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Democratization is the driving force for technological and economic change ☆

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ABSTRACT

The purpose of this paper is to analyze the relationship between democratization and technological innovation. In primis, the paper shows, through economic history, that democratization is an antecedent process (cause) to technological and economic change (effect). In particular, the primary finding is that democratization is a driving force for technological change: most free countries, measured with liberal, participatory, and constitutional democracy indices, have a higher level of technology than less free and more autocratic countries. In fact, "democracy richness" generates a higher rate of technological innovation with fruitful effects for the wellbeing and wealth of nations. These findings and predictions lead to the conclusion that policy makers need to be cognizant of positive associations between democratization and technological innovation paths in order to support the modern economic growth and future technological progress of countries.

Democratization is the bedrock of the foundation of technological progress

1. Introduction

Nowadays, the best opportunities to improve living standards and reduce poverty come from technological innovation, which is one of the main factors underlying the patterns of economic growth [1]. As a matter of fact, science and technology will play a growing role in future economic systems to support the paths of economic cycles in order to improve the world's economic perspectives (cf. [2]). Although several works have provided many valuable insights into the role of technological innovation within the economic system, there are also unresolved issues, such as analyzing the institutional driving forces and settings for technological and economic change in which science and technology can originate, develop and diffuse. This socio-institutional environment can foster innovations that transform today's luxury goods into tomorrow's cheaper and widespread goods and services that lead to longer, better and healthier living.

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Many interesting new questions arise for economic philosophy, such as (Huebner [3], p. 985):

What is the relationship between innovation and democracy?
Does innovation depend upon democratization process?

My aim, in this research, is to investigate this relationship in order to understand the socio-institutional driving forces for technological change, which can provide findings to forecast patterns of technological innovation as well as of economic growth of countries.

In particular, the purpose is to determine if and how democratization affects technological activities and their paths; in fact, this process has main political economy implications with fruitful socio-institutional interactions that fertilize the economic system and underpin the future development of societies.

The thesis of this paper is:

Let democratization be a process antecedent to technological and economic change.
Then, there is higher technological innovation when the countries have more democratization.

The purpose of this paper is to prove this fundamental proposition. Before analyzing the proposition and its proof by empirical analysis, let me introduce the theoretical framework and method of research applied to achieve this main objective which is important, very important for the future technological and economic progress of countries and societies.

2. Theoretical framework

An increase in scientific production and technological progress depends on an efficient "national innovation system" [4,5]–*the term refers to the complex network of agents, policies, and institutions, supporting the process of technical advance in economy*–and on the "triple helix mechanism" ([6], p. 310, passim). Within the "national systems of innovation", Steil et al. ([7], p. 9) point out several main sources of innovation for countries: "differences in technological opportunities across fields, and across eras, have been a driving force determining the path of technological progress. . . . the opportunities for technological change are not only a function of the technologies themselves but also the state of the underlying 'science'. . . . . abundant opportunities for technological change in these areas, [electronics, chemical technologies, information and communication technologies, etc.,] driven by scientific breakthroughs in specific areas, lead to abundant economic change". Other main determinants of the market place that affect innovation are: the size of the market; the appropriability of new ideas; the structure of the industry, and investment in public knowledge and institutions ([7], pp. 10-16). Metcalfe ([8], p. 19ff) states that policymakers justify R&D financing in support of technological innovation since there are returns in terms of national economic wealth and a higher standard of living for society. Actually, the social rate of return to R&D expenditure is the interest rate the society receives from this investment [9]. Moreover, public financing to R&D can either have a direct impact on the economic performance of firms or it can concur indirectly to stimulate private R&D expenditure, thus generating social benefits in the form of new knowledge and spillovers [10].

However, it is important to remark that these determinants of innovation are elements of the economic system and depend on the institutional structure, economic governance and political regime of countries, which are–through law, social rules and the education system–driving forces for technical change. Therefore, to understand the roots of the sources of technological regimes and trajectories, it is important to analyze their interactions with the level of democracy of countries. *In primis*, it is important to define "democracy", whose definition has been debated over since 400 B.C. Democracy can be seen as a set of practices and principles that institutionalize and protect freedom. Even if a consensus on precise definitions has proved elusive, most scholars today would agree that, at a minimum, the fundamental features of a democracy include a government based on the majority rule and the consent of the governed, the existence of free and fair elections, the protection of minorities and respect for basic human rights ([11], Chap. 3, passim). The Schumpeterian minimalist conception of democracy is a political system based on elections[1] ([12], quoted by [11] in Chp. 3). Przeworski et al. [13] consider democracy as the political system in which key government offices are filled through contested elections (quoted by [11], passim). Democracy presupposes equality before the law, due processes and political pluralism, and the democratization is a process that improves laws and economic governance over time for the wellbeing of people. Studies on the best political regimes are a main topic for social and economic progress and this issue has been analyzed since the time of Greek philosophers.

The political regime, like all social bodies, is a living entity, adaptive and responsive to external environment changes. Several researches have showed that political regimes based on democracy have been increasing over time. In fact, Modelski and Perry III ([14], pp. 359, 360 and 369ff) consider democratization as: a long-run process of social innovation that has taken 120 years to move from 10% saturation to 50% (roughly in year 2000), whereas 90% of institutional democratization will be achieved in the 2110s or thereabouts. As a matter of fact, democracy, by a Darwinian process of natural selection, is the best political regime that survives to the social change and is suited to absorbing economic and technological changes[2]. Zak and Feng ([15], p. 1) show that the primary factors affecting the speed of democratic transitions are inequality, the autocrat's perceived legitimacy and the rate of economic growth. The process of diffusion of democratization is also correlated to complex interactions with specific geographical–historical contexts ([16], p. 175).

[1] "The democratic method is that institutional arrangement for arriving at political decisions in which individuals acquire the power to decide by means of a competitive struggle for the people's vote" [12] (p. 269).

[2] "Dictatorship naturally arises out of democracy, and the most aggravated form of tyranny and slavery out of the most extreme liberty" Plato, Greek Philosopher 427 BC-347 BC.

In addition, the statement that wealthy society is usually also more democratic has a long lineage (see Lipset Seymour [17], p. 75ff). This hypothesis has been confirmed by Barro [18] and Przeworski et al. [13], although the precise estimate of effects is sensitive to each time-period analyzed, to the selection of control variables specified in the models, and to the measurement of both democracy and economic growth. Other questions remain about the most appropriate interpretation of the direction of causality in any relationship between wealth and political institutions. Barro (p. 160) [18] points out that "increases in various measures of the standard of living forecast a gradual rise in democracy". Norris [11] and other scholars argue that democratization comes together with economic growth. Conversely, Persson and Tabellini [19,20] claim that constitutional arrangements have the ability to influence economic policies and economic performance, and thus patterns of socio-economic development. Therefore, democracy may have effects on economic growth. This statement reverses the assumed direction of causality, as certain types of democratic institutions may impact upon a country's stock of wealth, as well as upon its level of democracy. Acemouglu et al. ([21], p. 808 ff) revisit the relationship between income per capita and democracy and argue that, "although income and democracy are positively correlated, there is no evidence of a causal effect. . . . results raise the question of why there is a positive cross-country correlation between income and democracy today. We provided evidence that this is likely to be because the political and economic development paths are interwoven" (p. 836). However, despite establishing a strong correlation between wealth and democracy, several scholars remain agnostic about the precise causal mechanism underlying this relationship and its policy implications (cf. [18] and [19]). In particular, although the statistical association between income and democracy is the cornerstone of the most influential modernization theory, the economic debate has not examined how the democratization of countries, as an institutional process, can affect the patterns of technological innovation, in the face of accelerating economic change and globalization dynamics [22]. Before that I analyze and shed light on this relationship and the effect of democratization on technological innovation (and *vice versa*), I will introduce historical evidence to show that democratization is a process antecedent to technological and economic change, in order to support econometric modelling that considers democratization as the explanatory variable of technical change.

3. Historical perspective of democratization as a determinant of technological revolutions

The Copernican revolution in the development of the democratic state means the granting of human and citizens' rights through the declaration of rights and the acknowledgement of the natural equality of all individuals. The state is considered *ex parte populi*. In favor of democracy there is the idea that people cannot abuse power against themselves: *vox populi vox dei*. Rousseau's beliefs state that without democracy there is autocracy, whereas Kant says that human beings are no longer underage and, since they are of age, they can make decisions about their individual and collective freedom. According to Hobbes, Spinoza, Rousseau, and Hegel, democracy allows humans to achieve their role of beings of reason by means of an orderly life in common, leading to personal fulfillment (see [23], pp. 130–150). The idea of representative states originates in England with the constitutional movement of the early 19th century and then spreads to the rest of Europe, laying the foundations of the first and second industrial revolutions, characterized by high levels of technological development, wealth, and wellbeing.

More specifically, the first industrial revolution originated in England and the background for its diffusion in the English economic system and society was the civil war in 1688, which established parliamentary monarchy and a more democratic government and institutions. After that, the French Revolution of 1789–1799 generated radical changes to government forms based on the principles of nationalism, citizenship, and inalienable rights. This social and cultural revolution, underpinned in the Enlightenment, created a more democratic political system in France and several European countries. In addition, the creation of big states with a large population led to the modern concept of democracy based on representative governments, which are the only possible democracy in certain situations linked to territory and population (see [23], pp. 141–147). In relation to this, the US representative government, established after the revolution of the 13 colonies (1775–1783), is of great interest for European new-born countries. Alexis de Tocqueville recognizes modern democracy in the New World (i.e. the USA), different from that of ancient populations. To sum up, new democratic laws in England and France, as well as the United States constitution of 1787–1788, are antecedent events and can be considered as the

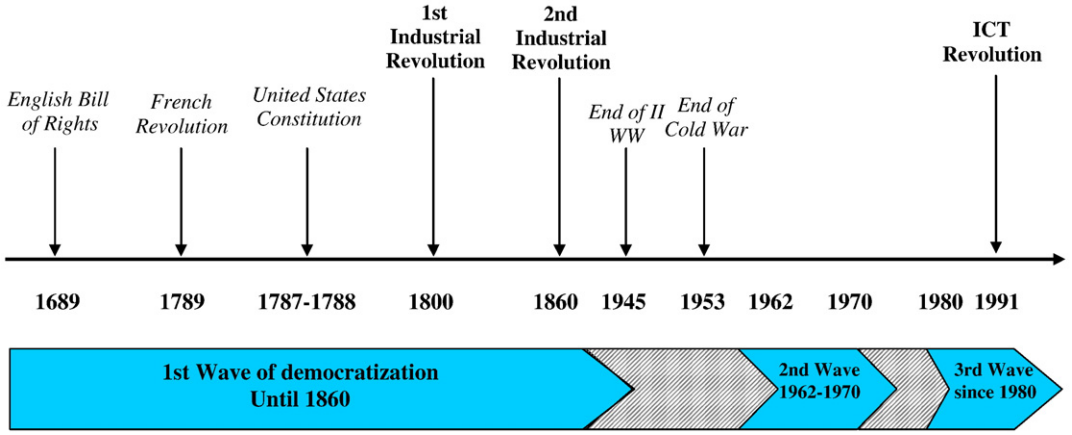

Fig. 1. Waves of democratization antecedent to technological revolutions.

foundations for the origins and diffusion of the first and second industrial revolutions (Fig. 1). They were based on several technological innovations (steam engine, spinning jenny, etc.) that changed the socio-economic structure of European and North-American economies, generating an exceptional increase in employment, wealth and economic growth (cf. Rae [24] Chp. X, Book II).

Mokyr ([25], p. 23) argues that: "the second Industrial Revolution [from 1860 onwards] brought technological progress to the advantage of consumer". In 1853, Greeley stated that: "'we have democratized the means and appliances of a higher life'" (quoted by Mokyr [25], p. 23). These effects were due to a democratization process of countries that became stable and represented the background of higher technological innovation production and diffusion, generating higher productivity and economic growth as well as higher well being for the people.

In addition, Mokyr ([25], Chp. 1), inter alia, points out that income growth in the twentieth century would not have taken place without technological changes, which are underpinned within more democratic countries. Kuznets [26] wrote that: "modern economic growth was based on the growth of the stock of useful or `tested knowledge'" (quoted by Mokyr [25], p. 25). In fact, Mokyr ([25], p. 29 and 35) claims that in the pre-1750 environment the failure of technological progress to generate sustained economic growth was due to institutional negative feedback. As a matter of fact, before the civil war in England, the French revolution and the democratization diffusion wave ([27], p. 42ff.), the social and environmental conditions to sustain worldwide technological progress were not present. The civil war in England (1688), the revolution of the American colonies (between 1775 and 1783) and the French revolution (1789–1799) generated a variety of social and political forces that reduced social and cultural friction (by a new social framework) and led to the exploiting of several techniques (starting in 1800) based on path-breaking classical inventions such as the steam engine ([25], p. 30, passim). Mokyr ([25], p. 29) also argues that the: "scientific revolution and the enlightenment [within most free and high democracy countries] helped expand the epistemic base of techniques in use and thus create the [socio-economic] conditions for more sustainable technological progress. In order to support this process", the Industrial Revolution "requires not just new knowledge but the ability of society to access this knowledge, use it, improve it, and find new applications and combinations for it" ([25], ibidem). As Headrick ([28], quoted by Mokyr [25], p. 29) emphasizes" the age of industrial revolution through a variety of technological as well as institutional innovations did exactly that", thanks to a new political and social climate generated by more democratic countries. "Had institutional feedback been negative, as it had been before 1750, technological progress would have been on the whole short-lived" (Mokyr [25], p. 29). Yet the feedback between democratic institutions and technology was and is positive. In particular, the years after 1815 were more and more subjugated by the free market liberal ideology, which provided incentives for scientific and entrepreneurial behavior within more democratic countries (cf. Mokyr [25], op. cit., p. 29ff).

Moreover, since the democratization of European countries as well as of the United States of America was at an early stage before 1815, innovations had minor effects on economic growth, real wages and living standards (Mokyr [25], p. 24). When the democratization processes of countries entered a steadier stage, another wave of innovations created–in a more global and democratic world–a new economic wind which, after the 1850s, increased productivity growth, income per capita and real wages (cf. Mokyr [25], p. 30ff). According to M. R. Smith : "`the nineteenth century has achieved triumphs . . . equal, if not superior to all centuries combined'" ([29], quoted by Mokyr [25], p. 23). The coevolution of democratization and technical change has been assuming new forms in the current economy and the most important development is the Information and Communication Technology Revolution (cf. [30]). As a matter of fact, the "Third wave of democratization (1980s–1990s)" [31] generated a receptive political and economic environment, which has been fostering a new techno-economic paradigm based on converging technologies (see also [32]).

This historical discussion shows that the democratization process underpins technical change and is prior to technological progress as well as economic growth (Fig. 2).

Moreover, Marchetti [33], Ayres [34], Ayres and van den Bergh [35] also consider the importance of energy as a driving force for economic cycles and growth paths. In fact, democratization is also an important process for the use of energy resources and energy conversion. For instance, some countries in Eurasia, which have the majority of the world's known energy resources, do not have–without diffused democratization–an efficient "national system of innovation" (NSI) that supports research and development of technology, absorbs it and drives economic growth patterns. In relation to this, Rock shows that in Asia: democratization can cause growth and higher investment ([36], p. 941).

The historical perspective discussed here is the background to analyze the interaction between democracy and technology innovation.

4. Data and their sources

A first aspect to consider is the measurement and evaluation of democracies that have received special attention and have had a long tradition in political science since Aristotle and Machiavelli. Classical philosophy applies several criteria to define democracy: Aristotle uses the rule of number of governors[3], Machiavelli and Kelsen use the criterion of production of legal and political systems (bottom-up and *vice versa*), Montesquieu uses the criterion of "ressorts" (springs that induce individuals to obey), etc. (quoted by [23]).

The modern indices used to measure the quality of democracy are: the Vanhanen Index of participatory democracy, the Polity-IV Index for the assessment of constitutional democracy, and the Freedom House Index of liberal democracy. These cover over 150 countries and, in part, go back to the 19th century (for details, see Bogaards [37]). They represent the most widely-cited standard indicators commonly used by scholars in democracy research.

[3] Aristotle (384 BC–322 BC), a Greek philosopher and a student of Plato, argued that democracy was the rule of many.

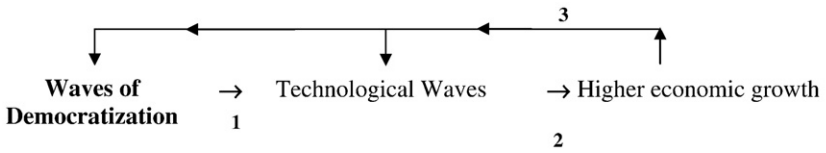

Fig. 2. Interaction among democratization, technological waves and economic growth boost (and positive feedback loop).

The Freedom House Index of liberal democracy was launched by Raymond Gastil [38] of the University of Washington in Seattle (USA). Gastil developed a methodology which assigned ratings of political rights and civil liberties for each independent nation. It now includes 192 countries and 18 independent territories. The index of political rights consists of 10 criteria, which are grouped into three parts: electoral process, political pluralism and participation, and government functioning. This index ranges from 1 (*best value*) to 7 (*worst value*) and, in many publications, it is shown on a rotated scale. The index monitors the existence of political rights in terms of electoral processes, political pluralism, and the functioning of the government. It has been employed by many scholars such as Diamond [39], Barro [18], Inglehart and Welzel [40]. Despite its virtues, the index has been subject to criticism on a number of methodological grounds ([41], quoted by Norris [11], Chp. 3).

The Polity-Index IV of constitutional democracy was developed by Ted Robert Gurr in the 1970s and is now connected to the University of Maryland and Colorado State University in the USA [42]. The Polity-Index includes 150 countries which have been integrated at different times. For all practical purposes, the index is two-dimensional even if its description lists three dimensions (free and competitive elections, horizontal power limitation, and liberty rights). The Polity-Index is based on the subtraction of a value on the autocracy scale from a value on the democracy scale. Thus, its range is from −10 (*very autocratic*) to +10 (*very democratic*). The Polity IV Index was originally conceived by Gurr for different purposes: to monitor the political stability and regime change. It also has some limits [41].

The Vanhanen Index of participatory democracy was developed in 1984 by Vanhanen [43], professor at Helsinki University (Finland), in cooperation with the International Peace Research Institute in Oslo (Norway). Data include 187 countries and cover the 1810–1998 period. Because of its proximity to Dahl's theory of democracy, the Vanhanen index is also informally known as the "polyarchy data set". Two dimensions are recorded–competition and participation–and aggregated over the following formula: *Competition* × *Participation* / 100, with values from 0 to 100 (see also Norris [11], Chp. 3).

Despite all the differences in the construction of democratic indices, it is striking that their measures most commonly correlate strongly with each other ([44], and also cf. Norris [11], Chp. 3). An updated dataset concerning the measurement of democratization across countries and over time was compiled by Norris [11] from Harvard University (USA). This dataset contains data on the social, economic and political characteristics of 191 nations, with over 600 variables, from 1972 to 2005, and it includes several indices of democracy applied by modern studies in comparative political science. Although no single metrics of democracy is entirely satisfactory, a combination of methodologies holds great promise for adopting the best features and avoiding the limitations of each metrics. Hence, this paper applies all the three metrics of democracy described: Freedom House, Polity and Vanhanen Index.

The second term of the relationship that is analyzed here is the technology. It has numerous connotations, ranging from an object to a pool of applied scientific knowledge. Technology is based on inventions and innovations. Invention is a commercially promising product or service idea, based on new science or technology that is protectable (by patents). On the other hand, innovation is the practical application of the invention and successful entry of a new science or technology-based product into a particular market. The formal concepts of technology follow two categorical viewpoints: *a)* there is the neoclassical concept of technology in the form of production function ([45], pp. 16–22); *b)* there is what might be termed as the "Pythagorean concept of technology in terms of patent statistics" (Sahal [45], pp. 22–25). I apply this second viewpoint that has a distinctly interdisciplinary origin. It is based on contributions from fields as diverse as economics, sociology, scientometrics, and so on. Appropriate measures of technological change are conceived both in terms of the number of inventions patented and of a potentially broad range of other variables, such as: number of articles published, number of researchers and technicians, R&D investments, etc. As a matter of fact, in order to analyze patterns of innovations a common approach is to measure patents, which offer a main indicator of innovative outputs ([7], p. 11ff).

The economic literature gives particular attention to how innovators can appropriate returns by patents and intellectual property rights, which have an increasingly important role in the innovation and economic performance of countries. The increasing use of patents to protect inventions by businesses and public research organizations is closely connected to recent evolutions in innovation processes that have become increasingly competitive, co-operative, global and more reliant on new entrants and technology-based firms [46]. Growth in patenting corresponds to a new organization of research that is less focused on firms and more based on knowledge networks and markets. Patents aim at fostering innovation in countries by allowing inventors to profit from their inventions (appropriability). Steil et al. ([7], p.11), quoting Cohen et al. [47], claim: "that patent protection is the central vehicle for investors to reap returns in only a few industries; . . . among them, pharmaceuticals, fine chemical products, and agricultural chemicals". In fact, a patent protects the owner of the invention for a limited period of time, generally 20 years (cf. [46,48]). In addition, Chen [49] also shows a significant positive effect of patent laws on invention rates. As there is a vast economic literature that converges towards patents as measures of innovation, I apply this indicator of innovative output of countries. More specifically, the paper does not use overall patents of countries since, for instance, about half of the patent applications to the U.S. patent office are filed by residents in countries other than the United States of America. To overcome this problem I use the patents of residents. However, patents as sources of innovation can have some limits: for instance,

transaction costs and disclosure rules vary among countries (see [7], p. 13). Moreover, patented inventions give no information on innovation and on the process of development of technology involving the translation of a blueprint into a working device suitable for mass production. On this basis, to increase the robustness of the analysis, patent statistics are integrated with payments of royalty and license fees within the country (see also [50]) and other indicators of innovative output according to the "Pythagorean concept of technology" (Sahal [45], ibidem), such as scientific and technical journal articles, researchers and technicians in R&D, and R&D expenditure (see [51,52] for some applications).

Data of technological innovation outputs are taken from World Bank's "World Development Indicators" [53]; in particular, the best indicator of production of technological innovation is the number of patent applications filed by residents. They are applications filed with a national patent office for exclusive rights to inventions - a product or process that provides a new way of doing something or offers a new technical solution to a problem.

The robustness of the research is based on other measures of innovative output which are:

1) Royalty and license fees are payments between residents and non residents for the authorized use of intangible, non produced, non financial assets and proprietary rights and for the use of produced originals of prototypes, through licensing agreements.
2) Scientific and technical journal articles include those published in a stable set of about 5000 of the world's most influential scientific and technical journals, tracked since 1985 by the Institute of Scientific Information's Science Citation Index and Social Science Citation Index.
3) Researchers and technicians in R&D are people engaged in professional R&D activities who have received vocational and technical training in any branch of knowledge or technology.
4) Expenditures for R&D are current and capital expenditures on the creative, systematic activity that increases the stock of knowledge. This includes fundamental, applied research and experimental development work leading to new devices, products, or processes.

These dimensions are a good proxy of technical change according to the "Pythagorean concept of technology" ([45], ibidem). Table 1 contains variables and their time periods.

5. Empirical strategy

First of all, the data undergo a preliminary process of horizontal and vertical cleaning. After that, the normal distribution of data is checked by descriptive statistics based on arithmetic mean, standard deviation, skewness, and kurtosis, as well as the normal *Q–Q* plot and the Kolmogorov–Smirnov and Shapiro–Wilk tests of normality, using the SPSS statistics software [54]. Logarithmic transformations are carried out to normalize the distributions and to apply the correlation and regression analysis. The correlation applied is the partial correlation with control variable either GDP per capita or population, whereas the econometric models are based on a Dataset that contains repeated observations of the same country over a number of years. In primis, the following assumption is stated, based on historical evidence discussed before.

Assumption. Democratization is the cause of the technological change.

The logic relationship is:

Technology = (*level of democratization*).

The static linear model is applied and its general specification is based on linear models of regression with a leading indicator:

$$Ln\text{Technology}_{i,t} = \beta_0 + \beta_1 \text{index of democratization}_{i,t-5} + \varepsilon_{i,t} \quad (1)$$

where *i* subscripts denote countries, *t* subscripts denote time. The production of technology ($\text{Ln}y_{i,t}$) is measured by the number of patents filed by residents per million people and other indicators described in section four. In addition, explaining $\text{Ln}y_{i,t}$ rather than

Table 1
Variables.

	Description and period
Index of democratization	□ Freedom House 7-pt rating— reversed scale 1 least free, 7 most free countries (1990–1996 period)
	□ Polity Combined democracy–autocracy score from -10 to +10 annual (1990–1996 period)
	□ Vanhanen index (1990–1996 period)
Production of technology	■ Patents of residents per million people (1995–2001 period)
	■ Royalty and license fee payments per capita (current US$)(1995–2001 period)
	■ Scientific and technical journal articles per million people (1995–2001 period)
	■ Researchers in R&D per million people (1995–2001 period)
	■ Technicians in R&D per million people (1995–2001 period)
	■ R&D expenditure as % of GDP (1995–2001 period)
Other variables used in correlation analysis	– GDP per capita, current prices, US$ (UNI) (1995–2001 period) Gross domestic product (GDP) is a measure of the economic activity. It is defined as the value of all goods and services produced minus the value of any goods or services used in their creation
	– Population (1995–2001 period)

$y_{i,t}$ may help in reducing heteroskedasticity problems. Moreover, democratization is inherently a dynamic process and countries will adjust in the medium-long run, which is necessary to rule and apply democratic laws in order to support technological and economic activities. Hence, a lag of 5 years of the democratization index (that is the explicative variable x) is included in the specification (1). This lag is also applied by Acemoglu et al. ([21], p. 817ff) in their standard pooled OLS regressions. It is assumed that the error term is normally distributed with mean zero and variance σ^2.

The second model includes a dummy variable $D_{i,t}$ (1; 0) that represents 1 for OECD members and 0 for non-OECD member. In this case, it is important to investigate which set has more cross-fertilization between democratization and technology and the model is:

$$Lny_{i,t} = \beta_0 + \beta_1 x_{i,t-5} + \beta_2 D_{i,t} + \varepsilon_{i,t}. \quad (2)$$

Models (1) and (2) have the error term $\varepsilon_{i,t}$ that represents all factors, except democracy $x_{i,t}$, that affect the technology production, such as the "national system of innovation" and innovation policies. Therefore, the following model is also applied to better analyze the impact of all factors that affect the innovation activity:

$$Lny_{i,t} = \beta_0 + \beta_1 \varepsilon_{i,t} + \beta_2 x_{i,t-5} + \beta_3 D_{i,t} + u_{i,t}. \quad (3)$$

The introduction of a lagged dependent variable in the linear model complicates consistent estimations. To investigate the dynamic properties of our technological and institutional variables, the dynamic specification is:

$$Lny_{i,t} = \beta_0 + \beta_1 x_{i,t-5} + \beta_2 Lny_{i,t-1} + \varepsilon_{i,t}. \quad (4)$$

The goal is to derive short and long-run estimates concerning the democratization elasticity[4] of technology and scientific activity.

The long-run impact of democratization ($y_{i,t}$) on technological innovation ($x_{i,t}$) is $\hat{\beta}_1 / 1 - \hat{\beta}_2$, based upon the assumption that the error term is normally distributed [55].

The equations are estimated by the Ordinary Least Squares (OLS) method and the Prais–Winsten estimation method, by the autoregression estimate procedure from time series with first-order autocorrelated errors. The latter method eliminates the problems of serial correlation.

The estimation of the parameters and the statistical analysis are performed using the SPSS statistics software [54].

6. Main results and forecasting

First of all, some variables have been transformed into logarithmic values (which is a monotonic transformation) to have normal distribution and to correctly apply the correlation and econometric models.

The thesis of this research is the following main proposition:

Proposition. *Let democratization be a process antecedent to technological change. Then, there is higher technological innovation when countries have more democratization.*

Different ways of proving the proposition are suggested, since they show different results.

Firstly, Table 2 shows that *"most free" and "high democracy" countries have higher arithmetic mean of technical change indicators than "least free" and "high autocracy" countries.*

More specifically, the descriptive statistics based on Freedom House show that most free countries have a higher level of patents per million people (indicator of technological change) than least free countries [about 375 (s.e.[5] 25.85) in most free countries *vs.* 6.7 (s.e. 1.35) per million people in least free countries]. These results are confirmed by the Policy score, which shows higher values of patents in high democracy countries than in autocracy countries [roughly 393 (s.e. 41.79) *vs.* 2.07 (s.e. 0.51)], as well as by the Vanhanen index. Other indicators of technological innovation confirm these results: royalty and license fee payments, scientific and technical journal articles, R&D expenditures, researchers and technicians in R&D have higher values in most free and high democracy countries than in least free and high autocracy ones. Moreover, higher democracy is associated to a longer period of independence: for instance, least free countries have an arithmetic mean of years of independence equal to about 66 years, whereas most free and high democracy countries have been independent for longer, more than 267 years. The latter countries also have higher GDP per capita in comparison to the former countries (Table 2).

To sum up, descriptive statistics show that democracy richness at $t-5$ generates a higher level of technology at t and cross-fertilization effects for economic growth patterns measured by the GDP per capita.

Secondly, the relationship between democratization and technological innovation is also analyzed by correlations. Tables 3 and 1A (in Appendix A) display that the indices of democratization have high positive associations with technical change indicators (control variables: GDP per capita or population). On the whole, the partial correlations analysis shows that the number of Patents by residents per million people has a high positive correlation with Democratic indices: in particular,

[4] Elasticity measures the *relative* change in the dependent variable due to a *relative* change in one of the x_i variables.
[5] s.e. = standard error of mean.

Table 2
Central tendency and dispersion.

Level of democracy-index		Arithmetic mean	Std. error of mean
Freedom House 1990–1996			
1: Least free	– Patents per million people (1995–2001)	6.72	1.35
	– Royalty and license fee payments Bop current US$ per capita (1995–2001)	38.00	37.80
	– Scientific and technical journal articles per million people (1995–2001)	11.51	5.60
	– R&D expenditure as % of GDP (1995–2001)	0.61	0.13
	– Researchers and technicians in R&D per million people (1995–2001)	1,294.35	310.61
	– GDP PPP current international $ per capita (1994–2000)	2,322.30	393.94
	– Population million people (1995–2001)	142.72	43.46
	– Age of independence (years)	67.87	4.90
7: Most free	– Patents per million people (1995–2001)	375.79	25.85
	– Royalty and license fee payments Bop current US$ per capita (1995–2001)	133.50	30.17
	– Scientific and technical journal articles per million people (1995–2001)	492.00	29.68
	– R&D expenditure as % of GDP (1995–2001)	1.77	0.14
	– Researchers and technicians in R&D per million people (1995–2001)	3,496.90	366.92
	– GDP PPP current international $ per capita (1994–2000)	22,730.66	634.24
	– Population million people (1995–2001)	24.21	5.34
	– Age of independence (years)	267.30	23.15
Polity 1990–1996			
-10: High autocracy	– Patents per million people (1995–2001)	2.07	0.51
	– Royalty and license fee payments Bop current US$ per capita (1995–2001)	7.39	4.31
	– Scientific and technical journal articles per million people (1995–2001)	22.63	5.01
	– R&D expenditure as % of GDP (1995–2001) — with −9 value	1.08	0.15
	– Researchers and technicians in R&D per million people (1995–2001)	1,197.46	301.70
	– GDP PPP current international $ per capita (1994–2000)	9,237.40	1,189.75
	– Population million people (1995–2001)	14.08	2.88
	– Age of independence (years)	66.20	5.50
10: High democracy	– Patents per million people (1995–2001)	393.86	41.79
	– Royalty and license fees payments Bop current US$ per capita (1995–2001)	114.65	25.08
	– Scientific and technical journal articles per million people (1995–2001)	428.79	23.51
	– R&D expenditure as % of GDP (1995–2001)	1.65	0.09
	– Researchers and technicians in R&D per million people (1995–2001)	3,025.36	198.92
	– GDP PPP current international $ per capita (1994–2000)	19,407.23	488.34
	– Population million people (1995–2001)	28.99	3.91
	– Age of independence (years)	324.80	31.13

$r = 0.533$ between the Patents and the Freedom House index (the residuals equal to 46.7% are due to "other factors" that also include the random factor), $r = 0.383$ between the Patents by residents and the Polity index, and $r = 0.583$ between the Patents by residents and the Vanhanen index (control variable GDP PPP). If the population is used as control variable, the Patents and Freedom House index have a coefficient of correlation $r = 0.631$, Patents by residents and Polity index have $r = 0.566$, while Patents by residents and Vanhanen index have $r = 0.401$. These results are confirmed by other indicators of technological change.

In short, coefficients of correlation r between most free and high democracy countries and indicators of technology are higher than between least free and high autocracy countries *and* technology. This confirms that most free countries, measured with liberal, participatory and constitutional democracy indices, have a higher interaction with technical change

Table 3
Partial correlation.

Control variables	Variables	Freedom House 1990–1996	Polity 1990–1996	Vanhanen 1990–1996
LN GDP PPP current international $ 1994–2000	LN patents per million people (1995–2001)	0.53	0.38	0.58
	Significance (2-tailed)	0.00	0.00	0.00
	df	467	467	467
LN population 1995–2001	LN patents per million people (1995–2001)	0.57	0.40	0.63
	Significance (2-tailed)	0.00	0.00	0.00
	df	481	481	481
LN GDP PPP current international $ 1994–2000	LN royalty and license fee payments Bop current US$ (1995–2001)	0.62	0.38	0.54
	Significance (2-tailed)	0.00	0.00	0.00
	df	329	329	329
LN population 1995–2001	LN royalty and license fee payments Bop current US$ (1995–2001)	0.64	0.45	0.55
	Significance (2-tailed)	0.00	0.00	0.00
	df	336	336	336

Table 4
OLS results — patents equations.

	Models and dependent variables								
	Leading indicator model 1			Dynamic model 2			2nd stage mod. 1A with explicative variable $\varepsilon_{i,t}$ added	Model 1A with OECD dummy variable	2nd stage model 3A' with explicative variable $\varepsilon_{i,t}$ added
	Ln $y_{i,t}$ = patents by residents per million people 1995–2001			Ln $y_{i,t}$ = patents by residents per million people 1995–2001					
Explanatory variables	1A	1B	1C	2A	2B	2C	3A	3A'	3A''
A. Freedom House 1990–1996	0.557*** (0.063)	–	–	0.062** (0.030)	–	–	0.560*** (0.035)	0.185** (0.075)	0.199*** (0.043)
B. Polity 1990–1996	–	0.114*** (0.019)	–	–	0.014* (0.009)	–	–	–	–
C. Vanhanen 1990–1996	–	–	0.044*** (0.004)	–	–	0.004* (0.002)	–	–	–
$D_{i,t}$ (1,0)	–	–	–	–	–	–		2.863*** (0.531)	2.725*** (0.480)
$\varepsilon_{i,t}$ for Ln $y_{i,t}$	–	–	–	–	–	–	0.635*** (0.020)	–	0.649*** (0.025)
Constant	0.603 (0.415)	2.824*** (0.308)	1.586*** (0.310)	−0.126 (0.142)	0.070 (0.088)	0.003 (0.103)	0.566* (0.337)	1.494** (0.474)	1.486*** (0.390)
Ln $y_{i,t-1}$	–	–	–	0.948*** (0.022)	0.959*** (0.020)	0.949*** (0.022)	–	–	–
R^2 adjusted	0.155	0.077	0.188	0.889	0.888	0.889	0.741	0.124	0.698
Std. error of the estimate	1.398	1.460	1.372	0.777	0.779	0.778	0.780	1.325	0.773
Durbin–Watson	2.042	2.001	2.045	2.572	2.581	2.590	1.255	1.909	1.167
F test sign.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N. cases	414	414	414	327	327	327	414	326	326

***Parameter is significant at 1 percent; **parameter is significant at 5 percent; *parameter is significant at 10 percent.
Note: the Prais–Winsten estimation method based on the autoregression procedure estimates true regression coefficients from time series with first-order autocorrelated errors. Standard errors are in brackets. Moreover, *i* subscripts denote countries, *t* subscripts denote time.

than least free ones, generating fruitful effects on the economic growth and the wealth of nations over time (see Tables 3 and 1A in Appendix A).

Thirdly, it has been shown, through economic history, that democratization is a driving force for technological and economic change. In addition, descriptive statistics and partial correlation show the positive association between democratization and technology in countries. In order to pinpoint the impact of democratization on technological change, the results of econometric modelling are described. On *a priori* grounds it might be argued that β_i is positive. The results are presented in Table 4.

The estimates have the correct signs. In addition, models have provided robust estimates by fairly high *t*-ratios (larger than 2) for all coefficients and *F* test significant at the level of 0.00, though the goodness of fit measured by R^2 adjusted (the coefficient of determination adjusted) does not have high values (Table 4). The result of the Durbin–Watson test, after correction with the Prais–Winsten estimation method, is no serial correlation (5% significance level).

To sum up, the coefficients of the econometric modelling have positive values, i.e. positive impact of democratization on technical change over time and across countries.

Strictly speaking, econometric modelling shows that an additional level of democratization, measured by the Freedom House index of liberal democracy, is estimated to raise the production of technology (measured by Ln patents per million people) by 55.7%, whereas technology is estimated to raise by 11.4% in the Polity model and by 4.4% if the democratization is measured by the Vanhanen index (models 1A–B–C in Table 4 and see also Table 5). In addition, if model 1A is considered, the error term represents the elements of the economic system that affect technology production, excluding democratization, such as the "national system of innovation" (NSI). Therefore, if the Freedom House and error term ε of first regression (model 1A) are used as explicative variables, model 3A and 3A'' show the impact of NSI on innovation patterns. The goodness of fit of these models is higher than 69%, though the models have a slight positive autocorrelation. To consider the different starting points of countries, the dummy variable OECD is inserted (i.e. 1 = OECD member country; 0 = non member country); Hence,

Table 5
Average impact of democratization on technology.

Model	Period	Democratization elasticity of technology production		
		Freedom House	Polity	Vanhanen
Static	–	0.557	0.114	0.044
Dynamic	Short-run	0.062	0.014	0.004
	Long-run	1.190	0.340	0.080

Table 6
Expected patents per million people based on least and most free countries, and OECD membership.

Models	Freedom House Index	Constant	Coefficient	OECD	Expected Ln patents per million people	Expected Ln patents with half-variance term	Expected patents per million people
1 A	Least free	0.603	0.557	–	1.16	1.859	6.42
1 A	Most free	0.603	3.899	–	4.50	5.201	181.45
3 A' (OECD)	Most free	1.494	1.295	2.863	5.65	6.315	552.53

considering the Freedom House index of liberal democracy, model 3A' of Table 4 shows that OECD member states have a higher impact–equal to 286.3%–of the democratization on technology production than non-OECD member states. The estimated democracy elasticity of the innovation production is 18.5%. In addition, model 3A'' confirms the higher impact of democratization on technology in OECD member states. This strong interaction between these key variables in OECD member states is due to higher efficiency and effectiveness of their "national systems of innovation" (NSI), which generate cross-fertilization and fruitful effects in advanced economic systems, in comparison with non-OECD member states.

The dynamic specification of the model has a significance of the lagged dependent variable (standards errors are given in parentheses) that suggests it should be preferred (Table 4, model 2). The estimated short-run democratization elasticity in model 2A (Freedom House Index) is 0.062, while long-run democratization elasticity of innovation generation is 1.19, which is higher than in the static model. Long-run democratization is 0.34 using the 2B model (Polity index) and it is 0.08 with the 2C model (Vanhanen Index). The impact of democratization on the generation of technology in the *long run* shows higher estimated values due to an intensive fertilization effect over time within economic, social and institutional systems (Table 5). The estimates suggest that more democratization (Freedom House index) increases the production of technology (measured by patents per million people) in the long run by 119%, in comparison with 55.7% in the case of the static model (Table 5).

One might also ask: does democracy depend upon innovation? As far as this issue is concerned, empirical evidences that use democratization indices as dependent variable and some technology indicators as lagged explicative variables do not show a consistent impact of innovation on democratization processes, although more investigation is needed in future researches.

6.1. Forecasting technological innovation patterns in different democratization settings

The expected Ln patents by residents per million people of a country with Freedom House index of democracy equal to 1 (least free) is 1.16, which corresponds to an expected patents by residents per million people of $exp\{1.16 + 0.5 \times 1.398\} = 6.42$[6]; whereas *mutatis mutandis* in case the Freedom House index is 7 (most free countries), the expected patents by residents per million people are roughly 181.45 (Table 6, using model 1A of Table 4). The expected patents by residents per million people of OECD countries that have a Freedom House index of seven (most free countries) are 552.53. This value is higher in comparison to countries that have a similar democratization level but that are not OECD member states (Table 6).

Taking the exponential of the fitted average values, it produces predicted patents per million people. For instance, the predicted average of patents per million people, measured by Freedom House, from 1 (min) to 7 (max), is 35.92, while the sample average of actual patents per million people of model 1A is 36.10 (Table 7). *Mutantis mutandis,* it is possible to compare the actual and predicted average of patents per million people for all the other models. Table 7 shows that the predicted averages of patents per million people are similar to the actual averages of the sample. These findings have vital forecasting policy implications focused on democratization as the main driving force for the future development of technology activity, and in general technical and economic change in order to achieve the wealth and wellbeing of countries.

6.2. Robustness

For the sake of briefness, this empirical analysis is displayed in Appendix B. In particular, robustness of these results is based on alternative variables that measure technology, such as royalty and license fees (Table 1B in Appendix B), scientific and technical journal articles (Table 2B), R&D expenditures (Table 3B), as well as researchers and technicians in R&D (Table 4B). Tables 1B–4B confirm the positive impact of democratization on the generation of technology in the *long run*.

To sum up, the synthesis of the empirical analysis is that *more democratization generates higher technological and economic change.*

7. Discussion on strengths and weaknesses, threats and evolution of democratization

The primary findings of this research are that democratization is the determinant of technological revolution and that higher democratization generates more technology level. In fact, "democracy richness" generates fruitful effects on technological innovation and boosts new economic growth patterns.

[6] $E\{y_i|x_i\} = \exp\{E(\log y_i|x_i) + 0.5\sigma^2\}$.

Table 7
Comparison between actual and predicted average of patents per million people.

Models		Actual LN average	Predicted LN average	Actual average	Predicted average	Difference
Freedom House (FH)— model 1A	Static	3.586	3.581	36.10	35.92	0.18
Polity — model 1B		3.586	3.582	36.10	35.93	0.17
Vanhanen — model 1C		3.586	3.583	36.10	35.98	0.12
Freedom House — model 2A	Dynamic	3.793	3.793	44.38	44.38	0.00
Polity — model 2B		3.793	3.793	44.38	44.38	0.00
Vanhanen — model 2C		3.793	3.793	44.38	44.38	0.00
FH + Error for LnFH of model 1A	Model 3A	3.586	3.584	36.10	36.02	0.08
FH + OECD dummy	Model 3A'	3.793	3.786	44.39	44.10	0.29
FH + OECD member states		5.213	5.281	183.57	196.48	0.83
FH + OECD NON members		2.597	2.533	13.42	12.59	− 12.91
FH + OECD dummy + Error for LnFH of model 1A	Model 3A''	3.793	3.791	44.39	44.32	0.07

An essential aspect of democratization must be considered:

Why does democratization have positive effects on technology?
Which are the underlying processes within democratic countries that boost technology?

The determinant of this effect of democratization on technological innovation and in general technical change is due to higher levels of literacy, schooling, education and media access, broadening the middle classes and reducing the extremes of poverty, as theorized by Lipset Seymour ([17], p.79ff). As a matter of fact, Lipset Seymour emphasizes that more egalitarian conditions, and in particular the expansion of the educated middle class, facilitate mass participation. This hypothesis is confirmed by Barro [18], Przeworski et al. [13] as well as by Lipset Seymour and Lakin [56]. To sum up, the underlying causes of the positive association and impact between democratization and technology can be based on the hypothesis by Lipset Seymour, who places considerable emphasis on the role of human capital in the democratization process. In fact, evolutionary processes of democratization and technological innovation have a common denominator represented by growing levels of literacy, schooling and education. These factors are a significant predictor of democratization and–one can add–of technological and economic change. Several studies confirm that societies, such as liberal systems, that invest in human capital are more likely to sustain democratization because literacy and education help access to information and generate new technical knowledge (see also [57], p. 143 for an analysis of the human capital in explaining per capita growth rates). In fact, the new growth theory [58] in Romer's version [59] introduces endogenous technological change (as a function of the level of human capital) into the Solow model. Economic development and education are also key factors determining the intensity of democratic reforms and how quickly democratic transitions will occur ([31], pp.365, 371–378). According to Castelló-Climent [60]: "the increase in the education attained by the majority of the population is what matters for the implementation and sustainability of democracy" (p. 179). Moreover, Tavares and Wacziarg [61] show that: democracy fosters growth by improving the accumulation of human capital and by lowering income inequality (p. 1341).

Although democracy has several advantages, it also has a number of drawbacks (see Lipset Seymour [17], p. 100ff). Pareto [62] defines democracy as that form of government in which the power to make laws is given to the not so large "governing class", which keeps the power by force and thanks to the support of the "governed class", which includes the vast majority of citizens. Pareto also points out that: "democracy can turn into plutocratic demagogy . . . . *the governing class is made up of people who try to govern in their own interest, arousing support through cunning and deceit*" (emphasis added, see also the remarks of Missiroli Mario in [62]). Mosca [63] notices that democracy can lead to the danger that the interests of a class which is given a defined social function might be conflicting with public interests (quoted by Bobbio [23]). Moreover, he claims that the political class actually holds power and it is characterized by the so-called "*power elites*" which, according to Schumpeter, compete in order to gain access to the government. The distribution of disaggregated power that is associated with democracy is also capable of marshalling forces against innovation. In fact, new democracies are often characterized by a set of parties which are organized on the *basis of presumptively general interests* and decide by means of compromising among themselves rather than according to the majority rule[7] (cf. also the discussion of Bobbio [23] on this topic).

In short, democracy based on "*power elites*" deciding by means of compromise can be subject to a crisis when it no longer manages to control the large interest groups competing with each other, thus slowing down the technological, economic, and social development of nations. Democracy is linked to market economies (capitalistic systems) and Judt T. (The wrecking ball of Innovation, vol. 54, n. 19, December 6, 2007 in the New York Review of Books) argues that Reich [64] shows as "[American supercapitalism] . . ., dominated by firms and financiers, . . . 'has spilled over into politics, engulfing democracy'. . . . [In fact, in the contemporary US democracy], public policy debates . . . ` are . . . matters of mundane competitive advantage in pursuit of

[7] In fact, in terms of game theory, if in democratic countries there were a full majority rule, the result would be a zero sum game: what the majority wins the minority loses. The balance in this system is re-established by the fact that the minority can become the majority over time. On the other hand, compromise is a positive sum game: both parties win something and the negotiation procedure preserves the balance of the social system.

Table 8
Driving technological, economic and social indicators of some socialistic vs. liberal economic systems (arithmetic mean).

		System		
		Socialistic-oriented	Transition economy	Liberal
		China	Russian Federation	United States
Democracy indices	Freedom House 1990–1996	1.00 *(0.00)*	4.43 *(0.45)*	7.00 *(0.00)*
	Polity 1990–1996	−7.00 *(0.00)*	4.40 *(0.89)*	10.00 *(0.00)*
Technological indicators	Patents (per million people) 1995–2001	11.98 *(7.87)*	135.47 *(27.62)*	541.06 *(95.46)*
	Research and development expenditure (% of GDP) 1995–2001	0.22 *(0.05)*	1.00 *(0.10)*	2.64 *(0.09)*
	Researchers in R&D (per million people) 1995–2001	481.11 *(73.94)*	3,522.62 *(161.56)*	3,981.3 *(167.00)*
	Royalty and license fees, payments (BoP, current US$) 1995–2001	0.79 *(0.48)*	0.47 *(0.85)*	41.98 *(13.25)*
	Royalty and license fees, receipts (BoP, current US$) 1995–2001	0.06 *(0.02)*	0.55 *(0.44)*	132.4 *(14.32)*
	Scientific and technical journal articles (million people) 1995–2001	7.32 *(1.50)*	115.09 *(6.70)*	625.27 *(36.38)*
Socio-economic indicators	GDP PPP (current international $) per capita 1994–2000	3004.02 *(581.32)*	6268.74 *(495.07)*	30,081.11 *(2640.16)*
	Population 1994–2000	1,240,377,857 *(24,345,748.1)*	146,671,286 *(1,211,972.1)*	275,152,143 *(7,450,863.2)*

Note: In parentheses and italics there is the deviation standard.

corporate profit´" in the short term rather than maximizing economic and social long term national strategic objectives. Although "supercapitalism" [64], thanks to technologies, has increased the productivity (cf. also [65]), it has also enlarged the inequality and this is a negative effect for modern democracy. The relationship between capitalism and democracy should not be taken for granted since "efficiency, growth and profit may not always be a precondition or even a consequence of democracy nor a substitute for it" (Tony Judt, ibibem, and see also [64]). *When democracy increases among countries of the world*–as claimed by Modelski and Perry III [14]–, *how will it transform*? The answer to this question is not simple because, if a philosophy of progressive history is applied, such as that of the philosopher Vico[8], the next step will be the perfecting of democracy. On the other hand, according to a cyclic-regressive view of history like that of Polybius, democracy is the last stage in a cycle which starts with monarchy, has aristocracy as its second phase and democracy as its third and last, then the process starts over again. Linstone [66] argues that: "Although the number of electoral democracies is increasing, we observe that such democracies readly elect an authoritarian leadership that then undermines democratic institutions" (p. 116, footnote n. 3).

Moreover, "democratization is not a continuous, smooth process but rather it moves forward in discrete increments" ([14], p. 371) that could be subject to shocks due to, for instance, terrorist, nuclear and spatial warfare. It is important to note that the recent "waves of terrorism . . . . 1970s to 2020s . . . especially by fundamentalist Islam" ([66], p. 115), is a form of warfare that is a continuous threat against freedom and democracies. In fact, the effects of terrorist attacks have a strong social impact–creating political, economic and financial instability in global and turbulent economies–, which affects economic and social systems in a negative way. The stability of modern democracy is based on security, however "the balance between security and freedom always presents a difficult choice. Both are desired but not always compatible" ([67], p. 232).

However, the future process of sustainable development of democracy (cf. [68]), in a condition of political and economic stability, should extend from the sphere of politics to that of society, in which every citizen is considered in relation to the multiplicity of his status: entrepreneur, consumer, etc. In addition, democratization depends on the country's level of economic development, its level of available resources and its long-term national objectives. Hence, the traditional concept of democracy, based on the extension of political and civil rights, should be applied in developing countries, whereas more developed countries should strengthen and broaden legal, economic and social equality (in firms, public institutions, etc.) for a future sustainable technological and economic development. Reform liberals claim that there is no inevitable tradeoff between substantive liberty and equity, on the one hand, and economic growth, on the other (cf. [69]). All this should occur within a framework of supranational economic and social cooperation, in order to create one economic system aiming at the progress of civilization and at overcoming future challenges. More than a century ago, J. S. Mill [70] argued that future democracies should be based on the idea of a free domestic and international market in order to increase technological progress and economic development. In other words, future democracies should foster human qualities, which are at the basis of knowledge, through the progress of *civil society*. Moreover, the equilibrium of democracies should be based on the theory of the *balance of powers*, in which each institutional body can hamper the others and/or collaborate with the others and none of the parties can go beyond their scopes

[8] Giambattista Vico (23 June 1668–23 January 1744) was an Italian philosopher, rhetorician, historian, and jurist. Vico is often claimed to have founded the modern philosophy of history.

and roles. In fact, Cicero believes that the best form of government is *Moderatum et premixtum* (cf. [23]). Mosca [63] states that the systems that have enjoyed a longer duration and have the merit of stability are based on mixed governing forces, which in modern economies should support the development of knowledge and, as consequence, the socio-economic growth of countries. Free economic systems have a spontaneous rationality that, in the opinion of Adam Smith, influences several decisions regarding the economy and guarantees the free circulation of ideas and goods, which increase the happiness of citizens as well as national wealth (for more discussion see [23,71,72]). New democratic systems should involve minimal intervention by states (cf. [73–75]) and their role should be that of fair referees, limited to the coordination of functional, economic, and cultural groups. Therefore, in the modern era of knowledge and converging technologies, in which scientists and entrepreneurs play a more and more crucial role, democracies should simply coordinate the economic and scientific subsystems in order to increase the future technological and social progress of countries and of the world.

However, if modern democracies have to survive to the "supercapitalism" [64], they need to be bound by something more than the pursuit of private economic advantage, particularly when the latter accrues to ever fewer beneficiaries: Mill also argues, inter alia, that the "idea of a society held together by pecuniary interest alone is essentially repulsive".

The comparison between "American supercapitalism", based on liberalism, and some socialist-oriented systems, (see also Galbraith [76]) such as China and the Russian federation (which is a transition country), is showed in Table 8. Despite some drawbacks of most free and democratic countries, the results show that the USA has higher values of democracy indices, innovation and economic indicators than socialist-oriented systems. According to Von Hayek [73], the pioneer of neoclassical liberalism, these higher economic performances are due to an efficient exchange of resources through the price mechanism in free markets. In fact, market processes are examples of democratic actions, so that Marshall [77] defined competition as economic freedom. Von Hayek also criticizes centrally planned economies that cannot constitute a proper economic solution because of the complexity of economic systems and he predicts the economic failure of pure socialist systems. In fact, socialist systems operate on different principles than liberal systems (see also the discussion of Lipset Seymour [17], p. 100ff). The establishment of a modern new socialist system in the Russian federation would release industry from market frictions and lead to the blooming of technological progress. Bukharin and Preobrazhenskii [78] argued that in "`communist society . . . every technical advance would be immediately adopted´" (quoted by Lewis [80], p. 129). In fact, rapid technological advance was achieved by adapting Western technology to Soviet conditions. Progress was uneven; resources were deliberately concentrated on key goods producers and defense industries. In these selected areas, the technological level of the advanced capitalist and more democratic countries was often reached, while much of the rest of the economic system lagged behind (cf. [79], p. 584, 588 and 592, passim and also [80]). In addition, the absence in the Soviet Union of high market competition tended to cause stagnation and lack of concern with practical results in R&D. The separation of research and development (R&D) from production, in addition to the relative under-development of experimental production facilities, reinforced the tendency of enterprises to be slow in absorbing research results into production ([79–80]). Moreover Lewis ([80], p. 129) claims that: "subsequent developments in Soviet industry, particularly during the drive for industrialization . . ., created an environment basically hostile to endogenous technological change". However, now Russia is a transition economy where universities have been creating human capital for managing competition and market processes of the new economic system. As for China, it is based on a wide socialistic structure, which shows lower scientific, innovation and economic performances than liberal systems over time. "China is characterized by the subordination of judicial, trade union and religious bodies to the all-dominating Chinese Communist Party (CCP)" (see [81]). The poor technological performance may also be the result of China's lack of freedom in several markets and public/private institutions [81]. However, the "Chinese government is far more efficient than most other authoritarian regimes, delivering economic growth and public services effectively in much of the country. In addition, although the government may seek to represent and serve the public, it is clear that the refusal to bow to foreign concepts of democracy and to surrender the supremacy of the CCP means that China's political leaders will inevitably fall short in their attempts to achieve their socio-economic goals" ([81], op. cit.). According to the Economist Intelligence Unit [81] the "main priority of the Chinese government is to support the economy, but wider reforms to increase democracy will not occur. How far China has gone in transforming its economy is a matter of debate. Unarguably, it remains a place where companies face heavy direct and indirect state control. However there is also a change and China has prospered as broader economic freedoms contributed to growth".

8. Concluding remarks

This paper shows a main insight: democratization as a process is a determinant of technological and economic change, *i.e.* democratization is an antecedent process (cause) to technology activity (effect), which is also a major determinant of economic growth [82,1,83]. In addition, another main primary finding of this paper is that democratization generates greater production of technology, *i.e.* technical and economic change. These results are important, very important in the modern era to sustain future technology and economic growth patterns in view of the accelerating globalization and market processes.

What countries now need for improving democratization is to bring out the value of people and to increase the education of human capital and, as a consequence, the intangible capital accumulation, based on knowledge, that has a greater and greater influence on technology production and on the competitive advantage of firms and countries [84]. In fact, according to Lipset [17], Barro [18] and other scholars, the human and social capital triggers the democratization and shapes institutional and productive structure of countries. Although democratization and technological innovation have a high

positive association, the evidence of a causal effect of democratization on technological and economic change needs to be investigated further on, considering several historical, social, economic and institutional factors that can affect this vital relationship. As a matter of fact, the philosophical concept of democratization is an evolutionary process and "is rather a complex of characteristics which may be ranked in many different ways" (Lipset Seymour [17], p. 73): in the *first stage*, when the country is new born, democratization is focused on constitution, civil right, right to vote, creation of political institutions, etc.; this basic democratization drives the fruitful effects for producing and absorbing technical knowledge and as consequence improving income nationwide; in the *second stage*, when the country is mature, democratization is a wider concept in comparison with the previous one that generates social progress such as associations with the aim to foster the common goods, efficient economic governance, the right to vote in non-political places (e.g. firms, universities, etc.), etc. The latter concept of democratization generates mutual interactions, by cross fertilization effects and positive feedback loops, with the technological patterns and income nationwide (cf. also [21]).

In addition, it is important to note that this analysis, focusing on socio-economic–institutional elements, is a difficult task due to the instability of human behavior and continuous new events, such as financial shocks, terrorist warfare, primary energy resources crisis, and so on. In fact, the socio-economic relathionship suggested is valid on a specific spatial-temporal context, and it can change over time and across countries.

Although democracy has some drawbacks and threats that cause political and economic crisis (cf. Lipset Seymour [17], pp. 100–103), as showed in the course of the economic history, the democratic institutions have several advantages, in comparison to other political regimes, in generating technological progress and economic growth. Modelski and Perry III [14] argue that: "The principal advantage of democracy lies in its capacity for enhancing cooperation and managing conflict. . . . . No wonder that people increasingly prefer to live in democracies, . . . No wonder then that the example of democracy is contagious, and that it spreads and snowballs." (p. 367).

Therefore, sustainable democratization should be much more diffused across developing countries and improved where already applied (i.e. developed countries).

The findings of the paper lead to the conclusion that policy makers need to be cognizant that democratization is a process that triggers the origin, diffusion and utilization of technology within economic systems. As a matter of fact, the main effects of technological innovation driven, ipso facto, by the democratization process may be an increase in factor productivity and purchasing power, due to cost and price reductions that boost the aggregate demand and, as a consequence, economic growth paths [52]. This cornerstone of the modernization theory and new economic growth patterns should be achieved considering the joint coevolution and intensive interaction of democratization and technological change, in order to distribute the total wealth generated among the widest fraction of population. These insights are important, very important for economists, policy makers and politicians, since in the future they will have to focus much more on encouraging sustainable democratization and competitive markets that, as proven, may support the driving forces for technological progress, economic growth of countries, and therefore the wealth and wellbeing of nations.

Appendix A. Partial correlations

Table 1A
Partial correlation with other indicators.

Control variables	Variables	Freedom House 1990–1996	Polity 1990–1996	Vanhanen 1990–1996
LN GDP PPP current international $ 1994–2000	Scientific and technical journal articles per million people (1995–2001)	0.68	0.54	0.73
	Significance (2-tailed)	0.00	0.00	0.00
	df	459	459	459
LN population 1995–2001	Scientific and technical journal articles per million people (1995–2001)	0.70	0.58	0.77
	Significance (2-tailed)	0.00	0.00	0.00
	df	479	479	479
LN GDP PPP current international $ 1994–2000	R&D expenditure as % of GDP (1995–2001)	0.36	0.32	0.29
	Significance (2-tailed)	0.00	0.00	0.00
	df	155	155	155
LN population 1995–2001	R&D expenditure as % of GDP (1995–2001)	0.38	0.29	0.34
	Significance (2-tailed)	0.00	0.00	0.00
	df	167	167	167
LN GDP PPP current international $ 1994–2000	Researchers and technicians in R&D per million people (1995–2001)	0.43	0.34	0.47
	Significance (2-tailed)	0.00	0.00	0.00
	df	173	173	173
LN population 1995–2001	Researchers and technicians in R&D per million people (1995–2001)	0.36	0.26	0.45
	Significance (2-tailed)	0.00	0.00	0.00
	df	183	183	183

Appendix B. Econometric modelling

Table 1B
OLS results — royalty and license fees payments equations.

Explanatory variables	Models and dependent variable: Ln $s_{i,t}$ = royalty and license fees payments Bop current US$ 1995–2001					
	Leading indicator model 1			Dynamic model 2		
	1A	1B	1C	2A	2B	2C
A. Freedom House 1990–1996	0.756***	–	–	0.041**	–	
	(0.064)			(0.020)		
B. Polity 1990–1996	–	0.131***	–	–	0.008	–
		(0.020)			(0.005)	
C. Vanhanen 1990–1996	–	–	0.022***	–	–	0.003**
			(0.003)			(0.001)
Constant	-1.766***	1.495***	1.292***	0.050	0.202***	0.143***
	(0.405)	(0.298)	(0.296)	(0.093)	(0.038)	(0.052)
Ln $s_{i,t-1}$	–	–	–	0.932***	0.942***	0.935***
				(0.014)	(0.012)	(0.013)
R^2 adjusted	0.287	0.113	0.159	0.959	0.959	0.959
Durbin–Watson	2.015	1.998	2.029	1.907	1.913	1.907
F test sign.	0.000	0.000	0.000	0.000	0.000	0.000
N. cases	339	339	339	338	338	338

***Parameter is significant at 1 percent; **parameter is significant at 5 percent; *parameter is significant at 10 percent.
Note: the Prais–Winsten estimation method based on the autoregression procedure estimates true regression coefficients from time series with first-order autocorrelated errors. Standard errors are in parenthesis. Moreover, *i* subscripts denote countries, *t* subscripts denote time.

Table 2B
OLS results — scientific and technical journal articles equations.

Explanatory variables	Models and dependent variable: $z_{i,t}$ = scientific and technical journal articles per million people (1995–2001)					
	Leading indicator model 1			Dynamic model 2		
	1A	1B	1C	2A	2B	2C
A. Freedom House 1990–1996	52.005***	–	–	0.742**	–	–
	(4.213)			(0.335)		
B. Polity 1990–1996	–	11.073***	–	–	0.098	–
		(1.252)			(0.085)	
C. Vanhanen 1990–1996	–	–	4.453***	–	–	0.061**
			(0.334)			(0.025)
Constant	−83.888**	112.163***	8.055	−1.537	1.175*	−0.099
	(34.415)	(32.688)	(31.944)	(1.449)	(0.634)	(0.855)
$z_{i,t-1}$	–	–	–	1.003***	1.005***	1.003***
				(0.003)	(0.002)	(0.003)
R^2 adjusted	0.234	0.134	0.276	0.998	0.998	0.998
Durbin–Watson	1.853	1.869	1.880	1.924	1.921	1.934
F test sign.	0.000	0.000	0.000	0.000	0.000	0.000
N. cases	493	493	463	462	462	462

***Parameter is significant at 1 percent; **parameter is significant at 5 percent; *parameter is significant at 10 percent.

Table 3B
OLS results — R&D expenditure as % of GDP equations.

Explanatory variables	Models and dependent variable: $u_{i,t}$ = R&D expenditure as % of GDP 1995–2001					
	Leading indicator model 1			Dynamic model 2		
	1A	1B	1C	2A	2B	2C
A. Freedom House 1990–1996	0.201***	–	–	0.004	–	–
	(0.040)			(0.005)		
B. Polity 1990–1996	–	0.049***	–	–	0.000	–
		(0.014)			(0.001)	
C. Vanhanen 1990–1996	–	–	0.013***	–	–	0.000
			(0.003)			(0.000)
Constant	0.122	0.870***	0.590**	−0.026	−0.012	−0.012
	(0.247)	(0.160)	(0.185)	(0.025)	(0.015)	(0.018)
$u_{i,t-1}$	–	–	–	1.039***	1.041***	1.042***
				(0.010)	(0.010)	(0.010)
R^2 adjusted	0.121	0.059	0.099	0.987	0.987	0.987

Table 3B (*continued*)

Explanatory variables	Models and dependent variable: $u_{i,t}$ = R&D expenditure as % of GDP 1995–2001					
	Leading indicator model 1			Dynamic model 2		
	1A	1B	1C	2A	2B	2C
Durbin–Watson	2.071	2.094	2.097	1.766	1.772	1.773
F test sign.	0.000	0.000	0.000	0.000	0.000	0.000
N. cases	170	170	170	169	169	169

***Parameter is significant at 1 percent; **parameter is significant at 5 percent; *parameter is significant at 10 percent.

Table 4B
OLS results — researchers and technicians in R&D equations.

Explanatory variables	Models and dependent variable: $r_{i,t}$ = researchers and technicians in R&D per million people 1995–2001					
	Leading indicator model 1			Dynamic model 2		
	1A	1B	1C	2A	2B	2C
A. Freedom House 1990–1996	386.030*** (77.542)	–	–	16.252 (28.989)	–	–
B. Polity 1990–1996	–	85.112*** (24.485)	–	–	−0.203 (8.957)	–
C. Vanhanen 1990–1996	–	–	27.901*** (5.044)	–	–	1.009 (2.135)
Constant	−71.220 (453.313)	1406.416*** (263.467)	662.918** (297.738)	64.159 (146.759)	136.464 (82.531)	103.980 (98.889)
$r_{i,t-1}$	–	–	–	0.913*** (0.031)	0.919*** (0.030)	0.912*** (0.033)
R^2 adjusted	0.110	0.052	0.134	0.844	0.844	0.844
Durbin–Watson	2.085	2.097	2.071	2.118	2.128	2.119
F test sign.	0.000	0.000	0.000	0.000	0.000	0.000
N. cases	186	186	186	185	185	185

***Parameter is significant at 1 percent; **parameter is significant at 5 percent; *parameter is significant at 10 percent.

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