INNOVATION POLICY

MINERVA PROGRAM - SPRING 2014

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The opinions expressed in this paper reflect research efforts towards understanding innovation policy and do not necessarily express the views of the Ministry of Communications or the Brazilian Government

Contents

I) Introduction

"The opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory to such concerns as U.S. Steel illustrate the same process of industrial mutation—if I may use that biological term—that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism. It is what capitalism consists in and what every capitalist concern has got to live in." (Schumpeter, 1950)

According to Joseph Schumpeter, capitalism can only be understood as an evolutionary process of creative destruction and continuous innovation. The relevance of innovation to capitalism and capitalists is evident, but why should governments worry about innovation?

An economic answer to this question came from Robert Solow that won the Nobel Prize for his long-run economic growth model. The model shows that productivity is the key to increases in GDP - where productivity can be measured by the ratio GDP per worker. But, how to increase productivity? One way is increasing the capital stock, i.e. physical capital, infrastructure, machinery. This is especially important for developing countries that lack adequate highways, airports, ports, trains. Another way is imposing a positive technological change, an innovation that raises the amount of output produced with a given amount of labor and capital.

Later Paul Romer showed that economic growth does not arise just from adding labor to more capital, but from new and better ideas expressed as technological progress. And what influences technological progress is the accumulation of knowledge capital, the result of R&D and innovation.

Thus innovation accrues long-run economic growth. And despite ideological limitations on the role of government and the concept of free market economics, both developed and developing countries - liberal or not - are pursuing policies and national strategies towards innovation.

The US has a long history on innovation. It was the home nation of the internet and of biotechnology. Past investments in scientific research produced products and processes that guaranteed the country's economic and military leadership. Other nations are racing to improve their capacities to innovate by even adopting a highly interventionist set of policies and programs.

Brazil lags behind on the global innovation index (64th position of the ranking The Global Innovation Index, 2013), in spite of the innovation policies that have been adopted. While its strengths rely on the academy (scientific publications, score of the three best universities), its weaknesses lay on the institutions (political, regulatory, and business environment) and market sophistication (credit, investment, and competitiveness).

This work attempts to examine the main US and Brazil innovation policies and institutions with a view of enlightening the discussion on the improvements that can be made to pave the route of innovation and consequently the path towards economic growth.

Section 2 presents some of the R&D figures that are used to indicate the R&D intensity of a country. Section 3 gives a background on Innovation theory, the process towards innovation and innovation S-curve. Section 4 outlines some of the key features necessary to impulse the innovation engine. Section 5 provides an overview of US policies and institutions. Section 6 outlines Brazilian's initiatives towards innovation and highlights some gaps that need to be surpassed towards a strategy on innovation and competitiveness.

II) R&D figures

a) R&D Expenditure

R&D expenditure is seen as a long-term investment in innovation. In fact, global gross expenditures on R&D (GERD) over the last decade has grown faster than global GDP, an indication that economies are more knowledge and technology intensive.

A measure of how much of a nation's economic activity is devoted to innovation through R&D is the ratio R&D/GDP. Many governments target 3% of GDP in pursuit of developing knowledge based economies.

Currently, the US is the single largest R&D performing country, making up one-third of the global spending, with a GERD of US$ 465 billion (2.8 % GDP) in 2014 (Battelle, 2014).

China has sustained a growth in GERD for a number of years, regardless to the global economic cycle, having surpassed Japan in 2010, it is now second on the list, having a forecast GERD of US$ 284 billion (2 % GDP) in 2014.

Japan and Germany follow with forecast expenditures for 2014 of US$ 165 billion (3.4 % GDP) and US$ 92 billion (2.9 % GDP) respectively. Brazil is ranked as the 10th country per volume of GERD, with US$ 33 billion (1.3 % GDP).

The source performer matrix for the US shows that US industry funds about 66% of all R&D. Brazil's numbers for 2013 indicate that industrial research accounts for 44% of its total R&D budget (Battelle R. a., 2013). As a comparison, the EU average is 54%, while in Asian countries industry funding ranges from 60% upwards.

Moreover, according to (Cruz, 2011), around two thirds of the Brazilian public funding reflect tax incentives given as a compensation for private investments in R&D.

Figure 1: The 2014 Source-Performer Matrix

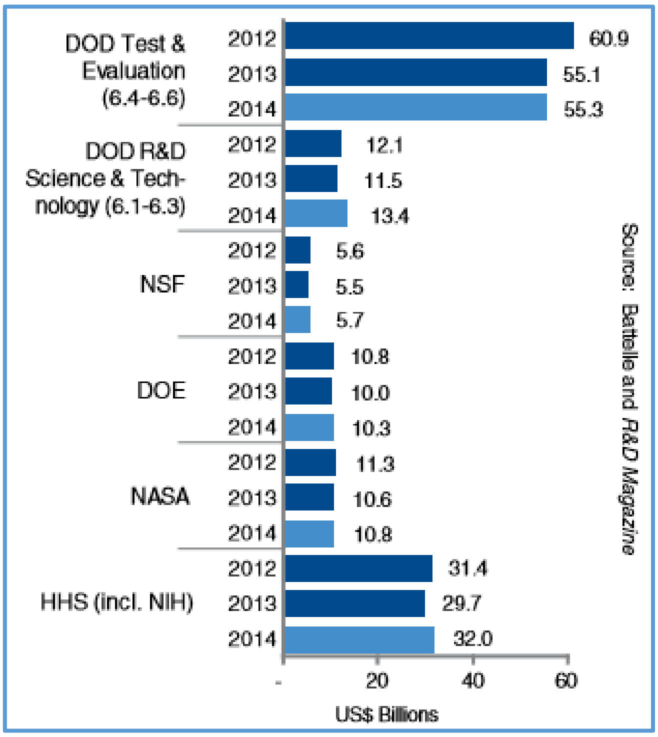
US$ Billions (Percent Change from 2013)

Source of Funds \ Performer of R&D	Federal Gov't	FFRDC (Gov't)	Industry	Academia	Non-Profit	Total
Federal Government	$35.7 1.0%	16.5 1.1%	27.8 1.1%	37.1 2.5%	6.0 1.1%	123.0 1.5%
Industry		0.3 0.7%	302.5 4.1%	3.3 1.7%	1.4 0.5%	307.5 4.0%
Academia		0.1 0.1%		13.2 2.0%		13.3 1.9%
Other Government		0.0 0.1%		4.0 1.1%		4.0 1.0%
Non-Profit		0.1 0.2%		5.3 2.2%	11.3 4.0%	16.7 3.4%
Total	$35.7 1.0%	17.0 1.0%	330.3 3.8%	62.9 2.2%	18.7 2.7%	464.5 3.2%

Source: Battelle, *R&D Magazine*

Funds from US Federal Government are sponsored greatly by the Department of Defense and Department of Health and Human Services, as it can be observed in the graph of leading federal sponsors of R&D.

Figure 2: Leading Federal Sponsors of R&D



III) Innovation theory

a) Innovation Process

In the private sector, innovation consists of transforming discovery, research and development in the implementation of new products or processes. The result obtained needs to add value to the firm.

The chain of activities called innovation is consistent with the 3Ds: Discovery, Development and Deployment. Other definitions of the activities in the R&D process have been proposed by the US Department of Energy and by the Frascati Manual.

Below is a common sequence of activities.

> Basic Research: A study directed towards acquiring knowledge or understanding of fundamental aspects of phenomena and of observable facts without specific applications.
>
> Applied Research: A study directed towards acquiring knowledge or understanding with a view to the production or improvement of products, processes and systems that meet specific needs.
>
> Development: Application of preexisting knowledge or understanding, aimed at proving new products, processes, systems and services, including the improvement of products and processes to meet specific requirements.
>
> Demonstration: Implementation of a technology in a production or commercial setting to prove the technology's real world performance, reliability, manufacturability, economics, or scalability.

In addition, technical support services might be needed to implement research projects, development or demonstrations and to train human resources devoted to these activities.

Several companies have succeeded in creating an innovation dynamic that has resulted in new profitable products. Examples include Google, IDEO, 3M, Apple.

Other companies, however, that made erroneous decisions along the innovation process have halted the implementation and commercialization of products and have been outshined by competitors.

The Xerox Palo Alto Research Center (PARC), for example, developed technology for personal computers (e.g. mouse, graphical user interface, Ethernet) that was never commercialized by the company. The business managers of Xerox were not able to foresee the impact of the research that took place at the PARC and the technology produced ended up being absorbed and economically explored by Apple and other competitors.

Another unsuccessful case was the Nokia mobile phones business. Nokia had already developed the sorts of devices that consumers are using today, however it did not bring them to market. On the contrary, it shifted the development focus from smartphones back to basic phones when iPhone overturned the market.

b) Innovation S-curve

"Practically every enterprise [is] threatened and put on the defensive as soon as it comes into existence. (Schumpeter J. A., 1939)*"*

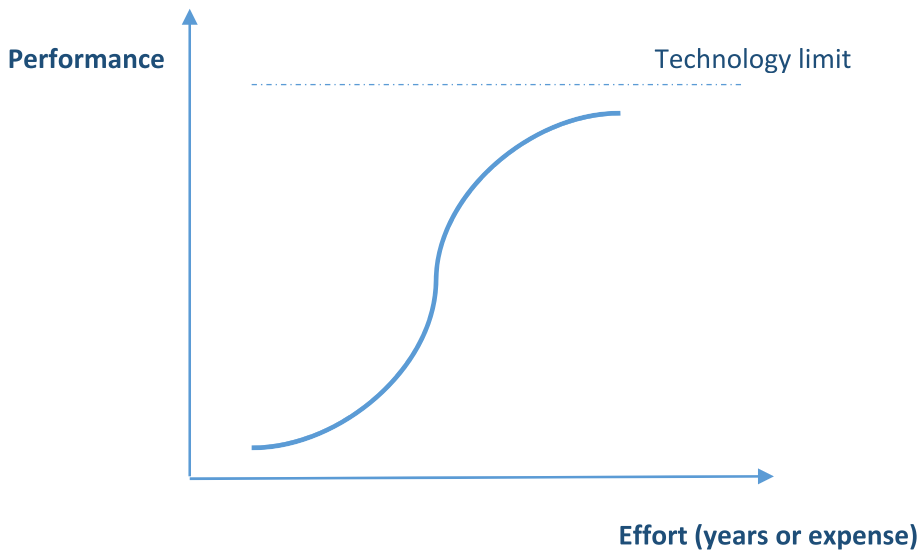
The rate of a technology's performance improvement can be shown to confirm to an s-shape curve (Schilling, 2013). It typically shows slow initial improvement, then accelerated improvement, then diminishing improvement.

In early stages the fundamentals of the technology are poorly understood and great effort may be spent exploring different paths of improvement or different drivers of the technology. No measure for assessing its potential exists and until the technology has advanced, it may be difficult to attract more researchers and private investment. This is the crucial stage for public investment.

Next the technology gains legitimacy and attracts researchers and developers. Public and mostly private investments makes performance escalate up the s-curve rapidly.

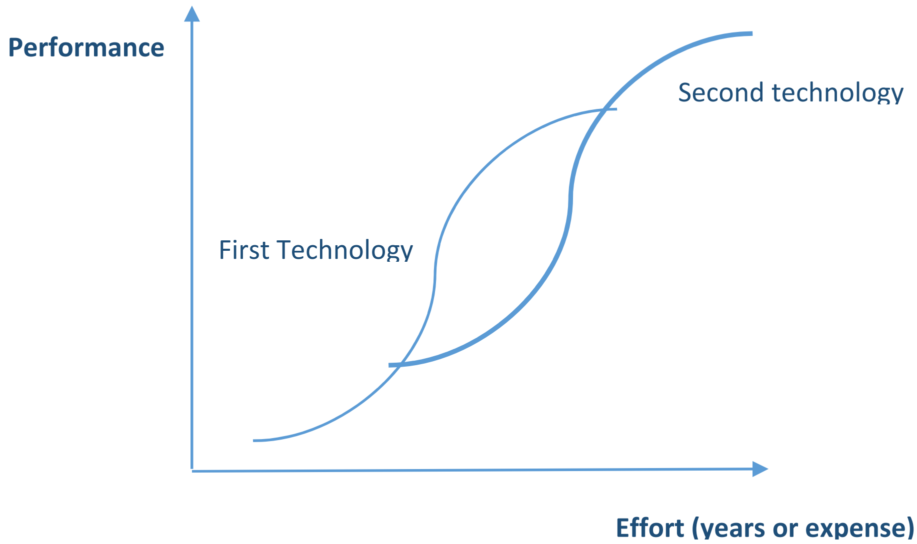
At some point the technology begins to reach its inherent limit, the cost of marginal improvements increases and the s-curve flattens.

Figure 3: Technology S-Curve



At this point, a disruptive technology may rise to higher performance levels and substitute the incumbent technology. New innovations can fulfill a similar market need using an entirely new knowledge base.

Figure 4: New technology S-Curve



For example, Gordon Moore, Intel's cofounder, established a theorem, known as Moore's Law, that says that the number of transistors on a computer chip will double every two years. In fact, this has happened for the last half a century by shrinking the size of transistors. However, physical limitations will not allow the downscaling of a transistor and the performance improvement to last forever. The traditional silicon technology has risen up the s-curve and begins to reach its inherent limit.

A possible disruptive technology for the current silicon technology is graphene, used to make hugely fast transistors. However, physicists need to find a solution of the problem that graphenes cannot switch off. Other possibilities being explored include silicon laser and ultraviolet lithography.

The National Science Foundation (NSF) is also funding research that could lead to a replacement for silicon by means of carbon nanotubes, quantum computing, software and architectural ideas that will contribute to the effort to develop chips.

While incumbent firms try to extend the life of their current technology, new firms entering the industry tend to choose a disruptive technology that has a much greater performance potential and, in the long run, will displace the incumbent technology.

This is especially relevant for developing countries. Innovation creates the opportunity for new firms and countries to become players in an existing industry. However, for this to happen, investment needs to occur at the very early stages of the s-curve to provide for laboratories and research.

Public funding is intended to help laboratories assist with research from private sector. When performance improvement is slow, it seeds academic laboratories and industry associations to conduct research. Then, once the s-curve has begun to rise, the commercial organizations may further invest in the research to drive it into mass production.

IV)Innovation Engine

"Times of innovation…are times of effort and sacrifice, of work for the future, while the harvest comes after…." (Schumpeter J. A., 1939)

Innovation is commonly associated with the concept of a falling apple, a bulb that lights in the mind of a special individual that has the capacity to transform a brilliant idea into an invention.

In fact, individual efforts towards innovation were considerable at the times of Thomas Edison and Lewis Pasteur. However they did not happen in a single strike, as most seem to believe. Innovations occurred due to long sequences of experiments and failures.

Today, as inventions became more and more complex, collective efforts are required. Indeed the idealization of Macintosh came from Steve Jobs, but the actual implementation of the different parts of the computer was a collective work of technical specialists.

Thus innovation requires more than a single brilliant idea. It requires an adequate environment where ideas can flourish, be implemented, tested and commercialized. Depicted below are some critical foundations of the innovation engine.

a) Education

According to the white house report "A Strategy for American Innovation" (http://www.whitehouse.gov/sites/default/files/uploads/InnovationStrategy.pdf), education is one of the building blocks of American Innovation. In fact, since the America Competes Act, the US has aimed to strengthen the educational opportunities, in particular in science, technology, engineering, mathematics (STEM).

To achieve this objective the US is investing in early learning and childhood programs through high standards and professional development.

Actions include strengthening the skills of thousands of math and science teachers by establishing training and education programs and expanding scholarship programs to recruit and train individuals to become math and science teachers.

The government has authorized grants for States to reform elementary and secondary education by aligning the knowledge and skills with the needs for success in postsecondary education.

Regarding graduate education federal loans available directly to students allows for investment in college affordability for low-income students. Moreover research fellowship and traineeship programs help create the skills and workforce necessary in an innovation-based economy.

b) Clusters

The National Research Council's report "Best Practices in State and Regional Innovation Initiatives: Competing in the 21st Century" revives the importance of states and clusters for innovation (http://www.nap.edu/catalog.php?record_id=18364, 2013).

Innovation clusters are geographically localized concentration of firms in related sectors that do business with each other and have common needs for trained workers, infrastructure and technology. In other words, they develop creative products and services within an active web of collaboration that includes specialized suppliers, service providers, universities, and research institutes and organizations.

While the codified and formal knowledge can be transmitted through the Internet and instant communication, the "tacit-knowledge" is attained through experience, observation of results, and experimentation that generally requires hands-on application and testing. This is a clear advantages of geographical co-location.

In addition, clusters benefit the local surroundings. They nurture the transition from unemployment to high-skill employment; the creation of high-wage job opportunities; the development of local business; the repurposing of idle assets and people; the manufacture of products in the region.

From a public policy perspective, clusters bring the innovation policy discussion from the federal to a state level. States used to pursue economic development by recruiting companies from other states, offering supportive regulatory environment, government policies, lower taxes, and financial and infrastructure incentives.

However, this paradigm has changed. Currently, states recombine existing federal resources, forge innovative partnerships and support the development of regional centers of innovation, entrepreneurship, and high-technology development. This approach has shown to be more effective for the development of new industries and jobs and for the long run economic growth and competitiveness.

The National Research Council's report examines some of the various state programs in the US. In all cases, first-rate universities are the heart of the innovation-based economic development.

Albany illustrates a successful case of a nanotechnology cluster. The University of Albany launched the College of Nanoscale Science Engineering (CNSE) and brought preeminent scientists of the industry to work with no teaching assignments. In a few years SEMANTECH agreed to house the headquarters of the company at CNSE. The college build a USD 100 million facility to accommodate the research consortium. From 2004 to 2013 the CNSE grew from 10 graduate students to 300 graduate and undergraduate students and have an 800,000 square feet facility space.

Silicon Valley arose in the surroundings of Stanford University. In the 1930s, engineering faculty Frederick Terman urged two students, William Hewlett and David Packard, to found a company to sell an audio-oscillator that Hewlett had developed. He helped them with the technical development of their product, arranged financing, rented property and helped them secure patent rights. Stanford University established a light industrial park on a land it owned and shortly Varian, Hewlett Packard, GE, Eastman Kodak and other companies become tenants in the Park. This was the start of Silicon Valley.

The Stanford Research Park and Xerox Palo Alto Research Center (PARC) had almost indistinct boundaries. Stanford research students participated in PARC projects and PARC staff collaborated on academic projects. Such a collaboration developed much of the underlying technology of personal computers.

In addition, the improvement made by the companies in Silicon Valley that derived in new products and technologies were soon incorporated in the engineering curriculum.

There are however less successful cases, as the biotechnology cluster in Illinois. Although Chicago had leading research and laboratories, it was not able to translate these assets into economic growth. It relied on a strategy to attract large companies to establish new facilities and ended up as a net exporter of graduates with medical degreed.

c) Science to Industry

The research in universities does not translate into products of a corporation on its own. Once the research has culminated in a patent or a product, the knowledge needs to be transferred to the industry; and it is the people who have the knowledge in their heads that do the transferring.

But, how to motivate faculty members to put efforts on applied research, patenting and technology transfer, in addition to scientific exploration and publication in academic journals? One possibility is introducing organizational incentives for faculty by attaching patenting to promotion and compensation.

Another option is to allow researchers to profit from their invention, either by consulting, licensing their patents, or by creating a start-up. According to Cerf [ref how to fire up us innovation] universities that allow faculty members to consult a day a week on average speed the process of business innovation. Furthermore, one of the keys to Silicon Valley successes is the transfer of professionals into the marketplace and the ability of researchers to start new companies.

i) Technology Transfer offices (TTOs)

The Bayh-Dole Act introduced a technology transfer model. Instead of researchers independently commercializing their inventions, universities concentrated their innovation activities in centralized Technology Transfer Offices (TTOs). These offices were created to manage intellectual property (IP) and were equipped with specialized staff in legal IP issues and business.

The step-by-step process of how TTOs transfer university research to the marketplace was described (Pascoe and Vonortas) as follows: i) the faculty performs the research that may lead to inventions; ii) the faculty meets with TTO personnel to discuss the invention; iii) the faculty and the TTO personnel write an invention report; iv) the TTO personnel reviews the report to determine the invention's commercialization potential; v) the TTO attorney begins the patent process; vi) the TTO begins reaching out to companies regarding the invention; vii) TTO defines licensing partner for the invention or directs the researcher to fund a start-up company; viii) TTO and researcher draft a license agreement; ix) licensee continues the advancement of the technology with or without the researcher; x) revenues received are split between the faculty-inventors, their department or lab, and the school.

Critics to the technology transfer model allege that TTOs can be costly and most may function at operational losses (Valdivia, 2013). This occurs due to the intrinsic risk of the innovation process and the probabilities related to a blockbuster patent.

Despite the risks and costs involved, this model has proved to be effective in incentivizing scientists to collaborate with industry and engage in technology transfer.

Other approaches to technology transfer include: allowing faculty members to choose their licensing agents, commercialize inventions through the internet, license inventions on a non-exclusive basis, or even create a start-up to develop the innovation.

ii) University start-ups

An alternative to the technology transfer model are University Start-ups. Valdivia proposes TTOs to act as business incubators, providing the necessary legal assistance, administrative support, and attracting capital influxes.

So in the start-ups model the faculty themselves engage in the entrepreneurial activity (besides formal technology transfer). Thus they constitute a firm, build and manage their intellectual property portfolio, use the university facilities, negotiate with capital investors (angel capitalists, venture capitalists, investment bankers), and can develop, manufacture and commercialize the invention.

The "nurturing start-ups model" relies on funding from the federal government to support early stage small business and from resources from state and local governments. The start-ups increase regional development, and better integrate universities into the market system by partnering with the private sector.

d) Capital

"We have to define that word which good economists always try to avoid: capitalism is that form of private property economy in which innovations are carried out by means of borrowed money" (Schumpeter J. A., 1939).

Start-ups may have difficulty to obtain in the market the funding necessary to develop new products. Therefore at early stages companies rely on government funding, angel investors and venture capital.

Government funding can be made available by federal institutions that aim at supporting new technologies that present high capital risks. However limited budget and rigorous processes (public calls, project submission etc.) may hamper a wide spread usage of this source.

Other sources include Private Equity, Venture Capitalists and Angel investors.

Equity investments are usually large-scale and commercially focused. Private Equity invest on mature companies that have consolidated products or services. The companies may be undergoing restructuring processes that may offer promising returns of investment.

Venture capitalists invest the funds of a pool of investors in companies that are in early stages. These companies have a potential to generate profits depending on the outcome of a product that does not have a tested business model.

Angel Investors invest their own funds to provide seed funding. They commonly follow the company more closely and may even provide management advice to start-ups. Start-ups are expected to provide return on investment that multiply the original investments dozens of times, but ROI may be more modest, as start-up companies may also fail to succeed.

The Jumpstart Our Business Startups (JOBS) Act, of 2012 (http://www.sec.gov/spotlight/jobs-act.shtml), called for new rules for crowdfunding. The intention is to allow for a wider pool of small investors with fewer restrictions. With a crowdfunding portal all internet users become potential investors of a small business. This was expected to raise billions of US dollars to finance start-up companies.

e) Patents

"Patent legislation is one of the few instances of legal recognition of the social functions of profit in capitalist society (Schumpeter J. A., 1939).*"*

Schumpeter's theory postulates that patents are crucial to provide incentives for innovation. Furthermore, supporters of free market tend to favor institutions of private property, including patents, trademarks and copyright, as private property is seen as important for growth.

In fact, patents have been used both as an incentive to innovate and as an indicator of innovation. A robust patenting system that offers the innovators an opportunity to capture the benefits (profit) from their own invention (by either selling or licensing it), is believed to foster new inventions.

Moreover, the number of patents has been accounted for as a measure of the countries capacity to create new products and services.

Schumpeter recognizes that the profit is temporary by nature and vanishes with competition:

Profit…is the premium put upon successful innovation in capitalist society and is temporary by nature: it will vanish in the subsequent process of competition and adaptation (Schumpeter J. A., 1939)*".*

Recent academic research (Boldrin and Levine, 2013) argues that patents are a government-granted monopoly that extends the profit of incumbents, blocks innovation and inhibits competition (rather than a property).

The theory of innovation emphasizes gains from competition and first-mover advantage as the main drivers of innovation, rather than the benefits of the monopoly power of patents. Historical evidence shows that the initial eruption of innovations leading to the creation of industries such as chemicals, cars, radios, computers were not born out of patent protection. They were the fruit of a competitive environment.

The “patent puzzle” suggests that policy changes to strengthen patent protection did not spur innovation. In fact, statistics have not demonstrated a connection between patents and innovation (and productivity). While the US R&D expenditure has oscillated around 2.5 percent of the GDP and the growth in the total factor productivity is just below 1 percent, patenting has exploded in the last decade. Studies do not prove that strengthening patent regimes increases innovation; it does, however, increase patenting.

There is a clear tradeoff between the social costs of monopoly power and incentives to patent holders. In real cases, the patent over Amazon’s “one-click” method to buy a product or a patent on “icons” are clear examples of the costs that new entrepreneurs might bear to implement a new product using these hardly innovative and very common tools.

Boldrin and Levine believe that in an “optimal” patent system very few patents would be awarded: only for those products with very high fixed costs of innovation, low costs of imitation and a highly inelastic demand. Moreover, the system would require incorruptible and impartial administration. However, they recognize this impossibility and thus suggest the abolition of the patenting system as a whole. This view of the abolition of patents does not appear to enjoy wide support in the economics profession.

Another view is present by Alex Tabarrok (Tabarrok). He proposes customized patenting depending on the ratio of innovation costs to imitation costs. Industries with high innovation-to-imitation cost (such as pharmaceuticals) could be offered patents that last 10 or even 20 years. On the other hand, industries with lower ratios (lower innovation costs and higher imitation costs, such as software) could be offered only a 3 year patent. Therefore maximizing innovation would require treating different industries differently.

In addition he presents other alternatives to the current patent system, such as: implementing a scheme where independent inventions are not considered an infringement to the law, increasing the role of prizes given to an innovation (rather than granting patents), making pharmaceutical patent owners eligible to governmental payments based on sales figures (rather than rendering them a monopoly power), auctioning patents.

Despite the controversy, patents have been widely used to transfer knowledge from Universities to the Industry and to allow inventors to capture the outputs of innovation.

Another way to capture the benefits of investment is by strengthening the brand and attracting the consumer loyalty. Some say this was done by Japan and South Korea to transition from commodity manufacturing to highly valued brands like Sony and Samsung. Apple has also invested in reputation for innovation and has been able to greatly capture the benefits of this reputation in the marketplace.

f) Regulation

Once huge investments have been made, vast research has been conducted, finally solutions have been designed and an innovative devices are available, regulation can still hamper the entry of the product into the market.

Risk regulation has two main goals, to reduce the old risks and to impede new technologies introduce new hazards in the environment (Huber, 1983).

The "standard-setting" regulatory procedure acts on old products to make them work better, posing less risks. E.g. emission limits for car pollution. The federal agency, proves that pollution from carbon dioxide is a threat to the health and reduces the permitted levels of emission from automobiles. Thus regulation attempts to remove old threats.

On the other hand "screening" regulatory procedure acts on new products and on potential hazards. E.g. new drug approval by the Food and Drug Administration. The regulated industry needs to prove to the FDA that the drug poses no risk to human health in order to receive a stamp from the FDA that permits open sales. In this case, regulation has a conservative approach towards possible new threats.

In the US, the precautionary approach towards "screening" regulation has increased the difficulty to bring new medical products to the market (Mannix). In fact, what has been observed is that medical device manufacturers are increasingly locating research and manufacturing facilities out of the US. Products are being developed, tested and produced out of the country and they are made available to patients elsewhere much earlier than available in the US.

Therefore caution is needed so that current regulatory procedures do not have a discouraging effect on the development of new products.

V) US laws in innovation

a) Bayh-Dole Act or the Patent and Trademark Law Amendments Act (1980)

The Bayh-Dole Act (Bayh-Dole-Act, 1980) intended to expedite US technological innovation by creating a single national policy towards patent ownership of inventions created with federal funded research.

As stated in the 35 U.S. Code § 200 - Policy and objective:

> *"It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally supported research or development; to encourage maximum participation of small business firms in federally supported research and development efforts; to promote collaboration between commercial concerns and nonprofit organizations, including universities; to ensure that inventions made by nonprofit organizations and small business firms are used in a manner to promote free competition and enterprise without unduly encumbering future research and discovery; to promote the commercialization and public availability of inventions*

made in the United States by United States industry and labor; to ensure that the Government obtains sufficient rights in federally supported inventions to meet the needs of the Government and protect the public against nonuse or unreasonable use of inventions; and to minimize the costs of administering policies in this area."

This uniform rule allowed universities, non-profit organizations, and small businesses to retain intellectual property and commercialize licenses that resulted from federal funded inventions.

The Act was designed to foster interactions between academia and the business community. It created the momentum necessary for universities to transfer technology to the industry and thus impulse innovation significantly.

The critics of the Bayh-Dole act claim that the commercialization of research may divert the primary role of universities from basic research and scientific exploration to applied research with a practical application. However, there is no evidence to fundament this shift and in fact, studies indicate that both basic and applied research activities have increased considerably in the last thirty years [university entrepreneurship].

Other concerns include the delays in publication of scientific articles, the increase in research secrecy, the difficulty to access proprietary research materials, the non-discrimination between patents for research tools and other inventions, and the deviation of focus of universities towards profit maximization.

In spite of these possibilities, the universities have managed to balance traditional teaching and research roles with entrepreneurial roles. Furthermore the industry-university collaboration has been the epicenter of the biotechnology revolution, not to mention the internet revolution.

Thus the stable regulatory environment and the cultural change promoted by the federal government Act allowed inventions to be commercialized and used to encourage competition and economic growth.

b) America Competes Act (2007)

The America competes act (America Competes Act, 2007) was a landmark legislation that aimed at maintaining and improving the innovation strength of the United States. It was a response of the congress to the recommendations contained in the National Academies' report "Rising Above the Gathering Storm". The report found that the scientific and technological building blocks critical to the US economic leadership were eroding at a time when many other nations were gaining strength.

In this regard the act focused on increasing research investment; strengthening educational opportunities; and developing an innovation infrastructure. Bellow each of these areas are further specified.

1) Increase Research Investment by funding the National Science Foundation (NSF) with 11.2 billion dollars; funding the Department of Energy's Office of Science with 5.2 billion dollars; funding the National Institute of Standards and Technology (NIST) with nearly 1 billion dollars (at least 8% for high-risk, high-reward innovation acceleration research); directing

NASA to increase funding for basic research and fully participating in interagency activities; coordinating research and education at the National Oceanic and Atmospheric Administration.

2) Strengthen Educational opportunities in science, technology, engineering, mathematics (STEM), and critical foreign languages from elementary through graduate school.

3) Develop an innovation infrastructure by establishing a President's Council on Innovation and Competitiveness to develop a comprehensive agenda to promote innovation and competitiveness in the public and private sectors, requiring the National Academy of Sciences to conduct a study to identify forms of risk that create barriers to innovation.

c) America Competes Reauthorization Act (2010)

The America Competes Reauthorization Act of 2010 (Reauthorization Act, 2010) authorized additional funding to STEM programs and reaffirmed the Committee's commitment to strengthening the foundations of the American competitiveness through sustained investments in science, innovation, and education. Despite these efforts, subsequent reports from the National Academies continue to show that the US leadership is in threat due both to national issues and to growing investments overseas.

d) America Competes Reauthorization Act (2013)

The America Competes Reauthorization Act of 2013 (Reauthorization Act, 2013) renewed the commitment to ensure US scientific and technological leadership by authorizing a 5 percent per year increase in funding for the National Science Foundation (NSF), the Department of Energy's (DOE) Office of Science, and the National Institute of Standards and Technology (NIST).

The act also fomented regional development by supporting innovation clusters and manufacturing innovation centers. It also included authorization of the Advanced Research Projects Agency-Energy, Energy Frontier Research Centers, and Energy Innovation Hubs to foster the transition to a clean energy economy and to support the growth of new sectors of the economy.

e) Recovery Act

The American Recovery and Reinvestment Act of 2009 (ARRA) (The Recovery Act, 2009) was a response to the economic recession. It comprised more than USD 787 billion in funding and aimed at rescuing the deteriorating economy, putting the country back in a path of recovery, and reinvesting in the country to build a new, more robust and competitive long term economy.

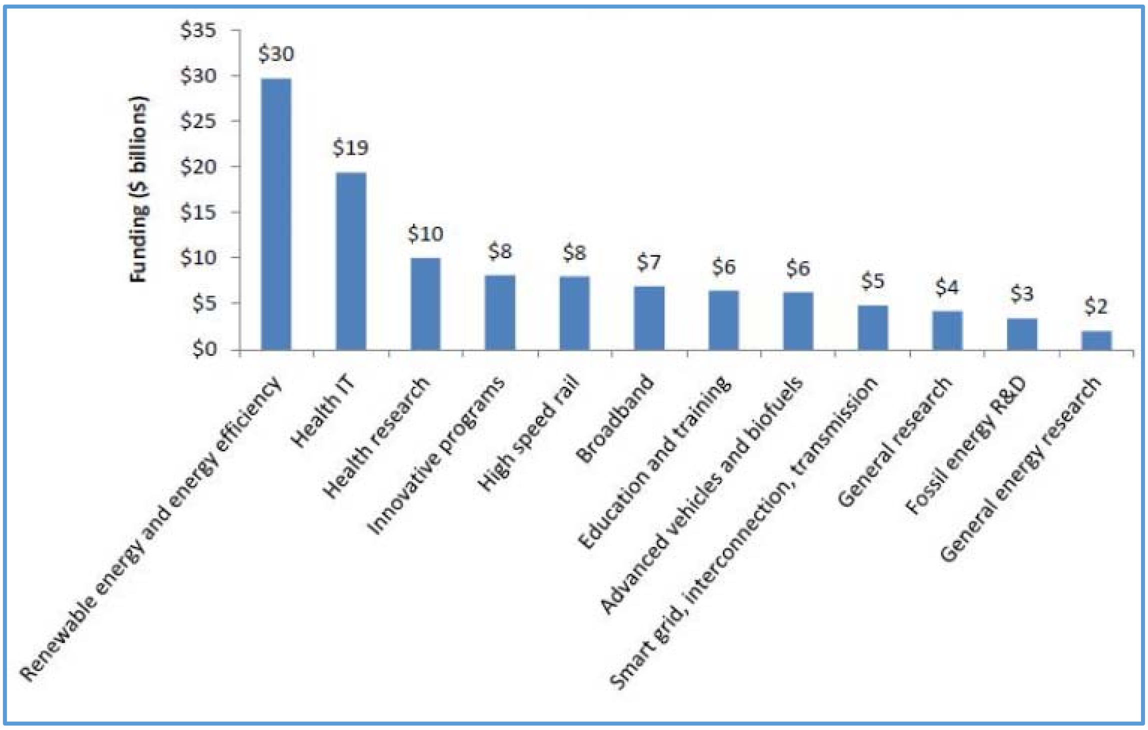
The act included unemployment insurance, food stamps, relieve programs for the most affected; recovery funds; direct spending in infrastructure, education, health, and renewable energy; grants and loans to clean-energy and other green technology companies; and tax cuts for companies to hire new workers, invest in their businesses, and deduct capital investments.

The reinvestment part of the recovery act focuses on transforming the American economy through innovation according to the premises laid in the white house report "A Strategy for American Innovation". The vision for innovation was to catalyze breakthroughs for national priorities, promote market based innovation and invest in the building blocks of American Innovation.

In this regard, the act concentrates over USD 100 billion in innovative and transformative programs mostly concentrated in the following four areas: i) transportation, including advanced vehicle technology and high-speed rail; ii) renewable energy sector through wind and solar energy; iii) private sector innovation through investments in: broadband, Smart Grid, and Health Information Technology; and iv) medical research.

The funding distribution is depicted in the chart below.

Figure5: Funding distribution of the Recovery Act



VI)US R&D institutions

Below are some examples of US R&D institutions. They show that the government is mostly focused in strategic areas of high-risk that are at early stages of the technology development. Moreover, research centers have been increasingly required to collaborate with and transfer technology to the private sector.

Despite the controversy regarding direct investment in R&D, it is important to note that biotechnology and the internet both were born in government agencies due to government-subsidized research.

a) Department of Energy's Office of Science

The Office of Science (http://science.energy.gov/)is a Program Office within the Department of Energy (DOE). Its origins trace to the Manhattan Project. The effort to create the world's first nuclear weapon built a vast research and development apparatus that is currently controlled by the Department of Energy.

The DOE Office of Science supports basic research in the physical science, offers laboratories, user facilities, university grants and funding opportunities. It introduced remote access for civilian researchers to supercomputers for open scientific research, created the Human Genome Project, the Global Climate Change Program, provided facilities for nanoworld, the environment and the atmosphere, and build an array of accelerator, particle colliders, and fusion energy experiments.

In addition, the Office of Science manages and supports additional programs and activities, including: the Workforce Development for Teachers and Scientists program, the DOE Small Business Innovation Research (SBIR), and Small Business Technology Transfer (STTR) programs.

b) Advanced Research Project Agency-Energy (ARPA-E)

The ARPA-E (http://arpa-e.energy.gov/) is a semi-autonomous agency established within the Department of Energy in 2007 to conduct high-risk, high-reward energy research. It advances technologies that are too early for private-sector investment with focus on developing new ways to generate, store and use energy. ARPA-E supports energy researchers with project funding, technical assistance, and market readiness.

The America Competes Act, officially authorized ARPA-E's creation as per the recommendations of the report "Rising above Gathering Storm" that warned policymakers that the advantages of technology and science that made the US a world leader were eroding.

In fact, the US has suffered severe economic shocks as a result of oil crises on several occasions. The consumption of oil in the last 200 years took nature millions of years to make and has caused serious environmental concerns associated with energy usage that range from local pollution to climate change. Thus the need to develop new class of solar cells, biomass substitutes for oil, bio-fuels (conversion of cellulose into chemical fuel) etc.

Moreover, economic competitiveness is intimately tied to energy costs and efficiency in energy usage and energy security is directly linked to national security.

c) National Institute of Standards and Technology (NIST)

The NIST (http://www.nist.gov/) is a non-regulatory federal agency within the US Department of Commerce. Its mission is to promote US innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve quality of life. This is accomplished by around 3000 scientists, engineers, technicians and support personnel.

The NIST innovation toolkit supports the innovation ecosystem by: i) operating the NIST Laboratories and Research Centers (such as the NIST Center for Nanoscale Science and Technology); ii) providing technical and business assistance to smaller manufacturers (Hollings Manufacturing Extension Partnership); promoting proven performance management practices to strengthen US organizations (Baldrige Performance Excellence Program).

In addition, NIST collaborates with several federal and state institutions to run Laboratories, operate physics institutes, foster multidisciplinary biotechnology and biomedical research, and establish public-private collaborations. America Competes also directed NIST to expand its work with the private sector.

d) National Science Foundation (NSF)

The NSF (http://www.nsf.gov/about/how.jsp) is an independent federal agency created to promote the progress of science, to advance the national health, prosperity and welfare and to secure the national defense. Their annual budget in 2014 is USD 7.2 billion. The NSF’s mission includes support for all fields of fundamental science and engineering, except for medical sciences. In addition to supporting the traditional academic areas, the agency also supports “high-risk”, “high pay-off” ideas.

NSF is tasked with identifying and funding work at the frontiers of science and engineering. They do so via a “bottom-up” process that keeps track of research around the country and the world, identifies areas that are most likely to result in spectacular progress, and choose the most promising people to conduct the research.

The grants and cooperative agreements with colleges, universities, K-12 school systems, businesses, informal science organizations and other research organizations are chosen in a transparent, fair and competitive manner. The projects and proposals are evaluated by independent reviewers (scientists, engineers and educators) who do not work at NSF or for the proponent institution. Around 50,000 experts review the projects each year and evaluate confidentially whether the projects are of the highest caliber.

VII) Innovation in Brazil

The policies used towards Brazilian innovation can be grouped in direct support (e.g. direct investment) and indirect support (e.g. fiscal incentives).

Financing agencies and banks offer direct support to innovation projects. Institutions as FINEP, BNDES and State foundations offer economic subvention directly to private companies. Thus public resources are used to share the costs and the risks on innovation projects.

Fiscal incentives intend to reduce the cost and the risk of R&D projects by deducting taxes or offering fiscal credit. The main incentives are concentrated in the "Lei da Informática" originally established in 1991 and in the "Lei do Bem", approved in 2005.

a) FINEP

FINEP – Innovation and Research - is a public company linked to the Ministry of Science, Technology and Innovation (http://www.finep.gov.br/). It aims at promoting the economic and social development of Brazil by funding science, technology and innovation work in companies, universities, technological institutes and other public and private institutions.

It manages the FNDCT - National Fund of Scientific and Technological Development - and finances the science, technology and innovation system by means of reimbursable and non-reimbursable resources.

FINEP has financed: the creation of graduate programs in Brazilian universities, the Tucano plane of EMBRAER (Empresa Brasileira de Aeronáutica), agricultural projects of EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária), and oil projects of Petrobrás.

b) BNDES

The National Economic and Social Development Bank (BNDES) is a federal company that provides long term funding for investments in all economy segments. Since its foundation, it has been a prominent investor in agriculture and infrastructure and has implemented social investments directed to education, health, sanitation and urban transport (http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/index.html).

In its Corporate Plan of 2009/2014, BNDES has defined innovation, local and regional development, and environmental development as its strategic priorities.

In this regard, it carries out long-term financing, offers guarantees and support to foment innovation policies. BNDES has products, funds, programs, and plans designed in a per segment basis (e.g. BNDES Inovação, Funtec, BNDES MPME Inovadora, Plano Inova Aerodefesa, Programa Inova Petro, Plano Inova Telecom). In addition, BNDES mutual funds stimulate entrepreneurship, the development of new innovative companies and the culture of risk capital.

c) Lei de Informática

The Law no 8,248, of 23 of October, 1991, known as "Lei da Informática" (Lei da Informática, 1991), sets the basis for the productivity and competitiveness of the information technology (IT) and automation industry.

Activities related to IT and automation could rely on a policy of tax incentives tied to R&D efforts. The stimulus was oriented to commit firms with the installation of certain levels of production and development of R&D activities in the country.

The tax incentives for goods developed in the country or produced according to the PPB (Processo Produtivo Básico), such as: i) preference in governmental acquisitions of goods; ii) decreasing reduction of the tax applied to industrialized goods (Imposto sobre Produtos Industrializados - IPI), subject to the approval of the project by the Ministry of Science and Technology.

To benefit from the tax reduction, the R&D efforts of the companies that develop and produce IT and automation goods must account for 5% of their total revenue, distributed in a manner that comprises credentialed research centers, institutes in the North and Northeast of the country and the FNDCT (Fundo Nacional de Desenvolvimento Científico e Tecnológico).

Studies show that there was no significant impact on R&D expenditure due to the tax incentive (IDB, 2012). The combination of tax incentives with requirements of mandatory content of nationalization of products, elements of regional policy and discretion in the approval of projects made it an instrument without effective results in regard to the additional R&D expenditures.

The efforts in R&D have been directed mainly to reduce costs, with a low impact on research and development of new products. And the act was unable to promote international competitiveness. These assumptions are based on interviews and on the factual perception that the IT sector in Brazil has not made considerable changes over the last 20 years.

d) Lei da Inovação

The Law No. 10,973 of December 2nd, 2004, known as "Lei da Inovação" (Lei da Inovação, 2004) aimed at providing incentives for innovation, and scientific and technological research in the production environment. It was also designed to encourage the creation of specialized and cooperative innovation environments; encourage the participation of Scientific and Technological Institutions (ICT) in the innovation process; encourage innovation in enterprises; encourage independent inventor and; encourage the creation of investment funds for innovation.

The law brought new possibilities of relationship between universities (and research institutions) and enterprises. A larger step could be achieved towards innovation if the government abdicated of their rights of intellectual property (IP) towards federally funded inventions to confer the title to the researchers. The researchers could then patent his invention, and sell the license of use either through a technology transfer office, or directly.

Finally, the law set a deadline for the Executive branch to send a bill to the Congress regarding fiscal incentives towards innovation. This was done and became the “Lei do Bem”, as it is described next.

e) Lei do Bem

The Law nº 11,196, of November 21, 2005, known as “Lei do Bem” (Lei do Bem, 2005), created tax incentives for corporations to undertake technological research and technological development, improving the old tax benefits defined in Law no. 8,661, of 1993.

The law aims at reducing the high risk associated with the innovation process and the uncertainty as to obtaining economic and financial results.

In short, if companies invest in R&D, have fiscal profit, declare income tax based on real profit, and have no pending issues with the fiscal office, they are entitled to a special tax regime.

Benefits of the regime include: deduction in income tax on corporations and social contribution due to expenditure on R&D; reduction of IPI in the purchase of machinery and equipment for R&D; accelerated depreciation of these assets; accelerated amortization of intangibles; exemption from income tax withholding remittances made abroad intended for registration and maintenance of trademarks and patents.

The Law delineates innovation as "technological innovation to design new product or manufacturing process as well as adding new features or characteristics to the product or process involving incremental improvements and effective gain in quality or productivity, resulting in greater market competitiveness".

The definition is broad enough to encompass basic research, applied research and experimental development, including the patenting of the product or process developed, but was narrowed down by the regulation to exclude managing of innovation as part of the R&D process.

According to the IDB report (IDB, 2012), a flaw in the law includes restringing the benefit to enterprises that declare the income tax based on a regime of real profit (usually Large and Medium enterprises). Thus Micro and Small enterprises that declare their income tax based on presumed profit and other regimes as the SIMPLES incur in less tax relieves. A policy that tends to favor large companies and needs to be reviewed if technology start-ups are to be fostered.

To add R&D benefits to the enterprises that use the SIMPLES requires the consent of the State governments, as this will generate a reduction of the (ICMS) tax collected.

Other critics point out that having pending issues with the fiscal authority is not so uncommon and hampering the applicability in these cases many exclude a large amount of enterprises.

Moreover, the subjective nature of the issue and the calculation of the tax deductions often require a specialized legal consultant. Even with these precautions there remains an intrinsic risk of equivocally interpreting the tributes and incurring in future fines by the tax audit authority.

The automatic adoption of fiscal benefits with no previous project approval simplifies the process, however companies believe that the post submission of projects to the Ministry adds a step without a clear outcome.

Despite the criticisms and recognizing the possibilities for improvement, up to now this law has been one of the most effective mechanisms for fostering innovation in Brazil.

This law was further amended by Law n^{o} 12.715, in 2012, that included tablets and smartphones in the list of equipment that are exempt of federal taxes PIS and CONFINS if assembled in Brazil.

f) Other legal instruments

Other instruments towards innovation have been proposed by the Brazilian government such as Law n^{o} 10.332 (Interest Equalization), Law nº 12.431 (Debentures for infrastructure).

VIII) Conclusion

The 21st century has shown that innovation increases productivity and competition, and leads to long-run economic growth. In fact, innovation has been the foundation of US economic leadership (and China's current surge).

In a knowledge-based economy, research, intellectual work and its commercial exploitation have growing importance. The role of the government is to reduce the risk and create the necessary environment and infrastructure for innovation, while the market place diverts capital towards R&D and innovation.

An evaluation of the R&D figures show that the US R&D spending is directed to university funding, research centers and industry expenditure. On the other hand a considerable amount of Brazil's GERD (1.3% of GDP) accounts for tax incentives. Furthermore US (as well as other developed countries members of OECD) plan to raise private and public R&D expenditure to a level of 3% of GDP by 2020.

Innovation theory shows that public funding is crucial especially in early stages of the innovation S-curve, as private investment may not be sufficient or willing to share high R&D cost, risks and time consumption.

Regarding the innovation engine, a remarkable part of the US educational system are the top-rate universities.

To improve the Brazilian educational system with a view to supporting innovation, STEM fields need to be promoted by: science fairs, prizes, adequate training of teachers, acknowledgment of STEM professionals, and expansion of exchange programs. Moreover, the few high quality universities (that are responsible for most of the scientific publications) need to be further impelled to transfer the knowledge into the industry.

In the US, the close collaboration between universities and the companies are at the heart of most high-tech clusters. Differently, in Brazil the heart of some high-tech clusters are big public companies, such as Petrobrás and Embraer.

Cluster formation can be stimulated by a closer interaction between universities, research centers and industries. This can be done, for example, by: combining federal and state initiative, nurturing start-ups, allowing civilians to use university facilities, and permitting professors to collaborate closer with startups and other companies.

Funding is also a major challenge for small business as they offer a great insecurity to potential investors. The US government is exploring policies that support angel funds, venture capital, and crowd funding. In Brazil, uncertainty towards public policies and economic outlook has recently lowered international fundraising. Regulation on crowd funding can allow a huge flow of smaller capitalists to fund innovation.

With regards to patents, the US is facing problems combating the problem of "patent trolls". The flood of patent litigation inspires a patent reform in the US that can also be considered by the Brazilian congress. The benefits and drawbacks of patenting are currently being discussed and liberal economists that have once defended patents as property rights now tend to see them as an unnecessary monopoly.

Finally regulation should be balanced considering both “standard-setting” regulation that acts on existing products and aims at protecting the citizens, and excessive “screening” regulation that hinders the advances of innovation.

A comparison of the institutions of the US and Brazil, show that besides the funding agencies, the US has well known laboratories and research centers (equipped with supercomputers, particle colliders etc), while Brazil lacks behind on infrastructure and relies on tax incentives.

Hence for companies to invest high sums of capital in a rink-intensive R&D business, they need a whole innovation environment that includes finding STEM professionals in the labor market, acquiring or creating the technology, partnering with universities, obtaining capital and funding and having freedom to experiment (capital, support and time). All this must be aligned with public policies and a national strategic plan that stimulates education, patent reform, technology transfer, capital investments.

Moreover, beyond the requirements previously mentioned, structural changes are sought: more infrastructure, reduced tariffs and explicit barriers to international trade, reduced customs bureaucracy, tax reductions, innovation culture, tolerance to failure, favorable economic and regulatory environment, commitment from top authorities, a strategic innovation plan, and the support of public policies.

Thus innovation is the key for the 21st century economic growth. The US is struggling to maintain its innovative advantage and Brazil faces tremendous challenges and opportunities to engage in times of knowledge-based economies.

References

(2007). *America Competes Act.* http://www.gpo.gov/fdsys/pkg/STATUTE-121/pdf/STATUTE-121-Pg572.pdf.

Battelle. (2014). *Global R&D Funding Forecast.* www.rdmag.com, www.battelle.org.

Battelle, R. a. (2013). *Global R&D Funding Forecast.* www.rdmag.com, www.battelle.org.

(1980). *Bayh-Dole-Act.* http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=949277a6b5dbb30e7459fae061240d7d&rgn=div5&view=text&node=37:1.0.4.13.1&idno=37.

Boldrin and Levine, M. a. (2013). The Case Against Patents. *Journal of Economic Perspectives*, 3-22.

Cruz, R. (2011). *Inovação a revolução do conhecimento nas empresas brasileiras.* Sao Paulo: SENAC.

http://arpa-e.energy.gov/. (n.d.).

http://science.energy.gov/. (n.d.).

http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/index.html. (n.d.).

http://www.finep.gov.br/. (n.d.).

http://www.nap.edu/catalog.php?record_id=18364. (2013). *Best Practices in State and Regional Innovation Inciatives: Competing in the 21st Century.* The National Academic Press.

http://www.nist.gov/. (n.d.).

http://www.nsf.gov/about/how.jsp. (n.d.).

http://www.sec.gov/spotlight/jobs-act.shtml. (n.d.).

http://www.whitehouse.gov/sites/default/files/uploads/InnovationStrategy.pdf. (n.d.).

Huber, P. (1983). Gatekeepers in Risk Regulation. *Regulation*.

IDB. (2012). *Incentivos Fiscais à Pesquisa, Desenvolvimento e Inovação no Brasil: Uma avaliação das políticas recentes.* Banco Interamericano de Desenvolvimento.

(1991). *Lei da Informática.* http://www.planalto.gov.br/ccivil_03/leis/l8248.htm.

(2004). *Lei da Inovação.* http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2004/lei/l10.973.htm.

(2005). *Lei do Bem.* http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2005/lei/l11196.htm.

Mannix, T. L. (n.d.). *The Future of Medical Innovation: Reaping The Benefits of The Knowledge Revolution.*

Pascoe and Vonortas, C. E. (n.d.). University Enterpreneurship: A Survey.

(2010). *Reauthorization Act.* http://www.nsf.gov/statistics/about/BILLS-111hr5116enr.pdf.

(2013). *Reauthorization Act.* http://democrats.science.house.gov/sites/democrats.science.house.gov/files/Competes%202013%20Fact%20Sheet.pdf.

Schilling, M. A. (2013). *Strategic Management of Technological Innovation.* McGraw-Hill.

Schumpeter. (1950). *Capitalism, Socialism, and Democracy.* New York: Harper and Brothers.

Schumpeter, J. A. (1939). *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process.* New York: McGraw-Hill.

Tabarrok, A. (n.d.). *Launching the Innovation Renaissance.* TED.

(2013). *The Global Innovation Index.* http://www.globalinnovationindex.org/content.aspx?page=GII-Home: World Intellectual Property Organization (WIPO), INSEAD, University of Cornell.

(2009). *The Recovery Act.* http://www.gpo.gov/fdsys/pkg/BILLS-111hr1enr/pdf/BILLS-111hr1enr.pdf, www.whitehouse.gov/recovery/innovations/introduction-innovation.

Valdivia, W. D. (2013). University Start-Ups: Critical for Improving Technology Transfer. *Center for Technology Innovation at Brookings*.