productivity increased by using a mobile phone instead of a fixed phone. Responders reported an average productivity increase of 34%.

Newspapers: Newspapers did not have a clear predecessor, and thus can be classified as having an arbitrarily large productivity differential.

Radios and TVs: Determining the productivity differentials between newspapers, radios, and TVs is difficult because though radio and TV were not more efficient ways to transmit information based on their recall rates (Kelley & Jugenheimer, 2003, p. 38), they added an entirely new dimension to the mass communication industry.

PCs and robots: Personal computers increased enormously our computing capacity at a rate that doubled every eighteen months after their invention. Robots lead to productivity increases of up to 560% in a sample of car manufacturing plants studied by Ayres and Miller (1983). In addition, robots made operation of hazardous materials in extreme environments safer, and computers greatly reduced the cost of completing computations, and organizing and distributing information, and revolutionized graphic design.

Railways: In the prerail era it took two to four days to travel the ninety miles that separate New York from Philadelphia (Oliver, 1956), giving an average speed of about two miles per hour. Within a few years after the introduction of the railroad, average passenger transportation speeds were ten times higher than that. Whether railways led to a similar revolution in freight transportation depended on the presence or absence of canals. As early as 1840, the Reading locomotives transported over four hundred tons of coal at average speeds of ten mph. In contrast, the size of freights transported by road was below ten tons. Fogel (1964) estimates that railways reduced the cost of transporting cargo relative to canals by slightly less than a factor of two.

Cars and trucks: Cars were first produced in Europe in the late 1800s. From their invention through the 1950s, cars were less productive than trains, first because cars took several years to even acquire enough power and reliability over long distances to compete with the speed of trains and then because of the slow pace of road construction and improvements (Curcio, 2000, p. 152; Weiss, 2003). Trucks were more efficient than trains only in very short distances, but when transporting cargo for distances above eighty miles, rail transportation was cheaper than road transportation, even when using twenty-ton trucks (Warner, 1962, p. 237).

Planes: The first commercial planes appeared in the late 1920s. The Stratolier, which appeared in 1938, transported 33 passengers at 250 minutes per hour. These speeds, while impressive, are still less than five times the speed of the fastest trains, which in 1894 traveled at an average speed of about 55 minutes per hour (Oliver, 1956).

Steam ships: The development and subsequent improvement of steam ships were long, arduous tasks. It was not until the end of the century, however, that the fastest steam ships sailed at speeds beyond the reach of the clippers (Oliver, 1956).

APPENDIX B

Size of Sunk Costs of Production of Predecessor Technologies

Appendix B documents the size of the sunk costs necessary to implement or produce technologies without revolutionary subsequent technologies.

Mule spindle (predecessor to ring spindle): The first mule was invented in a home in 1779 by a 26-year-old boy (Walton, 1925); similarly, the second mule was erected in a loft above a schoolhouse (French, 1862). The small, unsophisticated settings for the construction of these first mules indicate that producing mules required small sunk costs.

Bessemer (predecessor to open hearth): Liddel (1916) reports costs of setting up various types of metallurgical plants from Hofman (1913) at the turn of the century. The cost of building an acid Bessemer plant with capacity to produce two thousand tons of steel per day was $900,000.

Open hearth (predecessor to blast oxygen steel furnace): Liddel (1916) also reports that the cost of building an acid open hearth plant able to produce one thousand tons of steel per day was $1.5 million.

Telegraph (predecessor to telephone): To transit telegrams, it is necessary to set up a complex wire network, which supposes a large sunk cost to telegrams. In 1848, the average cost of constructing the six regions in the Atlantic, Lake, and Mississippi line—Atlantic and Ohio; Pittsburg, Cincinnati, and Louisville; Ohio and Mississippi; Ohio, Indiana, and Illinois; Lake Erie; and Illinois and Mississippi—was $240 per mile, or $150 per kilometer (Thompson, 1947). Additionally, construction of the New York to Erie line was projected in 1848 to cost $250 per mile for the first wire and an additional $100 for each wire after that (Thompson, 1947). In 1850, there were about four thousand miles of wire in operation in the United Kingdom. The quality of the lines in the United Kingdom was higher than in the United States. This emphasis in quality led to higher construction costs. In some cases, these amounted to $600 per mile. Finally, the total cost of manufacturing, laying, and bringing into working order the Persian Gulf submarine telegraph line, built in 1964, was £411,751 (Phelps, 1969).

Telephone (predecessor to cell phone): Similar to telegrams, setting up the telephone lines necessary for telephonic communication was very costly. By 1888, the American Bell Company had constructed telephone lines with 26,038 miles of wire, which covered a distance of approximately twenty times less than the actual wire length. These lines cost approximately $2,200,000, or $84 per mile of wire (Rhodes, 1929).

Newspaper (predecessor to radio): The cost of purchasing a printing press has always had a relatively low sunk cost. In the 1830s, for example, most radical, unstamped papers were printed on hand presses, which cost as little as £10 to acquire. The low sunk cost of buying a printing press has persisted even while printing presses have experienced significant technological advancements. After 1836, for example, most radical presses began using the technologically superior steam press. Even then, papers like *The Northern Star* cost only £690 to start (Curran & Seaton, 1981). In 1912, after the industrialization of the press, newspapers still required only a small sunk cost to start. For example, *The Daily Citizen* began in 1912 with only £30,000 and *The Daily Herald* used only £300 to start and, with the help of public subscriptions, achieved a circulation of almost 250,000 (Curran & Seaton, 1981).

Radio (predecessor to TV): The total cost of setting up a "modest" radio station was only around $50,000 (Archer, 1938).

Canal (predecessor to freight trains): Building a canal comes with a very large sunk cost, as shown by table A.1 in Comin and Hobijn (2005).

Railway (predecessor to trucks, cars, and planes): Establishing a rail network came at a very high sunk cost. Dodge (1910) described the cost and labor required to build the Union Pacific Railroad. When the project was initially considered in 1836, bills were introduced in Congress suggesting as much as $96 million for the railroad's construction. Once construction finally began, the Union Pacific was funded by government bonds paying $48,000 per mile for the first 150 miles west of Cheyenne and $32,000 per mile thereafter. A railroad in England that was constructed in the 1820s and ran from Liverpool to Manchester in England cost $187,495 per mile (Galloway, 1950).

Cars (predecessor to planes): Cars also require a high sunk cost to produce. In the early 1900s, Ford constructed a plant on the River Rouge at a cost of $3.5 million and a second plant in Kearny, New Jersey, which cost $2.5 million (Biggs, 1996). By the 1950s, the cost to Ford of updating its plants to produce its popular 1953 model car was $1 billion (Weiss, 2003). In 1922, William Durant purchased a plant in Elizabeth, New Jersey, for $5,525,000.

Sailing ships (predecessor to steam and motor ships): The value of all the shipbuilding materials in the Clydebank (Britain) yard of John Brown and Company was £131,220 in 1899 and £200,691 in 1910 (Pollard & Robertson, 1979).