On the Persistence of Human Capital and Patent Effects Around 1900 on Per capita levels in the 1960s

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Abstract

We assess the impact of schooling and important patents in 1900 and 1910 on national income in the 1960s. Even controlling for GDP per capita in 1910, we find that both the effects of schooling and important patents were always statistically and economically significant. Growth successes of the 20th century such as Japan or the Scandinavian countries were based on early human capital formation and their propensity to innovativeness.

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1. INTRODUCTION

In this paper, we study the number of importance-weighted patents in Germany which were issued to inhabitants of foreign countries. We argue that this can serve as an indicator of innovativeness. We assess the long-run impact of important patents as well as human capital formation over half a century.[1] Even controlling for GDP/c in 1910, the effect of human capital is always statistically and economically significant.

While enrolment rates are typically correlated with important patents, the correlation is not perfect. Sometimes governments spend unusually high or low amounts on education. For example, the Finnish people developed many important patents. Its inhabitants were quite active in patenting in Germany, which suggests that technical creativity was quite substantial in this country. But this nation was disadvantaged because the Russian Empire decided about educational spending and under-invested in the Finnish territory relative to its potential. On the other hand, the Habsburg Empire spent much on education in the Czech, Croatian, Slovenian and Bosnian parts of its Empire. Enrolment rates were relatively high. Good (2003) argued that the Habsburg Empire shifted government expenditure to the minority regions in order to constrain political upheaval. In contrast, the latter three territories had very few important patents in Germany. Hence, we find that our adjusted patent indicator expands our knowledge of this important indicator in a crucial phase of world development.

How do we measure important patents? Patent counts that compare different countries with their national patent statistics have been heavily criticized as an indicator of innovation, because the vast majority of patents had little economic impact, and the share of important innovations that became patents varied from country to country. Schankerman and Pakes and

[1] Inventions are inputs into the development of innovations, but this does not mean that all inventions can be potentially used for commercial success in the form of a patent. A patent not only prevents others from using a certain invention, it should also preclude imitators and other inventors who independently discovered the same thing.

others have emphasized that simple patent counts do not mirror the quality of innovations.[2] Various methodologies have thus been adopted to approximate the value of patents. Jaffe and Trajtenberg measure patent value based on the number of citations from more recent patents, whereas Pakes and Schankerman analyze the survival rates of patents.[3] They find that patents with a higher life span had a higher private economic value than patents which existed only for short periods. Renewal rates and fees proxy the patent value, as an inventor had to decide if he was going to renew his patent or not. The decision to hold a patent was clearly influenced by the renewal fees. Patent holders were only willing to keep their patents in force if the current value of the remaining expected future returns exceeded the present value of remaining future costs. Consequently, valuable patents were held longer. One important feature of the patent law was the annual patent renewal decision. The patent owner had to decide each year if he was going to renew his patent for another year or not. This microeconomic decision about expected profits from holding a patent allows to distinguish between important and unimportant patents.

The structure of the paper is as follows. We will first document the new dataset on foreign patents in Germany in more detail in section 2. Section 3 then regresses GDP per capita levels in the 1960s on important patents and human capital, and section 4 concludes.

2. Data

2.1. Historical overview: The German Patent System and the Importance of the Patent Law of 1877

Among others, Nirk has emphasized that Germany had no nationwide law for the protection of inventions before 1877 for several reasons: before the foundation of the German Empire,

[2] Schankerman and Pakes, “Value of Patent Rights.“
[3] Jaffe and Trajtenberg, “Market Value”; Schankerman and Pakes, “Value of Patent Rights“; and Schankerman “Patent Protection.”

Germany was split into 39 different states and each state had its own patent policy, if at all.[4] Also, the constitution of 1871 did not solve the fragmentation of patent protection in the former sovereign states immediately. A German patent authority was established under the patent act in May 1877. This act replaced the formerly existing, rather vague privileges and monopolies by a standardized Germany-wide patent protection system. Khan has highlighted that the German national patent law of 1877 was so sophisticated that it also had a strong influence on the patent policies of various countries, such as Argentina, Austria, Brazil, Denmark, Finland, Holland, Norway, Poland, Russia and Sweden.[5] Almost simultaneously, 14 countries[6] ratified the Paris Convention in 1883 in order to harmonize the protection of intellectual property. The German Empire did not join this convention at first, but became party to the Convention in 1903. This treaty was the first milestone towards the equal treatment of foreign and national intellectual property, as foreign patent applicants had hitherto been discriminated in many countries.[7]

2.2. How can we discriminate unimportant Patents? The concept of high-value Patents

According to German law, an annually rising fee had to be paid to the German patent authorities for each year of maintaining a patent. The fee was 50 Marks for the first year, and increased annually to up to 700 Marks for the fifteenth year, making the maximum total for 15 years 5,300 Marks. 5,300 Marks were 1,261 US $ in 1900 and correspond to 25,767 US $ in 2005 real terms, using the GDP deflator.[8] This allows us to identify the more profitable patents: while the fee was substantial enough to deter unimportant patents by amateurs, it was

[4] Nirk, *100 Jahre Patentschutz*, pp.345-402.
[5] Khan, "Intellectual Property."
[6] Belgium, Brazil, Ecuador, El Salvador, France, Great Britain, Guatemala, Italy, the Netherlands, Portugal, Serbia, Spain, Switzerland, and Tunis.
[7] Patel, "Patent System;" Singer, *Patentsystem*, p. 14.
[8] Lerner, "Patent Protection" estimated that 15 years would cost $22,694 in 1998 Dollars. He found that Germany in 1900 had a higher patent fee than 60 countries in the entire time period of 1850-1999.

not excessively high compared with the expected profit from important individual patents. We define "important patents" as patents that were renewed for ten years, because they must have been profitable enough to rationalize the cost of renewal.

MacLeod et al. have stated that the above assumptions are only valid for inventors who can handle credit constraints.[9] High renewal fees might have prevented some patent holders (who lacked access to capital) from extending their theoretically valuable patent because they might have been unable to reach (or realize) a decision as to whether the expected future returns of their patent would exceed the discounted future costs including interest payments, were they obliged to borrow money to pay the fees. Risk aversion also played a large role here. Especially patentees from less developed countries might not have been able to renew valuable inventions because credit markets were less developed. In contrast, if credit markets were sufficiently developed, an innovator would simply borrow the money. Our historical data set does not allow us to control for capital constraints for those countries, but due to the large dimension of our data set, lacking access to capital should not affect our study much over this time period, although it might have played a role for some individual inventors.

To which degree do important (10-year-prolonged) patents and all patents differ? To shed light on this question, we look at both important and all patents by industry.[10] We observe that more influential and more dynamic industries such as the chemical and electrotechnical industries had a higher share of ten-year-prolonged patents (Table 2). Chemicals even had a share of 27%. In contrast, only 6-7% of transport equipment and industrial machinery patents were extended for 10 years (this includes, for example, the producers of parts of steam engines etc., who were less innovative in this period). Hence, the

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[9] McLeod et al., “Inventive Activity.”
[10] We consider industries that obtained more than 250 German patents in 1905.

differences within our new, importance-based patenting source are substantial: chemical patents were renewed for ten years about four times as often.

[Insert Table 2]

We have to admit that some institutional changes of the rules might explain a part of the rise in patents from 1900-04 and the following two five-year periods, as the German government exempted patentees from paying renewal fees during WWI.[11] As a result, some patentees that would otherwise have decided not to prolong a marginally important patent took the chance of prolonging it for free. Hence, we have to design the regressions below in a cross-sectional way.

In sum, the decision to prolong for ten years allows us to distinguish important from unimportant patents, as patent holders in Germany had to pay a high fee to keep their patent in force, although McLeod et al.'s argument might apply that capital constraints could lead to a slight underestimation of innovativeness in poor countries with underdeveloped credit markets.[12]

2.3. MEASUREMENT STRATEGIES: GERMAN PATENTS PER CAPITA BY COUNTRY OF ORIGIN

Our prime source is the patent directory "Verzeichnis der im Vorjahre erteilten Patente" which was published each year by the German patent office. It lists all patents granted in the preceding year including the name of the patentee (person or firm), the location of the patent holder (town and country), the patent class code and patent number, and a short description of the invention patented. Our rich database consists of 33,953 high value patents that were granted to residents or foreigners in Germany between 1880 and 1913. For the purpose of this

[11] The sharp decrease of the patent cohorts' mortality rates during war times is reported in Table 3 in Streb, Baten, and Yin, "Knowledge Spillover."
[12] McLeod et al., "Inventive Activity."

paper, we filter out those 9,165 patents that were held by patentees from 36 countries. The original data – not divided by population – are reported in Table 1, and some summary statistics are shown in Table 3.

[Insert Table 1 and 3]

Who were the patent holders that lived in non-European countries? Were they perhaps mostly German migrants? We do not know much about investors from countries with smaller numbers of inventions. Emilio Magoldi had two inventions in the field "machine parts" in Buenos Aires, and his Italian-sounding name is quite typical for Argentina. Similarly, all patents from Uruguay went to T.L. Carbone from Montevideo, clearly also not a German migrant. The only patent from Vietnam was given to Adolphe Doutre from Saigon, probably a member of the French colonial upper class of what was Cochin China at the time. The Guatemalan patents were granted to people with Spanish and Italian-sounding names like Roberto Okrassa or Grote & Pinetta, but "Grote" could also have been a German. In the case of Brazil, matters are less clear: Brazilian patent holders had names like Mello, Benedetti, or Bandeira. All three Chinese patent holders, in contrast, were clearly of German origin, two of them living in the German colony of Tsingtao: Joseph Brilmayer, Leopold Schmidt-Harms, and Dipl.-Ing Konrad Baetz. But most patent-holders even of the smaller and poorer nations were probably not German migrants.

This paper aims at constructing data using two strategies established by Maddison, who created the most renowned worldwide compilations of GDP estimates.[13] Clearly, his worldwide studies also stimulated a lot of criticism, but even taken with a grain of salt, his strategies meant substantial progress. Like Maddison, we focus on today's borders for the

[13] Maddison, *Monitoring*; Maddison, *World Economy.*

aggregation of patents per capita. This is an advantage because long-run studies can later build on this paper.[14] We could divide the number of patents according to modern borders, as we know the city of residence for each patent-holder.

2.4 Comparison with Moser's sample[15]

A comparison of our indicator "important foreign patents" with similar measures compiled by others indicates that our sample is broadly comparable. Moser, for example, analyses data from two exhibitions (exhibitions at the Crystal Palace in London in 1851 and the Centennial Exhibition in Philadelphia in 1876) for 22 Northern European countries that exhibited in seven industrial categories (making the total number of observations 154).[16] Moser argues that her primary source is superior to traditional patent counts because different countries had different patent systems, whereas inventions displayed at exhibitions were more homogenously selected, and awards were a measure of the relative importance of the inventions.[17] Of course, exhibitions were not only events that distributed information about new technologies. They were also entertainment shows seeking to attract people and educate them. Therefore, a certain bias towards spectacular and enjoyable exhibits for the masses seems likely. Some economically important innovations might have remained at home, whereas scientific instruments that were suitable for entertaining demonstrations might have been presented even though they had not much economic impact.

Despite the differences between the sources and our method of distinguishing important from unimportant patents, we can compare our sample with Moser's. After adjusting for distance, we find a high correlation between the number of exhibits and per

[14] This data set will be freely available on the internet page of the new human capital data hub, which will be created by the ESF GlobalEuroNet Initiative.
[15] Moser, "Patent Laws 2003."
[16] See also the shorter version: Moser, "Patent Laws 2005."
[17] Compared with our approach, she does not control for distance, which is justified because of the similar geographical proximity of all her countries to their respective host countries.

capita patent numbers in Germany. Figure 1 shows a comparison of our per capita patent numbers in Germany in 1885 with Moser’s sample from exhibitions, i.e. the number of exhibits at the 1851 Crystal Palace exhibition in London. Moser found that Belgium and Switzerland had the highest numbers of exhibits, followed closely by Saxony. Württemberg, Prussia, France, Austria, the Netherlands, and the Scandinavian countries occupied the middle and lower middle position, while Russia ranked lowest among these "Northern European” countries. Given that we have no data on the four German states, we show the remaining eight countries (with some measurement error) in Figure 1. When plotting Moser’s values against our values for 1885 in a scattergram (we assign the same exhibition value to Norway and Sweden because Moser gives only one value for both), we find a general correspondence between the two studies in the pattern of patenting rates across countries. Both Switzerland and Belgium had very high German patenting rates in 1885 and most exhibits in 1851, whereas Russia is the laggard in both cases. As Figure 1 shows, Austria had the second-highest German patenting rate of these eight countries, but only the fourth-highest number of exhibitions. Austria’s higher ranking and Belgium’s slightly worse ranking also reflect the relative human capital growth rates of the two countries between 1851 and 1885. Austria grew from a relatively poor country to one of the rich economies of Europe, whereas Belgium was already an industrialized country and experienced more modest development in the late 19^{th} century. We conclude that our ranking of the aforementioned countries is similar to Moser’s. Our importance-weighted patent statistics and her exhibits measure similar degrees of innovativeness, despite the different institutional circumstances. This makes us believe that the measurement is quite robust (but our data set includes many more countries, of course).

[Insert Figure 1]

3. IMPACT ON LONG-RUN GROWTH: PATH DEPENDENCY OF HUMAN CAPITAL?

In this section, we will assess the impact of our new human capital measure on long-run economic growth. We want to explain the income level per capita in 1960. Modern growth theory considers human capital as one of the decisive determinants of economic growth (Barro 1999, 2003; Griliches 1997), but there are also critical voices about the impact of schooling (Pritchett 2001). However, none of theses studies has so far assessed the long run impact of both human capital and important patents. In the previous literature, only short-run effects of human capital have been studied, whereas we will check for the first time the long-run impact of this variable.

Figure 2 compares the income level with important patents adjusted for distance to Germany. Low numbers of patents are given in China, Indonesia, Romania, Turkey, and Poland, which also corresponds with their low national income in 1960. High values of both variables are reported for the U.S., Switzerland, Sweden, and, interestingly, an agricultural economy such as New Zealand. New Zealand had only 2 patents, but this is not less than other countries relatively far away from Germany. However, this observations makes clear that we should not exclusively rely on adjusted patent figures, but also test unadjusted figures below. Some countries feature not too bad in terms of patents, but have transformed this only in a modest income in 1960, among them Guatemala, Vietnam, and Brazil. On the other hand, some countries grew more than we would have expected based on the patent counts, for example the Netherlands. The Netherlands in contrast had a strongly schooling-led growth, as we can see in Figure 3 that shows the same for schooling levels in a variety of countries. Again, there is clearly a relationship in that countries with high schooling levels in 1910 also achieved high income levels in 1960. Romania, Spain, Hungary, and the Czech lands did not grow as rich as we would have expected based in the schooling level alone, whereas Finland

and Guatemala grew richer than expected. Obviously, the overall relationship is positive, but the question is, whether those results hold when initial GDP is controlled for?

[Insert Figure 2 and 3, Table 4 and 5]

Regression results for a potential impact of schooling and patents, controlling for real per capita GDP 1910, are reported in Table 5. We obtain statistically significant coefficients for important patents in all regressions. The coefficients of schooling are also significant in the first two regression, but they are insignificant in model (4) and (5). This might be jointly by the multicollinearity of schooling and patents (Table 4) and the small number of observations in this regression. If we consider only the regressions with sufficient numbers of cases, a 10% increase of human capital formation in 1910 causes a 32 to 37% higher level of per capita GDP in 1960, whereas for patents the values vary between 8 and 11 percent, depending in the decade and whether we consider adjusted (by distance) or unadjusted patents.

Of course, this is a reduced model of human capital path dependency that we estimated here. There were a lot of other developments during this period that would suggest a much weaker relationship between patents and human capital 1910, 1950 and 1980. For example, large migrations took place during and between the war periods (although immigration target societies tended to transfer some of their education to immigrants). Political events interfered, such as the Marshall Plan or the Korean War. It is quite astonishing, that we still find a significant influence in spite of those distorting developments and events.

4. Conclusion

In this study, we estimated new figures for important patents in 1900 and 1910 based on data of the German patent office. These, for example, differed negatively from schooling values for the Balkans and the Mediterranean regions, and more favorable for Scandinavia, especially Finland compared with earlier schooling-based estimates. We found that our patent and enrolment-based variables could explain a substantial share of economic growth even half a century later. There is a strong positive effect of the human capital in 1910 on the level of GDP per capita 1960.

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Tables and Figures

TABLE 1: IMPORTANT (10-YEAR) PATENTS BY PATENTEES FROM FOREIGN COUNTRIES (TODAY'S BOUNDARIES) IN THE GERMAN EMPIRE

Country	1880-84	1885-89	1890-94	1895-99	1900-04	1905-09	1910-14
USA	78	109	162	252	502	584	958
United Kingdom	109	122	183	203	248	313	444
France	88	81	95	133	193	276	486
Switzerland	26	32	46	46	114	196	422
Austria	38	37	63	65	116	181	261
Belgium	24	23	27	25	29	68	160
Sweden	11	10	21	17	34	66	154
Czech	11	15	22	22	19	38	66
Italy	3	2	10	13	29	53	62
Denmark	4	5	9	11	29	31	71
Russia	5	5	4	10	17	33	46
The Netherlands	3	7	3	15	12	23	43
Hungary	4	3	3	3	12	21	57
Norway	0	1	5	6	4	17	30
Poland	3	2	8	3	5	3	5
Ireland	2	0	7	1	7	3	8
Canada	0	1	2	1	6	3	13
Spain	1	1	2	4	0	3	10
Luxemburg	4	1	2	1	0	3	7
Australia	0	2	1	2	0	2	3
Brazil	0	0	0	1	0	0	7
Croatia	0	0	0	0	0	4	4
Finland	0	0	0	0	2	1	4
Romania	0	0	0	1	1	1	2
Japan	0	0	0	0	0	0	4
China	0	0	0	0	0	0	3
Guatemala	0	1	0	0	0	0	2
Uruguay	0	0	0	3	0	0	0
Argentina	0	0	0	0	2	0	0
Slovenia	0	0	0	0	0	1	1
New Zealand	0	0	0	0	0	0	2
Indonesia	0	0	0	0	0	0	1
Bosnia	0	0	0	0	0	0	1
Vietnam	0	0	0	0	0	0	1
Turkey	0	0	0	0	0	0	1
Peru	0	0	0	0	1	0	0
Total Foreign Patents	**416**	**460**	**675**	**838**	**1382**	**1930**	**3340**
Total German Patents	1134	1171	1995	1998	2550	4940	10197
Total Patents	1550	1631	2670	2836	3932	6870	13537

TABLE 2: SHARE OF 10-YEAR-PROLONGED PATENTS IN INDUSTRIES 1905 (WITH > 250 PATENTS)

Industry	Sic2 code	Share (in %)	10-year Patents	All Patents
Chemicals	28	26.86	152	566
Electronic	36	14.86	147	989
Primary Metal	33	14.09	81	575
Printing / Publishing	27	13.36	35	262
Food Products	20	11.50	33	287
Stone/Clay/Glass	32	10.80	35	324
Instruments	38	10.47	40	382
Fabricated Metal Products	34	10.01	90	899
Misc. Manufacturing	39	9.85	65	660
Agricultural Production	10	8.61	23	267
Textiles	22	7.53	21	279
Transport Equipment	37	7.20	58	805
Industrial Machinery	35	5.98	86	1439

Data source: 10-year Patents: Kaiserliches Patentamt, *Verzeichnis*.
All Patents: Kaiserliches Statistisches Amt, *Statistisches Jahrbuch*.

TABLE 3: DESCRIPTIVE STATISTICS

Variable	Obs	Mean	Std. Dev.	Min	Max
Log GDP 1960	50	8.23	0.75	6.41	9.50
Log GDP 1910	51	7.53	0.63	6.49	8.59
Log schooling 1910	45	5.75	1.00	2.30	6.88
Log schooling 1900	35	5.97	0.71	3.85	6.84
Patents per capita 1900	21	7.48	1.61	4.58	10.42
Patents per capita 1910	33	7.36	2.34	1.94	11.61
Adj. patents 1910	33	0.00	1.82	-3.69	3.36
Adj. patents 1900	21	0.00	1.41	-2.72	2.37

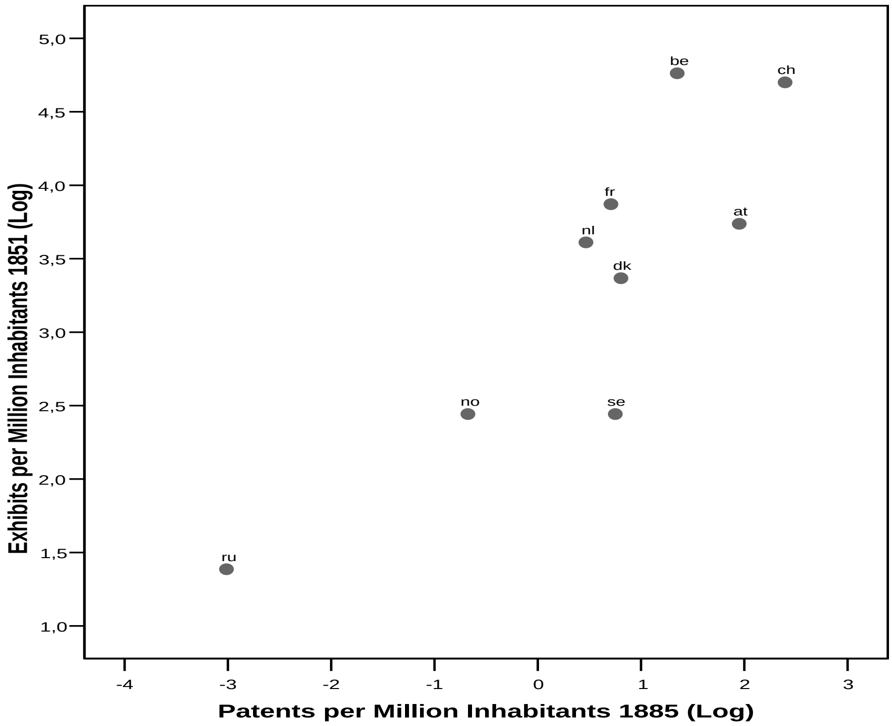
TABLE 4: BIVARIATE CORRELATIONS

	SCHL1900	SCHL1910	PAT1900	PAT1910	ADJP1900	ADJP1910	LGDP1910
SCHL1900							
SCHL1910	0.9766						
	0.0000						
PAT1900	0.6498	0.6166					
	0.0026	0.0038					
PAT1910	0.5712	0.6681	0.9646				
	0.0055	0.0001	0.0000				
ADJP1900	0.7118	0.6773	0.8754	0.8384			
	0.0006	0.0010	0.0000	0.0000			
ADJP1910	0.6108	0.5060	0.7434	0.7758	0.9347		
	0.0025	0.0071	0.0002	0.0000	0.0000		
LGDP1910	0.6775	0.6881	0.5614	0.7662	0.7178	0.7281	
	0.0000	0.0000	0.0081	0.0000	0.0002	0.0000	

TABLE 5: ESTIMATION RESULTS: DETERMINANTS OF PER CAPITA GDP IN 1960

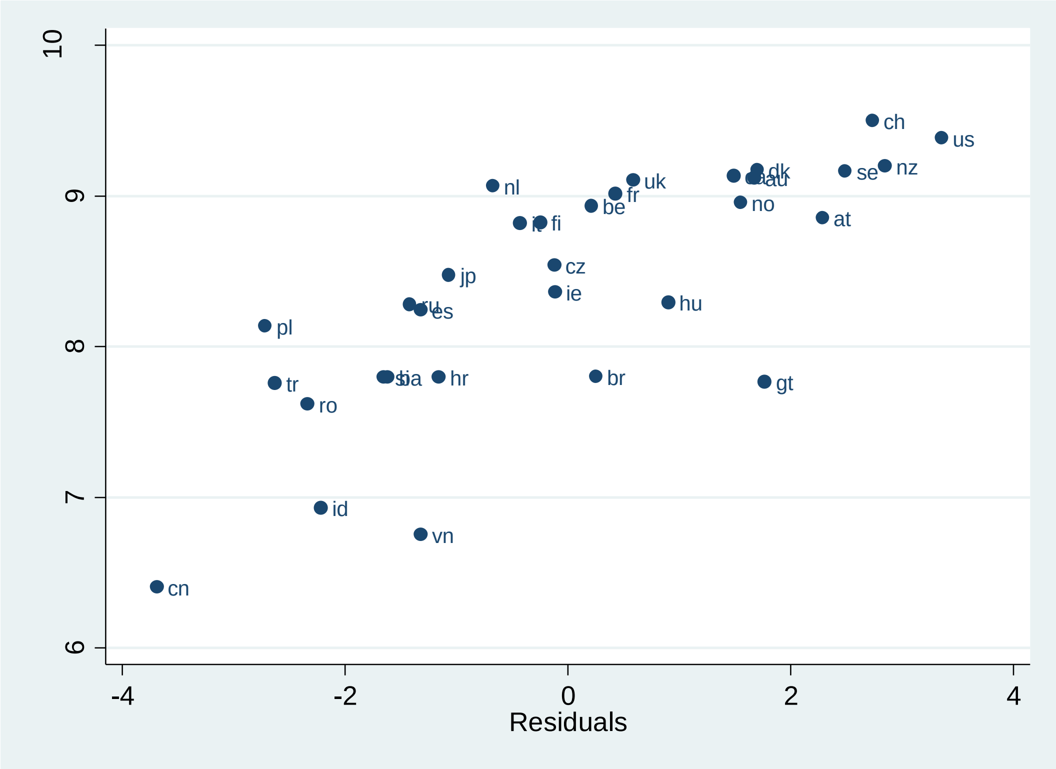
	(1)	(2)	(4)	(5)	(6)
Log schooling 1910	0.37***	0.32***		-0.05	-0.10
	(0.00)	(0.00)		(0.82)	(0.69)
Adj. patents 1910	0.11***				
	(0.01)				
Patents per capita 1910		0.08**			
		(0.02)			
Adj. patents 1900				0.16**	
				(0.03)	
Patents per capita 1900					0.12**
					(0.03)
Log GDP 1910	0.25**	0.31**	0.89***	0.56*	0.74**
	(0.02)	(0.01)	(0.00)	(0.06)	(0.02)
Constant	4.37***	3.60***	1.52	4.67***	2.62*
	(0.00)	(0.00)	(0.11)	(0.01)	(0.09)
Observations	27	27	50	20	20
R-squared	0.89	0.88	0.55	0.70	0.69

FIGURE 1: EXHIBITS IN 1851 AND PATENTS PER CAPITA 1885.



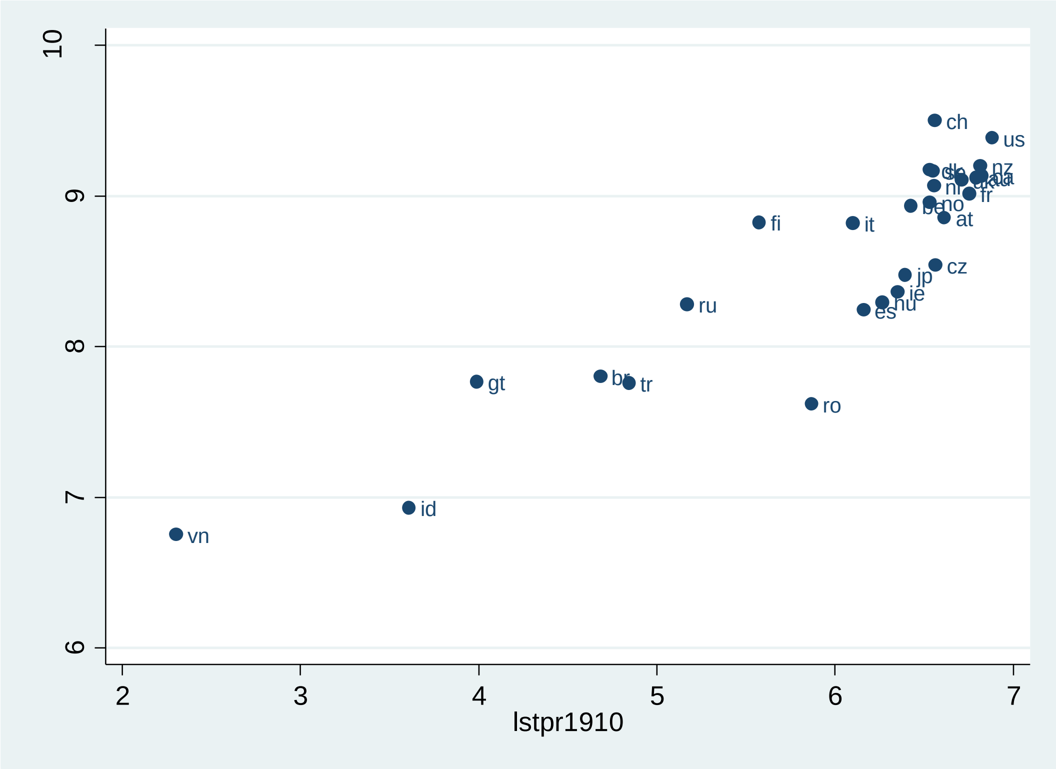
Data Sources: Exhibits per Million Inhabitants: Moser, Patent Laws 2003; Patents per Million Inhabitants: see Table 1. Note: For country abbreviations, see appendix B.

FIGURE 2: ADJUSTED PATENTS IN 1910 AND LOG GDP PER CAPITA 1960



Horizontal axis: Important patents 1910 adjusted for distance

FIGURE 3: SCHOOLING IN 1910 AND LOG GDP PER CAPITA 1960



APPENDIX

A. INTERNET ABBREVIATIONS FOR COUNTRIES.

ar - Argentina

at - Austria

au - Australia

ba - Bosnia

be - Belgium

bg - Bulgaria

bo - Bolivia

br - Brazil

ca - Canada

ch - Switzerland

cl - Chile

cn - China

co - Columbia

cr - Costa Rica

cu - Cuba

cz - Czech

dk - Denmark

es - Spain

fi - Finland

fr - France

gr - Greece

gt - Guatemala

hk - Hong Kong

hr - Croatia

hu - Hungary

id - Indonesia

ie - Ireland

in - India

it - Italy

jm - Jamaica

jp - Japan

lk - Sri Lanka

lu - Luxemburg

mx - Mexico

ni – Nicaragua

nl - Holland

no - Norway

nz - New Zealand

pe - Peru

pl - Poland

pt - Portugal

ro - Romania

ru – Russia

se - Sweden

si - Slovenia

th - Thailand

tr - Turkey

tt - Trinidad and Tobago

uk - United Kingdom

us - USA

uy - Uruguay

vn - Vietnam