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Abstract

The reasons why inventions that shaped industrial revolutions, occurred in the UK and in the USA, have been suggested by economic historians. For the first time, we access the determinants of more than a hundred inventions around the world, explaining why they occurred in a given country and why some occurred earlier than others. We confirm the importance of scale effects and dismiss the importance of education as triggers of inventions. Geographic and genetic distance from the UK and the USA have proven to be significant in explaining inventions. Both distance from the UK and proximity to the USA seem to have significant effect on the rise of the probability to invent and on the probability to invent earlier.
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JEL Codes: I25, N10, N30, O10, O50, Z10

1 Introduction

There is a proficuous literature on the drivers of industrial revolutions which could be translated into the drivers of earlier inventions. There are essentially three different views about the triggers of the first inventions in Britain, which shaped the beginning of the industrial revolution. First, a view that inventions occurred in Britain because it paid to invent them there. This is the view of Allen (2009a, 2009b) who bases the

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argument on the relative factor prices in Britain in the middle of the Eighteen century. In fact, Britain experienced at that time relatively high wages but relatively cheap capital and energy, which was an incentive to come up with inventions which would allow for the substitution of labor by capital. According to this view, this is the reason why the industrial revolution began in Britain and not, e.g., in France, where labor was much cheaper. Allen also recognizes that the supply of inventors is important and he points out that in the years prior to 1800, a cultural revolution had happened in Britain and that the stock of human capital at that time was much bigger than one or two centuries before. This difference in the relative supply of production factors has been used in models of endogenous growth to explain different patterns of industrial revolutions (see e.g. Iacopetta, 2010 and Gómez and Sequeira, 2012).

Second, a view that justifies the British Industrial Revolution due to the quality of institutions in Britain relative to other countries, since Britain had been committed on constructing solid and trustable institutions for a while. This is a view argued by Mokyr (2009). According to Mokyr's view ""Britain became the leader of the Industrial Revolution because, more than any other European economy, it was able to take advantage of its endowment of human and physical resources thanks to the great synergy of the Enlightenment: the combination of the Baconian program in useful knowledge and the recognition that better institutions created better incentives" (p.122). Mokyr believes that the combination of skilled scientists, engineers, entrepreneurs, and craftsman allowed for the invention and adoption of technologies by firms. Thus, the Enlightenment period in Britain has caused two main effects: it improved technological capabilities and institutional quality. The Baconian program comprised research based on experimentation and scientific method, directing the research to solve practical problems, and making results accessible (p.40). Mokyr acknowledges that the impact of the Enlightenment on institutions is hard to quantify but argues that the success of its ideology reduced rent-seeking and promoted competitive markets (p.63). It was manifested in terms of legislation, such as the abolition of the Corn Laws, but also strengthened informal institutions, in the form of social norms that favored gentlemanly capitalism rather than opportunistic behavior (ch.16). Clark (1996) also focused on the important political and institutional evolutions that preceded and influenced the Industrial Revolution. As the author writes: "The years between the Glorious Revolution and the Industrial Revolution saw widespread change in the British economy: the transport system was radically improved; a large scale conversion to purely private agriculture was accelerated; new institutions of finance and commerce were put in place; and the government debt was regarded as the safest asset in the economy" (p. 564).

Third, a view based on the unified growth theory (due to Galor, 2005) which argues that the transition to a post-Malthusian epoch (i.e., an Industrial Revolution) was due to scale effects provided by an increased or larger population. The transition to sustainable growth is supported by an increasing demand for human capital, provided by families, that increasingly bet on the quality of the offspring in opposition to the quantity.

Some empirical work has been published on the growth rates and factors in the Industrial Revolution. Stockey (2001) shows the rise of the industry sector in the composition of British GDP between 1760 and 1850. Greasley and Oxley (2007) show that patenting rose sharply during the Industrial Revolution, although they also show that this process did not cause (but is caused by) the industrialization. However, the important role that technologies and industry played in the Industrial Revolution growth period, is almost consensual in the literature. Although Britain had presented only a modest average growth rate, Broadberry *et al.* (2011) clearly show that the industrial sector was the one that presented the fastest growth (when compared with services and agriculture) between 1760 and 1860, and with accelerating growth during the period. The importance of technology has been emphasized (e.g. Crafts and Harley, 1992, Crafts, 2004), where estimates of TFP growth has been presented and compared with those from other references.

Our work is an empirical attempt to answer the question "why technologies appeared where they appeared?". This may be interpreted as a re-statement of the question "why in Britain?" that many authors addressed before. However, we depart from the existing literature in two important ways. First, we study a number of documented technologies that were invented throughout the centuries (e.g. tractor, cellphone, or spindle mule), and second, we assign those inventions to the countries in which they were invented. Hence, we are not only studying England only, like most of the previous literature did. We want to contribute to answer the question "why in Britain?" but also "why not in Britain?"

The paper is organized as follows. Section 2 presents the data and respective sources. Section 3 presents the main results and Section 4 concludes.

2 Data and Sources

We began collecting data on all the 104 technologies that were mentioned in the CHAT dataset of Comin and Hobijn (2009). However, we do not use data from the CHAT dataset, we only collected the designation of technologies. Then, we searched, in different bibliographic references, for the invention year of all technologies invented after 1600 (see Table Appendix A) and collected them. There were 14 technologies invented before 1600 and 6 other for which it was not possible to identify the invention year. So, we remain with 84 technologies to be studied. This allowed us to build two different and alternative dependent variables: a dummy variable which takes the value 1 for the country which invented the given technology and 0 for all the other countries, and then a variable which measures how many years ago the technology was invented (this was made by subtracting the year of invention from the year 2000). For the first variable, we have 84 technologies per country (which can be the inventor or not) and 10 countries which have invented at least one technology after 1600. While the first variable allows us to identify the reasons why a given technology was invented in a given country and not on some other country, the second allows us to explain the reasons why some inventions are discovered first than others. The countries presented in the database were the USA, with 40 technologies invented, followed by the UK, with 17, Germany with 15, France (4), Japan (3), and Switzerland, Netherlands, Austria, Australia, and Russia with one (1) each.

In what concerns explanatory variables, we tried to combine the alternative explanations that previous literature have identified as drivers of the Industrial Revolution. The shortage of human capital can be the source of higher wages in Britain in the mid-eighteenth century and its abundance may be the source of later inventions (e.g. in USA). Hence, several human capital proxies were used. We have tested the enrollment ratios in primary, secondary, and tertiary schools (as a percentage of the total population) 5 years before the date of each invention in each country. These data were collected from Mitchell (1998). The returns of the invention may also be determined by the access to a larger market. Population, Degree of Openness, and GDP *per capita* were the used proxies for the scale effect. While data for the population and for the degree of openness, which was our own calculation, were collected from Mitchell (1998), data for GDP *per capita* are from the Maddison Project (Bolt and van Zanden, 2013). To account for the idea that institutional changes may have occurred earlier to allow for an increase in the invention activity we use the overall knowledge presented in the country in 1500, a variable developed by Comin *et al.* (2010). This variable is fixed on different pairs of technology-year of invention, so it can be also regarded as a country fixed effect which allows to account for other institutional country-specific changes. Distance (or proximity) has been argued to be a determinant of the diffusion of technologies (e.g. Comin *et al.*, 2010; Spolaore and Wacziarg, 2011), since the diffusion of ideas can be spread through the countries' borders, which could happen even in earlier times. For instance, Mokyr (2005) studied the flow of scientists between European countries, as a contribution to understand the Industrial Revolution. Communication between different scientists is eased by geographic and cultural proximity. Cultural proximity can also be a determinant of similar values, norms, and preferences, which shape the demand for a given good and also make more profitable the use of a certain technology. We also include geographic distance (from Mayer and Zignago, 2011) and genetic distance, as a measure of cultural and communication affinity, (from Spolaore and Wacziarg, 2011) from the UK and the USA, as explanatory variables. Table 1 summarizes variables and sources.

Table 2 presents descriptive statistics for the main variables.

3 Results

We begin by considering a probit regression for the dummy of the inventor with the proxies we selected for human capital (primary education enrollment five years before the year of invention), for the scale effect (total population measured five years before the year of invention), for the diffusion of ideas, international spillovers (openness ratio measured in the year of invention), and a proxy for previous accumulated knowledge - the average of the technological adoption index in 1500 - which can also account for previous political and institutional reforms. For the human capital proxies, we have also tested school enrollments in secondary schools (E2 in Table 1) and enrollment ratio in colleges and universities (E3 in Table 1). However, these two variables proved to be always statistically insignificant in regressions, so we have dismissed them. For the scale effect we also tested GDP *per capita* and some results are presented below with this variable as a regressor.

Table 3 present this benchmark regression and also the marginal effects of each variable in determining if a country was an inventor or not. Column (1) shows a strong and positive scale effect related to the population size, meaning that a 2.7 increase in the number of persons will increase the probability to invent in 4.1%. However, the effect of education is small and negative. An increase in 1% in the enrollment ratio implies a decrease in the probability to invent in 0.113%. This result is consistent to the ones that argue that the first escape from the Malthusian trap was due to the scale effect and not to human capital. Easterlin's (1981) data show that a noticeable increase in British primary education occurred only in the second half of the 19th century, almost a century after the onset of the Industrial Revolution. The technological knowledge existing in the country in 1500 shows a puzzling negative effect, with a marginal effect of less 1.53% probability to invent for each increase of 0.1 in technology (the variable oscillates between 0 and 1).

Table 1: Variables

Dependent Variables	**Name**	**Measure (source)**	
Dummy for Inventor	DI	0 or 1. Various Sources (see Appendix A).	
Age of Invention	AI	2000-Year of Invention. Various Sources (see Appendix A).	
Explanatory Variables	**Name**	**Measure (years and source)**	
Education (Primary)	E1	Enrollment in Primary Schools/Population five years before the year of invention. Mitchell (1998).	
Education (Secondary)	E2	Enrollment in Secondary Schools/Population five years before the year of invention. Mitchell (1998).	
Education (Tertiary)	E3	Enrollment in Colleges and Universities/Population five years before the year of invention. Mitchell (1998).	
Openness	open	(Exports+Imports)/GDP in the year of invention. Mitchell (1998).	
Population	Pop	Logarithm of the total population five years before the year of invention. Mitchell (1998).	
GDP per capita	GDPpc	Logarithm of the GDP per capita in the year of invention. Maddison Project (Bolt and van Zanden, 2013).	
Technology in 1500	tr3	Average of the sectoral technology adoption indexes in 1500 AD. Comin *et. al.* (2010).	
Geographic distance from the UK	Dist UK	Geographic distance from the United Kingdom (distance between capitals) in kilometers. Mayer and Zignago (2011)	
Geographic distance from the USA	Dist USA	Geographic distance from the United States of America (distance between capitals) in kilometers. Mayer and Zignago (2011)	
Genetic Distance from the UK	GenD UK	Weighted FST genetic distance between United Kingdom and another country. Spolaore and Wacziarg (2011)	
Genetic Distance from the USA	GenD USA	Weighted FST genetic distance between United States of America and another country. Spolaore and Wacziarg (2011)	

Table 2: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
(a) Dummy for Inventor	0.7692	0.26659	0	1
(b) Year of Invention	1894.714	77.01409	1605	1994
(1) Primary Education	0.37377	0.33662	0.11115	0.99835
(2) Secondary Education	0.37223	0.22453	0.1112	0.99388
(3) Tertiary Education	0.39025	0.22593	0.1	0.99619
(4) Openness	24.12396	78.05917	0.15153	935.8247
(5) Population	64900000	108000000	438000	822000000
(6) GDP per capita	5309.041	4707.123	474.9642	24312.79
(7) Technology in 1500	0.74557	0.29821	0	1
(8) Geographic distance from the UK	3941.77	4695.531	0	17001.95
(9) Geographic distance from the USA	7931.33	3614.078	0	15961.95
(10) Genetic Distance from the UK	235.9719	324.759	0	1239.689
(11) Genetic Distance from the USA	441.9588	292.2913	0	1299.367

Column (2) repeats the regression but substituting population for GDP *per capita*. In this case, the only important change is that GDP *per capita* becomes statistically non-significant and openness becomes statistically significant with a negative sign and with a very small marginal effect, meaning that openness to trade has a small negative effect on inventions and that population is in fact the best proxy for the scale effect. We also consider subsets of the complete sample in regressions that we present in columns (3), (4), and (5). In particular, due to their leadership role in the first and the second industrial revolutions, respectively, we exclude the UK and USA from the sample, and analyze if results are maintained or not. All the regressions confirm the high importance of the scale effect due to population, a small negative effect of education, and a negligible effect of openness. The negative and significant effect of technology in 1500 is reverted to a significantly positive effect when the USA is dropped from the sample. This is explained because the USA is the only great inventor in the post-industrial revolution, that did not have a significant endowment of knowledge in 1500. Thus, when the USA is dropped from the sample, a strong positive effect of technology in 1500 appears, meaning that more 0.1 points in the technological index would increase in nearly 3% the probability to invent. On the contrary, the presence of the UK increases the importance of technology in 1500 as a explanatory variable for technologies after the sixteenth century. Thus the exclusion of both countries results on a non-significant result.

As a second step, we have included variables linked with the notion of distance (geographic and genetic) in the explanation of inventions (see Table 4). The analysis of these extended regressions allows the following conclusions. First, the introduction of variables for the distances to the UK and the USA decrease the statistical significance of education and openness and slightly decreases the quantitative significance of the scale effect. Now, on column 2, 2.7 more persons in the country increase the probability to invent in only 1.8% (compared with nearly 4.1% obtained earlier). GDP *per capita* continues to be non-significantly related to inventions, as before. The main change however is the statistical significance of technological knowledge in 1500. This variable is now positively and significantly related to invention and exhibits a huge quantitative effect. In fact, a change of 0.1 in technological knowledge in 1500 would imply a 3.8% to 6.2% increase in the probability of inventing. This result supports the argument according to which countries invented in the last centuries because they have previously built knowledge and institutions that allowed inventions to be paid for. The introduction of distances to the UK and to the USA present also interesting results. Paradoxically, distance to the UK and proximity to the USA enhances the capacity to invent, ceteris paribus the effects of other regressors. In fact, more 100 km distance to the UK imply 0.2%-0.3% more probability of inventing. On the contrary, more 100 km distance to the USA decreases the probability of invention between 0.4% and 0.5%. The genetic distance between populations of the inventing countries and the UK and the USA seem to have even bigger effects. More 100 points in genetic distance to the UK (roughly 1/3 of the genetic distance between the USA and the UK) implies more 7%-9% more probability of inventing.

One may wonder if these results are due to the presence of observations from the UK and the USA in the sample. So we run the same regressions first eliminating the USA, then eliminating UK, and finally eliminating both. When we eliminate the USA from the sample, geographic distances to the USA and the UK remain highly significant and the positive and significant signs of population and technology in 1500 are maintained (although, only marginally for technological knowledge in 1500). Moreover, the statistical significance of genetic distance disappears. When we eliminate the UK from the sample, geographic distance to the UK increases the probability to invent and geographic distance to USA decreases the probability to invent, a result that is almost replicated when genetic distance is considered. Population and technological knowledge in 1500 remain with a statistically significant (positive) effect (in the case of population it is only marginally significant in regressions that consider genetic distance). When we eliminate both the UK and the USA, geographic distance to the UK and proximity to the USA increase the probability to invent of other countries, recovering the initial effects described in Table 4. On the contrary, genetic distance turns out to be non-significant.

Overall, when the effect of distances (both geographic and genetic) to the invention leaders (the UK and the USA) is taken into account, positive significant effects of scale (population) and previous accumulated knowledge are evident on the probability to invent. Significant positive effects of distance to the UK and proximity to the USA have also been uncovered. However, when we remove these two countries from the sample, only the geographic distance (and not the genetic one) seems to influence the probability to invent.

3.1 Determinants of Earlier Inventions

In this section we present results for OLS regressions with a dependent variable that intends to measure how early an invention occurs. With this, our aim is to test the determinants of some inventions being invented earlier than others. The dependent variable is the difference between the year 2000 and the year of the invention. We run regressions using the same explanatory variables of the previous section. However, due to the lack of degrees of freedom, we successively eliminated variables that proved to be non-significant.

Table 5 shows the selected regressions. Column (1) confirms a small negative effect

Table 3: Benchmark Probit Regressions

	(1)	(2)	(3)	(4)	(5)
	Scale Effect: Population	Scale Effect: GDP p.c.	without UK	without USA	without UK and USA
Prim. Education	-0.852**	-0.624*	-1.974**	-0.678*	-1.425
	(0.403)	(0.322)	(0.929)	(0.388)	(0.927)
	[-0.113**]	[-0.084**]	[-0.134***]	[-0.029]	[-0.026]
Openness	-0.001	-0.019**	-0.001	-0.003	-0.0014*
	(0.001)	(0.009)	(0.001)	(0.006)	(0.0008)
	[-0.000]	[-0.002**]	[-0.000]	[-0.000]	[0.001]
Population	0.309***	–	0.500***	0.441***	0.646***
	(0.070)		(0.114)	(0.089)	(0.159)
	[0.041***]		[0.034***]	[0.019***]	[0.012*]
GDP p.c.	–	0.114	–	–	–
		(0.106)			
		[0.015]			
Technology (1500)	-1.152***	-1.356***	-1.333***	6.922***	6.232
	(0.288)	(0.301)	(0.324)	(1.857)	(3.932)
	[-0.153***]	[-0.182***]	[-0.091*]	[0.299***]	[0.115]
Pseudo R^2	0.220	0.225	0.354	0.133	0.1753
Pseudo Log-Likelihood	-103.5	-123.07	-72.79	-58.50	-35.99
Number Obs.	385	432	339	340	294

Note: Level of significance: *** for p-value<0.01; **for p-value<0.05;* for p-value<0.1. Values between parentheses are standard errors. Values in squared brackets are the marginal effects. All Models include a constant.

Table 4: Extended Probit Regressions

	(1)	(2)	(3)	(4)
Primary Education	-0.491	-0.392	-0.483	-0.274
	(0.373)	(0.377)	(0.345)	(0.377)
	[-0.032]	[-0.019]	[-0.043]	[-0.020]
Openness	-0.004	-0.006	-0.0117	-0.013
	(0.006)	(0.006)	(0.008)	(0.009)
	[-0.0003]	[-0.0003]	[-0.001*]	[-0.001]
Population	0.336**	0.372***	–	–
	(0.164)	(0.124)		
	[0.022]	[0.018***]		
GDP per capita	–	–	0.005	-0.083
			(0.145)	(0.141)
			[0.00046]	[-0.0062]
Technology in 1500	5.953**	11.708***	4.725**	8.309***
	(2.641)	(1.604)	(1.983)	(1.766)
	[0.382***]	[0.563***]	[0.424***]	[0.620***]
Geographic distance from the UK	0.0004**	–	0.0003***	–
	(0.0002)		(0.0001)	
	[.00002***]		[.00003***]	
Geographic distance from the USA	-0.0006***	–	-0.0006***	–
	(0.0002)		(0.0002)	
	[-.00004***]		[-.00005***]	
Genetic Distance from the UK	–	0.0152***	–	0.0120***
		(0.002)		(0.002)
		[0.0007***]		[0.0009***]
Genetic Distance from the USA	–	-0.0178***	–	-0.014***
		(0.002)		(0.003)
		[-0.001***]		[-0.001***]
Pseudo R^2	0.336	0.346	0.332	0.358
Pseudo Log-Likelihood	-88.08	-79.11	-106.06	-93.1
Number Obs.	385	356	432	401

Note: Level of significance: *** for p-value<0.01; **for p-value<0.05;* for p-value<0.1. Values between parentheses are standard errors. Values in squared brackets are the marginal effects.

of primary education to invent earlier (other levels of education were tested, but as before, they proved to be always non-significant), a non-significant effect of openness and a puzzling negative effect of technological knowledge in 1500. There is also a negative scale effect. This must be because when early inventions appeared, population levels were smaller than when latter inventions appeared, a natural effect due to the fact that population was growing in the analyzed periods. When openness - with a non-significant effect - is dropped (column 2) education also becomes statistically non-significant and the other effects remain qualitatively similar to those in column (1). In columns (3) and (4) we dropped education and included geographic and genetic distance, respectively. An increase in 2.7 in population would have deterred inventions by 47 to 51 years, a strong effect. However, the sign of the technological knowledge in 1500 effect is switched to a more intuitive effect. Now, more technology in 1500, say more 0.1, fostered inventions in 14 to 17 years. The introduction of distance has again interesting effects. In positive fact distance to the UK and proximity to the USA (both geographic and genetic) have a role in fostering inventions. While the quantitative effect of geographic distance is rather modest (a 100 km distance from the UK have fostered inventions in 1 year while 100 km closer to the USA fostered inventions in 1 year and 1/2), the quantitative effect of genetic distance is more important. In fact, 100 additional points in genetic distance from the UK would have deterred inventions for more 22 years, while 100 additional points in genetic proximity to the USA would have fostered invention in 25 years.

4 Conclusion

We collected the invention dates for more than 100 inventions, since the seventeenth century, around the world. With that we studied the determinants of the probability of inventions to occur in a given country, trying to contribute to the literature that explains the triggers of industrial revolutions.

We found evidence according to which the scale effect of the country, measured by its population, is an important determinant of the probability to invent. This strong effect means that nearly more 30 inhabitants in a country could increase the probability to invent from 12% to 41%. Our results show a small negative effect of education, reflecting the relatively lower importance of education as a source of inventions. This corroborates the opinion of some economic historians, which argue that the advent of formal education was posterior to the rise of inventions during the industrial revolution. Openness is rarely a significant determinant of inventions and when it appears to be significant has a negative sign. Inventions from 1600 onwards are also related to previous technological knowledge in the country. We found a negative effect if the USA is included in the sample and a positive effect otherwise. This reflects the fact that the United States developed a strong industrial revolution without any substantial technological development in 1500. A standard-deviation increase in technology in 1500 (near 0.3) would increase the probability to invent from 3% to 9%.

We also found evidence of the influence of geographic and genetic distance on the probability to invent. Generally and interestingly, distance to the UK and proximity to the USA increased the historical probability of invention for a given country. In particular, the statistical significance of geographic distance is robust to all specification changes we have performed. However, the quantitative effects are small. An increased distance of 100 km to the UK implies 0.2%-0.3% more probability to invent. On the

Table 5: OLS Regressions for Earlier Inventions

	(1)	(2)	(3)	(4)
Primary Education	-182.82**	-201.04	–	–
	(74.34)	(137.84)		
Openness	-0.624	–	–	–
	(0.797)			
Population	-73.896***	-59.475***	-47.948***	-51.406***
	(3.35)	(12.215)	(6.854)	(8.033)
Technology in 1500	-81.214***	-82.33***	168.833***	140.455***
	(22.023)	(16.632)	(48.075)	(27.482)
Geographic distance from the UK	–	–	0.0115***	–
			(0.004)	
Geographic distance from the USA	–	–	-0.0158***	–
			(0.003)	
Genetic Distance from the UK	–	–	–	0.2199***
				(0.035)
Genetic Distance from the USA	–	–	–	-0.2489***
				(0.039)
R^2	0.90	0.705	0.608	0.642
F-stat	157.24	10.68	29.07	15.18
Number Obs.	42	43	61	49

Note: Level of significance: *** for p-value<0.01; **for p-value<0.05;* for p-value<0.1. Values between parentheses are standard errors.

contrary, more 100 km distance to the USA decreases the probability to invent between 0.4% to 0.5%. More 100 in genetic distance to the UK (roughly 1/3 of the genetic distance between the USA and the UK) implies more 7%-9% more probability of inventing.

Finally, we have tested the influence of the same regressors on a variable that intends to measure how early inventions occurred. Now, a rise in population by 30 persons would have deterred inventions by 47 to 51 years. More technological knowledge in 1500, say more 0.1, foster inventions in 14 to 17 years. Distance to the UK and proximity to the USA (both geographic and genetic) did foster inventions. While the quantitative effect of geographic distance is rather modest (a 100 km distance from the UK foster inventions in 1 year while 100 km closer to the USA foster inventions in 1 year and 1/2), the quantitative effect of genetic distance is more important - 100 genetic distance from the UK would have deterred inventions for more 22 years, while 100 genetic proximity to the USA would have fostered invention in 25 years.

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A Invention Dates and Sources of Technologies

Techs	Description	Year	Inventor	Source
ag_harvester	self-propelled machines that reap and thresh in one operation	1912	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
ag_milkingmachine	installations consisting of several complete milking units	1878	USA	Burton, L. D. V. (2010).Agriscience: Fundamentals and applications. Clifton Park, NY: Delmar Cengage Learning.
ag_tractor	wheel and crawler tractors (excluding garden tractors)	1892	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
atm	electromechanical devices that permit authorized users, typically using machine-readable plastic cards, to withdraw cash from their accounts and/or access other services	1960	USA	Simjian, L. (1963). Patent N. 3079603. United States of America.
aviationpkm	Civil aviation passenger-KM traveled on scheduled services by companies registered in the country concerned. Not a measure of travel through a countrys airports	1903	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
aviationtkm	Civil aviation ton-KM of cargo carried on scheduled services by companies registered in the country concerned. Not a measure of travel through a countrys airports	1903	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
bed_acute	beds available for those seeking in-patient acute care, including diagnosis or treatment of an injury or illness and performance of surgery	1874	USA	National Association of Bedding Manufacturers, March 1964, Nation's Oldest Family-Held Bedding Firm: Adam Wuest, Inc.

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Techs	Description	Year	Inventor	Source
bed_hosp	beds, including inpatient beds available in public, private, general, and specialized hospitals and rehabilitation centers. In most cases beds for both acute and chronic care are included	1874	USA	National Association of Bedding Manufacturers, March 1964, Nation's Oldest Family-Held Bedding Firm: Adam Wuest, Inc.
bed_longterm	beds for people who need assistance on a continuing basis due to chronic impairments and a reduced degree of independence in activities of daily living (including those in both hospitals and nursing homes)	1874	USA	National Association of Bedding Manufacturers, March 1964, Nation's Oldest Family-Held Bedding Firm: Adam Wuest, Inc.
cabletv	Number of households that subscribe to a multi-channel television service delivered by a fixed line connection	1948	USA	Hitchner, J. R. (2010).Financial valuation: Applications and models. Hoboken, N.J: Wiley.
cellphone	Number of users of portable cell phones	1973	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
cheque	Number of payments by cheque (in millions)	1717	UK	Cheque & Credit Clearing Company. History of the Cheque: Cheque & Credit Clearing Company.[1]
computer	Number of self-contained computers designed for use by one person	1973	France	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
creditdebit	Payments by credit and debit cards (in millions)	1949	USA	Bulliet, R. W. (1998).The Columbia history of the 20th century. New York: Columbia University Press.
eft	Number of transactions using payment cards at points of service (retail locations)	1949	USA	Bulliet, R. W. (1998).The Columbia history of the 20th century. New York: Columbia University Press.
elecprod	Gross output of electric energy (inclusive of electricity consumed in power stations) in KwHr	1882	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
fert_total	Metric tons of fertilizer consumed. Aggregate of 25 individual types listed in source	1910	Germany	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
internetuser	access to the worldwide network	1983	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.

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[1] Accessed on 1st of November of 2013 from: http://www.chequeandcredit.co.uk/cheque_and_credit_clearing/history_of_the_cheque/from_handwritten_to_printed_cheques/

Table A.1 – continued from previous page

Techs	Description	Year	Inventor	Source
kidney_dialpat	patients receiving dialysis treatments, both at centers and at home	1945	Netherlands	Ronco, C., Bellomo, R., & Kellum, J. A. (2009).Critical care nephrology. Philadelphia: Saunders/Elsevier.
kid-ney_homedialpat	patients receiving dialysis treatments at home	1962	Japan	Ing, T. S., Rahman, M. A., & Kjellstrand, C. M. (2012).Dialysis: History, development, and promise. Singapore: World Scientific.
loom_auto	operable looms (of a certain size) in place at year end and are either automatic or have automatic attachments (as opposed to ordinary looms)	1924	Japan	Mosk, C. (2007). Japanese Economic Development: Markets, Norms, Structures. New York: Routledge.
loom_total	operable looms in place at year end, including those that are automatic (as defined above) and those that are ordinary.	1924	Japan	Mosk, C. (2007). Japanese Economic Development: Markets, Norms, Structures. New York: Routledge.
mail	items mailed/received, with internal items counted one and cross-border items counted once for each country. May or may not include newspapers sent by mail, registered mail, or parcel post	1840	UK	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
med_catscanner	computed tomography (CT) scanners, also known as 'CAT' scans for computed axial tomography	1972	UK	Alshibli, K. & Reed, A. (2010) Advances in Computed Tomography for Geomaterials. London: ISTE Ltd.
med_lithotriptor	extracorporeal shock wave lithotripters, a machine typically used to break down kidney stones	1980	Germany	Nakada, S. Y., & Pearle, M. S. (2013).Surgical management of urolithiasis: Percutaneous, shockwave and ureteroscopy. New York, NY: Springer.
med_mammograph	dedicated mammography machines	1966	France	Karellasa, A. & Vedantham, S. (2008). Breast cancer imaging: A perspective for the next decade, Medical Physics, 35(11): 48784897.
med_mriunit	magnetic resonance imaging (MRI) units	1977	USA	Placidi, D. (2012). MRI: Essentials for Innovative Technologies. New York: CRC Press.
med_radiationequip	pieces of equipment for treatment with x-rays or radionuclide	1895	USA	Beyzadeoglu, M., Ozyigit, G., & Ebruli, C. (2010).Basic radiation oncology. Heidelberg: Springer.
newspaper	newspaper copies circulated daily. Note that there is a tendency for news circulation to be under-reported, since data for weekly and biweekly publications are not included	1605	France	Spira, J. B. (2011).Overload!: How too much information is hazardous to your organization. Hoboken, N.J: Wiley.
pctday-surg_cataract	cataract surgeries performed without a hospital stay	1967	USA	Yearly, P. (2005). They Were Giants 2005. Lincoln: iUniverse

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Table A.1 – continued from previous page

Techs	Description	Year	Inventor	Source
pctday-surg_cholecyst	cholecystectomies performed without a hospital stay	1882	Germany	Norton, J. A. (2008).Surgery: Basic science and clinical evidence. New York, NY: Springer.
pctday-surg_hernia	hernia procedures performed without a hospital stay	1982	Germany	Schumpelick, V., & Fitzgibbons, R. J. (2007).Recurrent hernia: Prevention and treatment. Heidelberg: Springer Medizin.
pctday-surg_lapcholecyst	laparoscopic cholecystectomies performed without a hospital stay	1985	Germany	Reynolds, W. (2001). The First Laparoscopic Cholecystectomy. JSLS, 5(1): 8994.
pcthomedialysis	dialysis patients who receive treatment at home	1963	USA	Blagg, C. (2006). Its Time to Look at Home Hemodialysis in a New Light. Hemodialysis Horizons: Patient Safety & Approaches to Reducing Errors: 22-28.
pctimmunizdpt	children aged 12-23 months who received a DPT immunization (including all three doses) before the age of one year	1942	USA	Institute of Medicine (U.S.)., Howson, C. P., Howe, C. J., & Fineberg, H. V. (1991).Adverse effects of pertussis and rubella vaccines: A report of the Committee to Review the Adverse Consequences of Pertussis and Rubella Vaccines. Washington, D.C: National Academy Press.
pctimmunizmeas	children aged 12-23 months who received a measles immunization (one dose only) before the age of one year	1963	USA	Ndhlovu, Z. M. (2009).Cellular immune responses to measles virus-infection and vaccination.(Order No. 3356972, The Johns Hopkins University).ProQuest Dissertations and Theses,, 219.
pos	retail locations at which payment cards can be used Note: Per-capita data was converted to level data using WORLD BANK (2007) population data	1949	USA	Bulliet, R. W. (1998).The Columbia history of the 20th century. New York: Columbia University Press.
radio	Number of radios	1896	Russia	Ilcev, S. D. (2005).Global mobile satellite communication for maritime, land, and aeronautical applications. Dordrecht: Springer.
railline	Geographical/route lengths of line open at the end of the year. Narrow gauge lines generally included, but mountain railways, purely industrial lines not open to the public, and urban systems generally excluded	1825	UK	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
railp	passenger journeys by railway. Free passengers typically excluded but may be included for some countries	1825	UK	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.

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Table A.1 – continued from previous page

Techs	Description	Year	Inventor	Source
railpkm	Passenger journeys by railway in passenger-KM. Free passengers typically excluded but may be included for some countries	1825	UK	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
railt	freight carried on railways (excluding livestock and passenger baggage). Freight for servicing of railroads is typically excluded but may be included for some countries	1825	UK	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
railtkm	freight carried on railways (excluding livestock and passenger baggage). Freight for servicing of railroads is typically excluded but may be included for some countries	1825	UK	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
ship_motor	motor ships (above a minimum weight) in use at midyear. Please see also general note on all ship-related series at end of list	1886	Germany	Guetat, G., & Ledru, E. (1997).Classic speedboats, 1916-1939. Osceola, WI: Motorbooks International.
ship_steam	steam ships (above a minimum weight) in use at midyear	1788	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
ship_steammotor	steam and motor ships (above a minimum weight) in use at midyear	1788	USA	Inventors. The history of steamboats.[2]
shipton_motor	motor ships (above a minimum weight) in use at midyear	1886	Germany	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
shipton_steam	steam ships (above a minimum weight) in use at midyear	1788	USA	Inventors. The history of steamboats.[3]
ship-ton_steammotor	steam and motor ships (above a minimum weight) in use at midyear	1788	USA	Inventors. The history of steamboats.[3]
spindle_mule	mule spindles in place at year end	1779	UK	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
spindle_ring	ring spindles in place at year end	1828	USA	Wallace, A. F. C. (2005).Rockdale: The growth of an American village in the early Industrial Revolution. Lincoln: University of Nebraska Press.
steel_acidbess	Crude steel production (in metric tons) by the acid Bessemer process (an early steel process)	1855	UK	Gasik, M. (2013).Handbook of Ferroalloys: Theory and Technology. Butterworth-Heinemann.

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[2] Accessed on 1st of November of 2013 from: http://inventors.about.com/library/inventors/blsteamship.htm

Table A.1 – continued from previous page

Techs	Description	Year	Inventor	Source
steel_basicbess	Crude steel production (in metric tons) by the basic Bessemer process (an early steel process)	1878	UK	Almqvist, E. (2003).History of industrial gases. New York, N.Y: Kluwer Academic/Plenum Publishers.
steel_bof	Crude steel production (in metric tons) in blast oxygen furnaces (a process that replaced Bessemer and OHF processes)	1952	Austria	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
steel_eaf	Crude steel production (in metric tons) in electric arc furnaces (a process that complemented and improved upon Bessemer and OHF processes)	1907	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
steel_ohf	Crude steel production (in metric tons) in open hearth furnaces (a process that complemented the Bessemer process)	1865	UK	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
steel_other	Crude steel production (in metric tons) by methods other than those listed here	1614	UK	McCosh, F. W. J. (1984).Boussingault, chemist and agriculturist. Dordrecht: D. Reidel Pub. Co.
steel_stainless	Stainless steel production (in metric tons). Stainless and crude steel have different functions	1904	France	Reardon, A. C. (2011).Metallurgy for the non-metallurgist. Materials Park, Ohio: ASM International.
surg_appendectomy	Number of appendectomies performed	1735	UK	Stockman, J. (2013).Year Book of Pediatrics 2013: Pediatrics. London: Elsevier Health Sciences.
surg_breastcnsv	breast conservation surgeries performed	1976	USA	Ueno, N. T., & Cristofanilli, M. (2012).Inflammatory breast cancer: An update. Dordrecht: Springer.
surg_cardcath	cardiac catheterizations (insertion of a catheter into a chamber or vessel of the heart) performed	1929	Germany	Lilly, L. S., & Harvard Medical School. (2011).Pathophysiology of heart disease: A collaborative project of medical students and faculty. Baltimore, MD: Wolters Kluwer/Lippincott Williams & Wilkins.
surg_cholecyst	cholecystectomies (gallbladder removals) performed, either laparoscopically or by other methods	1882	Germany	Norton, J. A. (2008).Surgery: Basic science and clinical evidence. New York, NY: Springer.
surg_corbypass	coronary bypass surgeries performed	1960	USA	DeSilva, R. (2013).Heart disease. Santa Barbara, Calif: Greenwood.
surg_corinterven	percutaneous coronary interventions (used to reduced or eliminate the symptoms of coronary artery disease) performed	1977	Switzerland	Estafanous, F. G., Barash, P. G., & Reves, J. G. (2001).Cardiac anesthesia: Principles and clinical practice. Philadelphia: Lippincott Williams & Wilkins.
surg_corstent	coronary stenting procedures performed. This is a particular type of percutaneous coronary intervention	1994	USA	In Bandhyopadhya, A., & In Bose, S. (2013).Characterization of biomaterials.

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Table A.1 – continued from previous page

Techs	Description	Year	Inventor	Source
surg_hernia	procedures performed to correct inguinal and femoral hernias (the most common types)	1879	UK	Hupp, F. (1924). Intra-abdominal rupture of intestine following strangulated femoral hernia. Ann. Surg. 80 (4): 504-10
surg_hipreplace	hip replacement surgeries performed	1891	Germany	Gomez, P. & Morcuende J. (2005). Early Attempts at Hip Arthroplasty. Iowa Orthop J. 25: 25-29.
surg_hysterectomy	vaginal hysterectomies performed (does not include abdominal or laparoscopic procedures)	1813	Germany	Mettler, L. (2007).Manual of new hysterectomy techniques. New Delhi: Jaypee Brothers Med. Publ. [u.a..
surg_kneereplace	knee replacement surgeries	1968	UK	Scuderi, G. R., & Tria, A. J. (2002).Surgical techniques in total knee arthroplasty. New York: Springer.
surg_lapcholecyst	cholecystectomies (gallbladder removals) performed laparoscopically	1882	Germany	Norton, J. A. (2008).Surgery: Basic science and clinical evidence. New York, NY: Springer.
surg_mastectomy	mastectomies performed	1882	USA	Pilnik, S. (2003).Common breast lesions: A photographic guide to diagnosis and treatment. Cambridge: Cambridge University Press.
surg_pacemaker	pacemaker implantation procedures performed	1926	Australia	Torok, S. & Holper, P. (2006). Inventing Millions: Creating wealth, changing lives. New Delhi: Orient Paperbacks
telegram	telegrams sent	1835	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
telephone	mainline telephone lines connecting a customer's equipment to the public switched telephone network as of year end	1876	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
trans-plant_bonemarrow	bone marrow transplants performed	1956	USA	Kidder, D. S., Oppenheim, N. D., & Young, B. K. (2009).The intellectual devotional health: Revive your mind, complete your education, and digest a daily dose of wellness wisdom. Emmaus, Pa.: Rodale.
transplant_heart	heart transplants performed	1968	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
transplant_kidney	kidney transplants performed	1954	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.

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Table A.1 – continued from previous page

Techs	Description	Year	Inventor	Source
transplant_liver	liver transplants performed	1963	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
transplant_lung	lung transplants performed.	1963	USA	Couture, K. A., & Couture, K. A. (2001).The lung transplantation handbook. Victoria, B.C: Trafford.
tv	television sets in use	1884	Germany	Peddie, J. (2013).The history of visual magic in computers: How beautiful images are made in CAD, 3D, VR and AR. London: Springer.
txtlmat_artif	artificial (cellulosic) fibers used in spindles	1865	UK	Baird, G., Mertins, D., & Mies, . R. L. (1994).The presence of Mies. New York, NY: Princeton Architectural Press.
txtlmat_synth	synthetic (non-cellulosic) fibers used in spindles	1924	USA	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
vehicle_car	passenger cars (excluding tractors and similar vehicles) in use. Numbers typically derived from registration and licensing records, meaning that vehicles out of use may occasionally be included.	1885	Germany	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.
vehicle_com	commercial vehicles, typically including buses and taxis (excluding tractors and similar vehicles), in use. Numbers typically derived from) registration and licensing records, meaning that vehicles out of use may occasionally be included	1885	Germany	Comin, D. & Mestieri, M. (2013). If Technology Has Arrived Everywhere , Why Has Income Diverged? INET Research Notes 26.