Driving Change: The Interplay of Science and Revolutions in Modern History

Mehr Un Nisa Shahid
Lahore University of Management Sciences

What are the driving forces behind a revolution? While it is not easy to identify a single transformative factor in the course of history, science has always had a key role as an indirect agent of social and economic change. Different countries' scientific output is directly linked to whether they are merely information and service economies, or hold active manufacturing industries. In particular, since the birth of Western Enlightenment, crucial elements including transportation, communication, agriculture, medicine and even the "key democratic institution of voting, are profoundly dependent on science and technology" (Sagan, 1996). In fact, the rise of scientific values in many parts of Europe and America has been coincident with the appearance of parliamentary democracies and in some cases the overthrow of monarchies in these regions. Dennis Overbye goes as far as to say that "science and democracy have always been twins" (Overbye, 2009).

At the same time, political regimes also heavily influence the evolution of science. This is because the funding that science and technology institutes receive, the freedom to pursue critical inquiry, the research grants available to scientists, the kind of education system that is in place and the overall emphasis laid on social welfare, strongly rely on government inclinations. Thus exploring the historical roots of how governments and societies integrated scientific thinking can yield useful lessons. This essay will focus on how science goes hand in hand with the structural transformations that are characteristic of a revolution. I will analyze particular aspects of the French, American, Russian, and Chinese revolutions to gauge not only the role of science in shaping the causal forces behind these revolutions, but also the impact these violent social changes had on the development of science. Finally, in light of the relationship underlined between science and political changes throughout the essay, I will comment on what possible future directions the Arab Spring may take in the specific domain of science and society.

Before moving on to specific cases in history, it is important to shed some light on certain characteristics of scientific thinking—particularly those that are held as "values of science"—that will enable us to understand why science could challenge totalitarianism, or why science flourishes in one kind of society but not another. Science by its very nature is anti-authoritarian (Campbell, 2010). Every step of the scientific endeavor—from the formulation of a theory to its testing by experiment—contains repeated questioning of ideas, skepticism, and a rigorous demand for verifiable evidence. There are "no appeals to authority or voting

procedures to create consensus" (Kuhn, 1970), which means the effects of human whims on the results are absent. In fact, as pointed out by Thomas Kuhn, science advances by overthrowing existing paradigms (Kuhn, 1970). Progress in fundamental science relies on taking an existing world-view and proving that our thinking needs refinement. This also implies that "science is vulnerable every single day of the year, to experiments, to revisions and to complete debunking by new generations of scientists" (Campbell, 2010). The notion that nature can be investigated by a form of reasoning that is independent of the cultural, social or religious background of the individual applying it is in itself a unique binding force capable of cutting across class differences. There is no absolute leader or a grand plan in this scheme of things creating a unique culture that teaches certain values. These values include "honesty, doubt, and respect for evidence, openness, accountability and tolerance and indeed hunger for opposing points of view" (Overbye, 2009). Arguably, a democratic culture also espouses and thrives on similar values, including the willingness to embrace debate, respect for the rule of law, and the freedom to shun received wisdom (Overbye, 2009). However, science does not simply create structural changes in a society by virtue of its ability to alter people's way of thinking. Rather it goes on to have deep-rooted consequences for the economic sphere that affect societies. By providing the requisite knowledge and skills, science and technology became integral to the enterprise of industrial capitalism that transformed the modes of production and infrastructure of various societies (Freeman & Soete, 1997).

The foremost example of how the scientific way of thinking inspired people to stand up to a tyrannical regime is that of the French Revolution. Its ideological foundations can be directly traced back to the age of Enlightenment in Europe when reason and scientific inquiry began to overtake the traditional sources of knowledge. The likes of Isaac Newton and Galileo Galilee had already shown that the universe was subject to strict laws that could be used to predict the trajectories of objects under given circumstances. The success of an elegant mathematical formulation in explaining and predicting the behavior of the universe, inspired many philosophers to look for similar natural laws governing people and society. John Locke studied Newton's theories carefully and was amongst the first who considered the idea of natural laws or natural rights for humans. He argued passionately for the freedom of religion and wrote that every person has the natural right to defend his "life, health, liberty or possessions" (Cline, 2011). Locke was also influenced by how the scientific process demands skepticism and doubt. Kelly Cline writes:

> He argued that because we have so much doubt about so many things, each person should have as much freedom as possible. Because we really don't know the best way to organize and improve our society, all people should make their own decisions about what they want to do with their own lives. (Cline, 2011)

This point of view along with the ideas of French philosophers like Voltaire and Rousseau on civil liberties, religious freedom, race, slavery, and equality of all humans became immensely popular in the aristocratic circles of Paris. But once these ideas trickled down to the commoners, they came to undermine the very existence of a society with a powerful clergy, nobility and monarchy. The burgeoning political crisis, aggravated by Louis XVI's financial mismanagement and serious food shortage in France provided the stimulus to put the flourishing ideas into practice (Shahid, 2012).

The effects that the French revolution had in the realm of science are also evidence of how deeply the development of science is embedded in culture and politics. Here it must be pointed out that, by evolution of science I simply mean the advancement of scientific culture, its pace of spread and its trajectory. It is very different from the method of science that is completely independent of the social and cultural context within which a scientist operates. The results and products of science are only dictated by nature, not social movements. In the aftermath of the revolution, science initially faced an assault in the Jacobin dictatorship. Seen as incompatible with the radical premeditated ideals of the newly proclaimed French Republic, science was slandered as a stubborn bastion of aristocracy and a tyranny of the intellectual (Gillespie, 1959). Lavoisier was executed, Robespierre rejected Condorcet's proposal to base education on science, and preferred a Spartan education in civic virtue. Paradoxically, natural history and biology were seen more in line with the Republic's vision:

> For the Revolution, which suppressed organized physics, provides institutional testimony to the deep instinct of romanticism to seek shelter in the humane metaphors of biology, which proposed organism rather than mechanism as the model of order. The Convention transformed the old *Jardin du Roi* into the modern Museum *d'histoire naturelle*, and established twelve chairs of biological science. This was a truly munificent provision. It made possible the great age of comparative anatomy and the French tradition of experimental biology (Gillespie, 1959).

It was later after the Thermidorian reaction that amends were made. There was massive revamping of scientific institutions and many new ones were erected including the Ecole normale and Institut de France. The need to reorganize science for teaching resulted in a general movement of rationalization. One of the most remarkable initiatives in this regard was the introduction of the metric system in 1799.

Similarly, the history of American Revolution is abounding with evidence of the diffusion of scientific knowledge at many levels. Ideas from the Scientific Revolution and Enlightenment were well-received in America and gained institutional support as Hindle notes:

> Works on science were very well represented in individual libraries as well as in some of the outstanding institutional libraries, notably the Library Company of Philadelphia. Books on science, especially natural history, were imported, advertised

> in newspapers, and sold in the bookstores. Science was honored by educated men and respected in some measure much more widely (Hindle, 1976).

Thomas Jefferson, James Madison, Alexander Hamilton and many of the other founding fathers of the United States carefully studied Locke's ideas about freedom and natural rights. When Jefferson wrote the Declaration of Independence, he echoed Locke, writing about "life, liberty, and the pursuit of happiness" (Cline, 2011). The role of a scientist of Benjamin Franklin's caliber in the revolutionary struggle has a lot to say about the penetration of science in America. Hindle recognizing Franklin's importance writes:

> Franklin's achievement was not unrelated to the colonial environment. Prevailing attitudes toward science and supports available for science made it possible. He worked integrally with a circle of Philadelphia experimenters. He used the library resources available to him, and pursued his investigations in intimate relationship with the scientific community and scientific institutions of the mother country (Hindle, 1976).

The American War of Independence was one of the first occasions when espionage made extensive use of science, especially cryptology and chemistry for encoding ciphers. The movement of armies into America gave some Americans first-hand acquaintance with French medicine and British surgery. The severing of ties from Britain also resulted in other conditions conducive to the advancement of science. The Baconian line of thinking had convinced leaders of the need for science and technology as a tool of material welfare (Hindle, 1976). Moreover, America by virtue of its location had a considerable advantage for pursuing certain fields, for instance natural history and astronomy. In the largely unexplored patches of land, many species were studied adding great value to the field of taxonomy. Similarly, there were many untapped vantage points as far as astronomical observations were concerned, leading to the springing up of many observatories across the country (Bartusiak, 2009). In addition, American institutions replaced many of the British institutions that had earlier served the cause of colonial science. In the Decade of Discontent, the first general American scientific society, the American Philosophical Society was established; the society went on to publish the first general scientific journal, the *Transaction*. Thus isolation from Britain led Americans to rely on and develop their indigenous resources. These conditions coupled with the conviction that the government should support science and that science should aid and advise the government, laid the foundations of a progressive post-revolutionary United States.

In contrast to the American Revolution, the organization of scientific research in Soviet Union was also profoundly affected by revolution in a different manner. C.D. Harris points towards the ideologies of communism in order to explain the dissimilarities:

> The Communist Revolution, in sharp contrast to the American, was developed on the basis of great faith in the power of government to transform society for the betterment of man… They have aspired fundamentally to remold society through a state monopoly of the production of goods, of means of communications, of education, and of science. Thus, whereas much of the support for science in the United States comes through private or state universities, through individual interests, or through great corporations, in the Soviet Union support comes from the state and is directed in accordance with comprehensive state plans and policies (Harris, 1959).

The communist regime recognized the role of science as an important tool as far as its goal of creating a socialist society was concerned. Lenin wrote about how the natural riches of Russia were to be tapped using latest technological methods in order to unleash new productive forces (Keldysh, 1967). This vision broadly, served as the motivation for heavy investment in science following the October Revolution. Many breakthroughs were made, including the creation of national science centers, developments in atomic physics, electronics, and most notably Russia's space program. At no point in time, was science separated from the cause of advancing Communism. While, having science linked to a state's revolutionary ideals sometimes has the benefit of ensuring funding and support of research, the persistence of dogma also led to selective support of research in Soviet Russia. Research that was seen as irrelevant or impractical was often rejected. This approach was particularly strict during the time of Stalin, whose ideological control of science lead him to endorse the Agronomist Trofim Lysenko. Lysenko rejected Mendelian genetics as "bourgeois pseudoscience" and instead supported hybridization theories that caused widespread agricultural destruction and major setbacks in Soviet biology (Dr. Alakbarli, 2005). Many scientists, who publicly opposed Stalin were imprisoned. In spite of heavy ideological dictatorships in Russia, science has progressed a great deal. C.D. Harris points towards evidence of how Russia "has succeeded admirably in training and [by] productively utilizing a very large number of scientists, it has been able to achieve high levels of scientific effort in many fields, and that it has been able strongly to motivate scientists by a system of high financial rewards, high social status, and appeals to patriotism and social responsibility as well as to scientific curiosity" (Harris, 1959).

China also embodies an interesting case where the forces of nationalism, ideology and science have manifested themselves in epochs of conflict and mutual benefit. The earliest seeds of a political movement in China—aimed at challenging the imperialist forces—were sowed with the weakening of the Manchu state in the face of British colonial incursions during the 19th century. Some scholars concede that among the main reasons for the Chinese defeat during the opium wars was the superior weaponry of the British (Harman, 2008). The recognition of industrial inferiority and backwardness by the Chinese intellectuals gave way to sentiments echoed later in the first Chinese revolution of 1919. The students and intellectuals felt that a modernization of China along the lines of Western Enlightenment was being held back by Confucian orthodoxy.

The students and teachers set out to challenge those traditional shackles through a "new style" educational establishment throughout the country, proclaiming science as a cornerstone of the alternative tradition (Harman, 2008). In fact, one of the slogans used in the May 4th Movement was, "Science and Democracy" (Gungwu, 1990). Chen Duxiu and Hu Shi were two professors particularly concerned with laying emphasis on modernity and scientific thinking. The latter launched a "common language" movement essential for promoting science and democratic ideals as well as spreading the message of liberalism, freedom of thought and speech, of faith, of association; all supported by laws that protected private property and human rights. (Gungwu, 1990)

It was after the First World War that a majority of Chinese intellectuals' focus shifted from liberal democracy to a more radical revolution along the lines of the Communism. Again, as in the case of Russia, Marxist intellectual monopoly stood in the way of free inquiry on certain occasions. Gungwu presents this as a problem that resulted from PRC's mistaken presumption that Marxism-Leninism itself is an all-encompassing scientific way of thinking writing, "it also argued quite unconvincingly that all other forms of scientific thought were class-based (in particular, the bourgeois class) and therefore biased and ultimately unscientific" (Gungwu, 1990).

The aforementioned attempts to make science subservient to Marxism, along with the division it created in the revolutionary camps manifests itself in modern China in two ways. Firstly, Marxist dogma despises science when it represents dissent. For example, Dr. Fang Lizhi's research on cosmology, and support of the Big-Bang theory in particular, invited criticism because his work was in contradiction to dialectical materialism (Overbye, 2009). Secondly, instead of being valued as a worthy endeavor to seek fundamental answers about the universe, science is only looked up to for the practical benefits it may provide. This has somewhat restricted the practice of science to the development of technology and industry only. Consequently, while heavy industrialization has yielded many economic benefits to China, the application of the scientific method to produce new non-Marxist ideas in politics, economy and culture is limited.

Having explored how science has fared in times of political turmoil though four different historical revolutions, we are now in a position to do a comparison with modern day Middle East. Traditionally, the Arab world has considerably lagged behind the rest as far as scientific productivity is concerned. For example, the region on average spends just 0.38 percent of its GDP on research and development compared to a global average of 1.7 percent. Similarly, the region has just 407 researchers per one million people, compared to a global average of 1,544 (Moneef R. Zou'bi, 2011). However, just prior to the Arab Spring a number of Middle Eastern countries were witnessed taking steps towards the development of science and Technology. These include the establishment of centers like KAUST

(King Abdullah University of Science and Technology), SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East), which are trying to attract qualified researchers and students from all over the world for the benefit of Middle Eastern economies. How far will the effects of these multi-billion dollar ventures trickle down to the masses, in these countries is yet to be seen. However, the violence and political turmoil triggered in places like Yemen, Syria and Bahrain have raised the concern about whether or not these countries will be able to maintain their investment in R & D.

On the other hand, there are places like Egypt where besides widespread corruption, the Mubarik regime was also known for underpaying scientists and intellectuals. Educated but unemployed youth demanding meritocracy had a tremendous involvement in the protests against the regime (Tatalović, 2012). In this way, the Arab Spring has revealed a huge potential work force—earlier held back by corruption—now willing to engage productively with the economy as long as the new regimes create employment opportunities by investing in science and technology. The post-Mubarik government in Egypt, for example, has announced a plan to establish US dollar two billion Zewail City of science and technology. Since the forces that move in to fill the power vacuum in the aftermath of the revolution prioritize water, food and energy security as well as the creation of jobs, the Arab Spring holds considerable promise for the development of science.

Science tends to flourish in societies that value evidence, excellence and transparency in every sphere; be it governance or academia. In addition, an active top-down approach on part of the government to promote institutional science has always appeared to benefit science's advancement through history. We have observed that revolutions aimed at establishing democracies, generally tend to provide such a space where science can thrive. While the free pursuit of science supported liberal democracy, liberal politics supported science (Ezrahi, 1990). Exceptions also occur, where an authoritarian regime also ends up supporting science for ideological reasons, but only as far as the scientific endeavor does not conflict with the ideology. It would be interesting to see how the Islamist government that has taken Mubarik's place—having announced an increase in science and technology spending—will let its stance evolve if at any point science appears to be cultivating liberals values that may not be acceptable to the non-secular government. Regardless of what course they take, revolutions through history have conclusively demonstrated that science has always had a positive impact as far transforming societies in concerned.

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