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# Policy forum

## A trans-Keynesian vision of innovation for the contemporary economic crisis: 'picking winners' revisited

Henry Etzkowitz and Marina Ranga

We argue that the current economic crisis is a fault line in the transition from an industrial to a knowledge-based society and is thus potentially subject to a different set of dynamics than previous crises, like the Great Depression of the 1930s, which occurred within an existing mode of production. A qualitatively different response is needed to address the current downturn: one that puts in place new drivers for long-term knowledge-based economic renewal and growth. Keynesian methods, are no longer sufficient. Large-scale targeted government intervention in the innovation system and support to knowledge-based firms, technologies, products and services are required to compensate for declining innovation support from the private sector and boost economic growth. 'Picking winners' approaches that proved successful during World War II and afterwards need to be revisited, to hasten recovery from the current economic crisis and manage the transition to a knowledge-based regime.

*The Keynesian approach should be looked at as a band aid, not a surgical performance.*
(Main, 2009)

THE CAUSES OF THE ECONOMIC CRISIS that emerged in 2007–2008 have been subject to a wide international debate but have oft been misunderstood. Triggered by the collapse of the real estate market as a result of reckless and unsustainable lending practices in the US, and facilitated by the failure of regulators and supervisors to spot and correct the emerging weaknesses, the crisis spread fast to the global financial system and then into the world economy. Comparisons with previous crises have been often made, arguing that this recession is likely to be 'unusually long and severe, and the recovery sluggish...[and] could spiral down into a full-blown slump unless further action is taken to stop feedback effects gathering force' (IMF, 2009). Recovery may be slower than after the Great Depression of the 1930s, due to the global integration of markets that synchronized the recession (IMF, 2009).

Such comparisons, however, fail to acknowledge a fundamental difference from other crises: the fact that it occurred in the transition from an industrial to a knowledge-based society and is thus potentially subject to a different set of dynamics than those manifested for instance in the Great Depression, which occurred within an existing mode of production. An industrial mode of production has now run out of steam in many countries, making it more urgent to foster the generation of knowledge-based growth firms, products, technologies, services and an innovation culture altogether. Therefore, a qualitatively different response is needed to address the current downturn: one that ensures that the recovery is durable and sustainable, and does not damage the drivers of long-term growth, but rather uses them as

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a springboard to accelerate structural shifts towards a stronger economic future.

In contrast to the 1930s when Keynesian measures to stimulate use of existing productive capacities might have sufficed to end the depression, the current downturn requires new productive capacities. Beyond putting people to work as an end in itself, we now face the need to create new forms of work to compensate for job loss in shrinking industries. Policy-makers faced with the continuing dilemma of putting resources into saving the old or building the new should simultaneously pursue a dual strategy, balancing Keynesian stimulation of the old economy and infusing salvageable old firms with new technologies and advanced research and technology to create new industries.

We argue that a 'picking winners' approach that has long been criticized for ineffective government intervention in the economy should be pragmatically revisited beyond ideological strictures. It may prove useful in re-assessing the mechanisms, policies and strategies that government could employ to speed the recovery from the economic crisis and assist transition from an industrial to a knowledge-based mode of production during a downturn.

We start by providing a brief account of the evolution of the 'picking winners' concept over the last three decades or so, emphasizing the shift from the strong ideological opposition of the 1980s to the more flexible approaches adopted by many countries in recent years as a result of largely disappointing results in implementing free-market reform packages in various parts of the world, such as Latin America or the transition countries of central and eastern Europe. We continue with an analysis of the rationale for government intervention in the economy, contrasting neo-classical, Keynesian, evolutionary economics and the triple helix model, and assessing their capacity to respond to the challenges of the current crisis. Next, we provide four examples of large-scale government support to innovation and technological development in the US, which show not only that a well-thought out 'picking winners' approach may be beneficial to fostering innovation and long-term growth, but also illustrate the importance of joint action by government, industry and university actors in this process. We conclude with a set of general principles for 'picking winners' which can be further examined in specific national and regional economic and political contexts and serve as the basis for a new range of government policies to foster innovation and economic recovery.

## The rise and fall of free-market fundamentalism

The 'picking winners' concept has long been used in a negative context associated with ineffective government intervention in industrial policy. One possible reason is the perpetuation of '…an ideology that says government intervention is always bad and leaving the private sector to its own devices is always good… despite… its failure…in practice' (Krugman, 2009). Another is the need to limit and regulate government intervention in the economy for fear of breaking competition rules. Yet another is that many scientists, fearing loss of research funds, argue that the existing breadth of scientific expertise provides a present and future competitive advantage that would be lost by investing in only a few potentially new and innovative developments (Cobyrn, 2009).

The controversy surrounding the term was present already in the 1980s, during the Thatcher/Reagan era. Although the two leaders promoted largely similar liberal and *laissez-faire* policies, there often were important differences of vision between them. Reagan's supply-side economics (also known as Reaganomics) aimed to stimulate the economy through reduced business regulation, controlling inflation, reducing growth in government spending and large tax cuts, had both a positive effect, with improvements in certain key economic indicators, and a negative one, with large increases in federal budget deficits and the national debt. Thatcher, Reagan's close political ally, promoted a philosophy based on deregulation, particularly of the financial sector, flexible labour markets, and the selling off of state-owned companies. However, Reagan did not share Thatcher's ideological consistency in rejecting intervention, but pragmatically put ideology aside to further pressing national interest.

The implications of these different visions were far-reaching. For example, Lord Sainsbury recently asserted that the UK missed its opportunity to develop a viable semiconductor industry when Thatcher turned down a proposal to support further

development of innovations made by the Ferranti firm that were beyond the company's ability to take forward without governmental assistance, and the field devolved into a marginal enterprise in the UK, while the Republic of Korea successfully developed a semiconductor industry (Sainsbury, 2009). In contrast, when the leaders of the US semiconductor industry asked for government support to establish a consortium to develop new production machinery to leap frog Japanese advances, President Reagan, despite his rhetoric, gave the go-ahead for the Defense Department to support the project jointly with industry. SEMATECH, a joint industry–government program, was thus created to develop collaborations like the Center for Integrated Systems at Stanford that brought researchers from firms across the industry together with academics to work on joint projects. SEMATECH successfully moved the US semiconductor industry to a new generation of technology and, once the industry was profitable again, continued without further government support. Industry leaders have recognized that government support was indispensible to their revival, but the strength of anti-government ideology has been so strong that there has been little public recognition of the government's role.

The strong belief in the expanding role of the free market and reduced government intervention was disrupted in the 1990s, after the mixed success of neoliberal reform policies generally associated with the so-called 'Washington consensus' that emerged in the early 1990s as a reaction to the macroeconomic crisis that hit much of Latin America and some other developing regions during the 1980s (Williamson, 1989). In spite of some longer term improvements in economic performance in a number of countries that adopted relevant policy changes (e.g. Chile, El Salvador, Uruguay and Brazil), the Washington consensus is generally thought to have failed to provide significant overall results on growth, employment and poverty reduction in many countries, e.g. the transition economies of central and eastern Europe.

Much of this limited impact was attributed to its lack of emphasis on mechanisms for avoiding economic crises and application in reforms that were incomplete and insufficiently targeting improvements in income distribution (Williamson, 2002). Although a 'second generation' of reforms and policies addressing inequality and social issues was subsequently proposed (e.g. Birdsall and de la Torre, 2001; de Ferranti and Ody, 2006), the Washington consensus has lost much of its influence and new mechanisms to boost economic growth are fervently sought:

> While the lessons drawn by proponents and skeptics differ, it is fair to say that nobody really believes in the Washington Consensus anymore. The question now is not whether the Washington Consensus is dead or alive; it is what will replace it. (Rodrik, 2006)

Indeed, various government-supported national initiatives aimed to recognize and exploit opportunities for economic growth emerged in the 1990s, such as the UK Technology Foresight Programme (Georghiou, 1996), exemplifying a declining pressure on welfare societies to conform to *laissez-faire* dictates, as well as some of the constraints on government intervention. In late 2003, a renewed focus on 'industrial champions' has emerged in Europe, in the context of concerns about deindustrialization repeatedly expressed by various Member States and the European Council, but also following the commercial and industrial successes of Airbus coupled with Europe's weak performance in other high-technology sectors. France's new Agency for Innovation, established in 2005, that allocated over €80 million to big innovation projects in biotechnology and pharmaceuticals, medical technologies, agro-food and environment technologies is a good example of new forms of government direct support to innovation and economic growth. The French bail-out of Alsthom, the E.On–Ruhrgas saga in Germany, the Franco–German–Spanish calls to create a European 'champion' in shipbuilding and the trade conflict with the US on subsidies to Airbus and Boeing, are also examples of the drive to protect or support industrial champions (Maincent and Navarro, 2006).

Since the end of 2007, the large-scale government interventions generated in response to the current economic crisis in order to forestall depression as well as rescue the financial system, have revealed fundamental flaws in the market self-regulation myth, shaken confidence in the virtues of lightly regulated markets and free capital movements, and opened the way to a less ideologically charged debate about the role of the state in development (Wade, 2009).

After rescue plans to avoid a collapse of the financial and banking systems and limit the economic effects of the credit crunch, economic stimulus packages meant to revive economic growth became the most common policy tool in many countries, including the US, the EU, China, India, Japan, Australia and Argentina. In addition to political responses provided by individual nations, a globally coordinated response, including proposals on international financial regulation, economic support and anti-protectionism measures, was considered at the November 2008 summit of the G20 group of major economies. The OECD is also developing a strategic response to the crisis focusing on two priority areas: finance, competition and governance; and restoring long-term growth.

Moving away from the ideological opposition of the last decades, a 'picking winners' approach, especially in innovation and technological development, could aid recovery from the current economic crisis. It has now become clear to many governments that, rather than attempting to restore economic growth by adopting expansionary fiscal and monetary policies, inflation strategies, cuts in health insurance and

retirement pension benefits, downsizing or even using bankruptcy as a way to drastically cut wages and benefits, the ability to scale-up innovation initiatives in selected areas is essential for long-term economic growth.

The need for targeted government intervention in innovation and technology development is all the more needed as these areas have been hit hard by the economic crisis: research and development (R&D) spending has declined in many countries, US venture capital investments plunged 60% in the first quarter of 2009, similarly to Europe and in China, patent applications have gone down and incentives to develop a greener economy have been weakened by the crisis (OECD, 2009).

The necessity to foster innovation, entrepreneurship, and investment in R&D goes hand in hand with the need for education and labor policies to upgrade workers' skills, provide adequate numbers in the workforce and ensure stable employment. Layoffs are announced at worrying pace almost daily in high-tech industries, like information technology, aeronautics or pharmaceuticals, and knowledge-intensive services like financial services. This human capital is likely to depreciate quickly if the downturn is protracted. Industrial firms are shrinking, and even if they recover with the help of an infusion of new technology, their employment bases will be smaller. A crisis of biblical proportions (a seven-year downturn) may be at hand if effective action is not taken to foster employment growth (Herbert, 2009). To renew employment and stimulate demand, government action has to extend beyond saving existing industries into creating new industries that rely more heavily on a knowledge base.

The task is by no means easy. A downturn creates pressure for even a *laissez-faire* government to rescue old industry, while the support for creating the new may be weak or even missing, potentially reducing the government funds that may be available for innovation and entrepreneurship. The 'innovation contradiction' is that it is in the downturn, when human resources are most available and when firm formation is especially needed to generate new jobs, that private sector resources to support entrepreneurial activity are least available. 'Creative destruction' is all too apparent during a downturn, but its positive side, 'creative reconstruction' may be less evident because it is policy-driven rather than market-driven. Government leadership is required to make the case for building the new economy through countercyclical measures (going against the business cycle) to provide funds through public venture capital.

The practical, concrete ways to achieve 'creative reconstruction' need to be defined, in a collaborative, synergic manner that goes beyond traditional institutional boundaries. Large-scale targeted government intervention in the innovation system, balancing long- and shorter-term policy measures requires strategic options at the level of both governments and societies as a whole. Public support is essential to cross the ideological divide from *laissez-faire* to active government. To bridge this gap, public understanding needs to be sustained that we are at the cusp of transition from an industrial to a knowledge-based society, requiring policy initiatives to cross the Rubicon. Churchill provided the leadership that scaled up British preparation for the onslaught of World War II through speeches that catalyzed public support. Roosevelt similarly gained support for far-reaching measures to address the depression through his 'fireside chat' radio addresses. Having faced the crisis of economic transition in the early 1990s, Finland's political leadership responded by focusing attention on innovation issues and raised them to the highest level of national priority. Technical, political and financial resources have been mobilized to create new knowledge-based industries for almost two decades, providing a policy model for other countries to emulate (Peltonen, 2009).

## Grounds for government action: from neo-classical economics, Keynesianism and evolutionary economics to the triple helix model

While the role of the government in restoring economic growth has become a subject of little dispute in the context of the economic crisis, the key areas and mechanisms of intervention remain at the centre of a heated debate. Economic stimulus packages in various countries around the world have been an unproven success so far. Uncertainty over the adequacy and effectiveness of the proposed measures has determined some countries' reluctance to spend more money addressing the crisis. 'The switch from decades of supply-side politics all the way to a crass Keynesianism is breathtaking' declared the German Finance Minister Peer Steinbrück in early December 2008, arguing that 'A Great Rescue Plan...doesn't exist. Dealing with an unprecedented crisis is a puzzle, a trial-and-error' (*Newsweek*, 2008). In a similar vein, the EU presidency warned the European Parliament in March 2009 that the US and UK economic recovery plans are 'a way to hell' (*Daily Telegraph*, 2009).

Keynesianism and neo-classical economics have been so widely embraced as they appeared to be the best-known schools of thought that offered a justification for, and an example of, government intervention in the economy.

Neo-classical economics provides a specific criterion for government action: the existence of a 'market failure', i.e. when the production or use of goods and services by the market is not efficient, or an activity cannot or will not be taken up by the private sector, but there is a public good to be attained, especially one that will advance the productivity of industry. In this case, it is allowable, possibly even incumbent upon government to act. Nevertheless, some types of government policy interventions

which aim to correct market failure, such as taxes, subsidies, bailouts, wage and price controls, may also lead to an inefficient allocation of resources, sometimes called 'government failure', which complicates the choice between imperfect market outcomes and government interventions.

Keynesianism advocates a mixed economy: predominantly private sector, but with a large proactive role of government and public sector in exploiting unused industrial capacity to stabilize the business cycle. Keynes' ideas for government to revive the productive capacities of the industrial society were intermittently adopted during the Great Depression of the 1930s, and later served as the ideological base to recover from World War II and manage the economic growth of the post-war Golden Age of Capitalism (1945–1970). Even before that, he prematurely noted the end of the *laissez-faire* regime, expecting acceptance of a significant role for government in the economy (Keynes, 1926). For example, public infrastructure, social and cultural capitals were enhanced through various conservation, economic development and employment programs (Rose, 1994). Young people undertook reforestation projects under army supervision in the Civilian Conservation Corps. The Works Progress Administration (WPA) employed millions of people in virtually every locale on projects large and small, building everything from roads and bridges to schools enlivened by artists' murals. The WPA also sponsored theatre groups and hired writers to produce guidebooks to each state. The Public Works Administration undertook larger scale projects such as dams to produce power, reduce flooding and irrigate farmland. The Rural Electrification Administration lit farms, reducing isolation and social disparity. It also hired photographers to document gritty perseverance in the face of economic and social adversity. However, as programs to create employment had an effect, they were often scaled back due to ideological opposition. The Roosevelt administration's response to the Great Depression was large scale, yet intermittent. By 1937, the success of Keynesian measures led the Roosevelt administration to conclude that government should relax, rather than redouble its efforts to revive the economy, causing an unnecessary downturn (Romer, 1991).

Evolutionary economics is vague, offering no specific criteria for government intervention, just a theoretical context for a broad institutional framework for the development of markets. In particular, the so-called 'evolutionary targeting' provides a dynamic policy perspective focused on triggering, re-enforcing and sustaining market-led evolutionary processes of emergence of multi-agent structures (industries, clusters, markets, etc.) through discrete policy interventions in varying areas of system/market failure that appear at difference phases of the overall process (Avnimelech and Teubal, 2008; Barber, 2009). Government is one element of this framework that may engage in trial-and-error efforts to improve the innovation process and induce learning.

Both neo-classical and evolutionary approaches expect innovation to be a firm-based process that takes into account incremental change, but not the effects of a large-scale economic crisis, requiring discontinuous innovation.

The triple helix model of university–industry–government interactions goes beyond the boundaries of firms and markets, emphasizing knowledge-based linkages between innovation actors that are much more relevant in addressing the current economic crisis, as it takes place in the transition from an industrial to a knowledge-based society, rather than within a single mode of production. Industry as a single helix strategy was inadequate to transcend the 1930s depression: industry by itself was a sub-optimal economic actor. A double helix of industry–government as primary institutions of the industrial society was the great transformation of the 19th century (Polanyi, 1944)[1], but in the 20th century it proved insufficient to bridge the transition between industrial and knowledge-based modes of production. A triple helix of university–industry–government as the key stakeholders of the knowledge society emerged, first at the national level during World War II to promote development of scientific weapons, and later at the regional and local level in support of knowledge-based economic growth. After World War II, some scientists learned the lesson that their ability to translate technical knowledge into weapons and other useful devices not only gave them access to government officials, but also admitted them into decision-making circles. In subsequent decades, scientists enacted a variety of insider and outsider political roles, from controlling the consequences of atomic weapons to highlighting the economic potential of scientific research in the debate over re-industrialization during the downturn of the 1970s.

Conflicts arising from new modes of production were solved by adopting new legal frameworks that not only allowed conflict resolution, but also provided a framework for knowledge-based innovation. For example, the US Bayh–Dole Act of 1980, giving universities an economic role by granting them control of intellectual property rights from federally-funded research with the mandate to promote commercialization, was a landmark event and was replicated, in more or less similar forms, in many other countries. More recent examples include US open industrial policy initiatives, such as the virtual nationalization of the greater part of the automotive industry, in contrast to previous indirect and hidden measures (Etzkowitz, 1994). In Sweden, a third mission was introduced to encourage universities to foster technology transfer and firm formation. The VINNOVA agency was established, drawing together elements of previous agencies focused on supporting particular industrial and technology sectors, playing a broad role through its education and grant programs, incentivizing regional triple helix

coalitions to coalesce, and developing projects to revive existing industries and foster new ones (Benner and Sandstrom, 2007).

## Picking winners: learning from the past

In the run-up to World War II, the UK Air Ministry issued specification F.7/30, with general design criteria for a high-speed fighter aircraft capable of mounting a battery of machine guns. The field was open to design innovations since F.7/30 did not specify how to reach these objectives. Limited resources had to be focused, so a few candidates was a reasonable choice. The ministry selected two firms' proposals to back: the Hawker Hurricane and the Supermarine Spitfire. In the end, it was the Spitfire, the 'long shot' presented by a marginal firm, previously known for racing success with its seaplanes, which emerged as the clear winner. If the well-known firm had been given all the resources, the ultimate winner would have been discarded. Indeed, the Spitfire aircraft has been widely credited with providing the technological edge that won the Battle of Britain (Bishop, 2003).

This example illustrates a leading role for government in technological innovation that was well accepted in wartime *laissez-faire* societies. Many other innovations, including radar, the proximity fuse and penicillin were brought to fruition during the war with government playing, if not always a first mover role as with F.7/30 a significant and indispensible role, typically in partnership with leading scientists who were brought into government both as scientific advisors and as S&T agency administrators. Government actions thus took place at the intersection of the state and the scientific community, through hybrid organizations in the US, like the Office of Scientific Research and Development (OSRD) and through scientific advisors, with the ear of Churchill and Roosevelt. Significant resources were put at the disposal of scientists who had a considerable say on which technological innovations to back in contrast to World War I in the US, when scientists were largely limited to following the prescriptions of the military. The key difference was that the military largely worked within existing technological paradigms, frustrating the scientists who often wished to move 'outside of the box'.

Once *laissez-faire* strictures are removed, several models of government intervention in innovation are available to address the economic crisis. We now discuss four successful US initiatives in picking technology winners spanning the period from World War II to the present:

- The Office of Scientific Research and Development (OSRD);
- The Defense Advanced Research Projects Agency (DARPA);
- The Small Business Innovation Research Program (SBIR); and
- The Advanced Technology Program (ATP).

The first three may be viewed in chronological order as representing a descending order of scale and scope, from an integrated innovation regime, moving from problem to solution and from idea to production, to one that addresses only the upstream stages. OSRD shows the importance of adequate scale of resources to address the problem, while ATP shows the consequences of inadequate resources and the importance of placing academic centres at the heart of industrial consortia to achieve continuity and commitment. ATP largely failed due to a mismatch between the scale of the problem selected, typically large, and the resources it could bring to bear, usually small. SBIR reduced the 'valley of death' by funding upstream translational research, but there a gap further downstream often remained, sometimes addressed by state government programs and sometimes not, leaving some significant projects to wither and fall by the wayside. DARPA suggests the importance of creative leadership. SBIR provides a model to bridge the early stages of commercialization, especially in a downturn, when private venture capital dries up, necessitating a countercyclical public substitute to stimulate the innovation process. All examples also show the importance of focusing relevant technical resources on a clear goal, once an objective is set, whether at a common site or through decentralized collaboration.

In addition, the four examples discussed below not only suggest the viability of a 'picking winners' approach to discontinuous technology development, with a strong role for government, but also illustrate triple helix collaborations of university–industry–government that might be more relevant nowadays in addressing the current economic crisis than Keynesian, neo-classical or evolutionary economics. Even in the ATP case, an explicit bi-lateral government–industry program with academics excluded from leadership roles, in its actual operation, some of the most successful projects in the healthcare information initiative involved universities as subcontractors who played a more significant initiatory and operational role than indicated by their subordinate status in the project (Etzkowitz and Spivack, 2001). Universities provided a neutral ground for centers to carry out the SEMATEC project, bringing company researchers together at federal government-subsidized facilities on campus, reprising some of the wartime OSRD model. Similarly the policy entrepreneurs at NSF and DARPA incentivized university researchers to participate in joint university–industry–government R&D projects, promoted circulation around the triple helix spheres and collaboration among them. By providing a research-based format to commercialize academic research, SBIR created a seamless web between university, industry and government to move incipient technologies towards the marketplace.

### The Office of Scientific Research and Development

In the run-up to World War II, an elite group of academic and industrial scientists pondered how they could best use their skills and the potential of science to advance the nation's cause in the expected war. They took the leading role in creating OSRD, recruiting the heads of leading industrial labs as their junior partners before proposing an organizational plan that was accepted by government at the highest level (President Roosevelt and his key advisors), with whom the academics built a working relationship from the base of the Carnegie Institution of Washington, a research institute which became their representation arm in the Capitol. Initially recognized as a government-sponsored committee and then as an agency independent of the military, the OSRD had the remit to address problems posed by the military, but also originate significant projects on its own, going from fundamental science to final production and testing (Stewart, 1948; Baxter, 1946). There was a balance between autonomy and direction with loose coupling between a stated goal and the means for reaching that objective. Research was carried out through contracts with universities to establish labs rather than in government labs at their own sites. Recruiting a leader who was a key node in a technical network with ability to recruit the best available researchers was the key to the success of a lab (Leslie, 1993). Frederick Terman, who was called to Harvard from Stanford Engineering School to head the Radar Countermeasures Lab, exemplified the academic with a broad range of university–industry contacts, who was able to move from successively mentoring a relatively few students in peacetime to directing a large-scale wartime lab.

Thousands of university researchers were recruited from around the country to the so-called Rad Lab at Massachusetts Institute of Technology for the development of radar. Innovation was pursued from all angles simultaneously: forward linear from scientific ideas, reverse linear from military needs, projects that combined research with small-scale production in the lab. Boundary-spanning innovation formats, integrating research and production, were invented to collapse time frames. These resource-rich, time-limited R&D projects sent scientists into the field to identify problems in test models and brought manufacturing experts into the lab from firms to start preparing manufacturing designs to make experimental devices ready for production runs before R&D was completed. Innovation gaps that plagued government-supported research in the post-war period, and were only partially resolved over the decades, were expeditiously solved in the 'anything goes' atmosphere of wartime where university, industry, and government worked in harness.

Although Vannevar Bush, its Director, immediately disbanded OSRD at the conclusion of hostilities, he had earlier arranged for President Roosevelt to request a proposal for a government role in peacetime research. The result was *Science: The Endless Frontier*, a volume whose title became a widely accepted metaphor for 'blue sky' research (Bush, 1945). The specific chapters of the report, prepared by committees of academics, industrialists and government officials on health, transportation, housing, military research, etc. are seldom referred to (Stokes, 1997). One element of the report, fundamental research, led to the National Science Foundation (NSF), a pared down version of the much broader agency that Bush envisaged (Hart, 1998).

OSRD exemplifies a mechanism of a scientist-led research agency through which the government introduced and supported discontinuous innovation into military conflict during World War II. It also illustrates a full-scale model of a university–industry–government concerted approach to technological advance and economic development that was invented at the advent of World War II. Wars were previously fought with weapons available at the inception of the conflict, the objective being to produce large quantities and achieve incremental improvements along the way. World War II led to the scale-up of research models and transformed academic research, at least in physics and engineering, from an individualistic to a group phenomenon and from a parsimonious endeavor to a well-funded enterprise. Once the apple of government largesse had been bitten, few wished to return to a scarcity regime.

### The Defense Advanced Research Projects Agency

DARPA was created in response to the 'Sputnik shock' of 1957 when the Soviet Union surprised the US by launching a satellite first. This was broadly interpreted as implying not only Soviet leadership in the space race, but more broadly in S&T in general. Statistics on graduation rates of engineers in the two countries were cited to further deepen the gap. The response thus included: new graduate fellowship programs, a cabinet-level advisor to the US president on S&T and DARPA, an agency with the mission to advance emerging areas of S&T that had broader relevance than any single mission oriented agency might foresee.

DARPA was given the authority to do whatever was necessary, from funding basic research to provision of venture capital to achieve its goals. The DARPA program officer, a public entrepreneur, is the key to the DARPA model, which is for a program officer in temporary government employ, typically seconded from academia or industry, to design an innovation program bringing together relevant university researchers and firms to accomplish a far-reaching objective. All phases of the research and innovation process may be supported over a relatively long time period. The Harvard psychologist J C R Licklider, who envisaged a new format for computer communication that led to the internet, exemplifies these highly skilled, broad-gauge technologists and visionaries, often drawn from

universities. Following the DARPA format, Licklider had the freedom and the resources to fashion a consortium from across university, industry and government laboratories to realize his vision of fault-tolerant computer-mediated communication networks (Haffner, 1998).

Although DARPA is required by law to achieve military goals, many of its initiatives, like the internet, have had significant spillover into the civilian economy. A data mining initiative provided the framework and resources for the invention of the Google algorithm. Nevertheless, discussions of the origins of Google typically begin with the meeting of two like-minded graduate students, ignoring the substrate of government goal-oriented research support that underpins much of graduate training in computer science at Stanford and other leading universities. There have been various proposals for a civilian DARPA, but the political will has been lacking until quite recently. Only military objectives have been granted an exemption from the dictum of government's supposed inability to pick winners.

The Obama Administration has recently established an Energy ARPA. However, at least in its first iteration, it is said to be functioning according to an NSF individual investigator-led model, more appropriate to basic research in accepting a broad range of research proposals and exercising little strategic direction (*Science*, 2009). This 'over the transom' approach was perhaps necessitated by time, urgency and an initial small staff, and perhaps even lack of awareness of how the DARPA model, that it is presumed to be following, actually works. On the other hand, the Obama Administration's Energy leadership has exercised strategic direction in pulling back from the very long-term 'hydrogen economy' models favored by the Bush administration, but has not yet set a clear priority or two. Perhaps a specification like F.7/30 is in order and/or recruitment of Licklider-like individuals with a technological vision.

### *The Small Business Innovation Research Program*

In recent decades, despite being limited by *laissez-faire* ideology to provide basic research capabilities that industry is unwilling to support, government has played an innovative role in supporting new high-tech firms through the SBIR.[2] Begun by program officers at the NSF in the early 1980s, its founders hid their industrial policy intentions by extending the NSF's basic research funding model, relying on technology experts, often from the private sector, to judge commercial potential even as it typically relies on academics to certify scientific and technical merit (Gulbrandsen and Etzkowitz, 1999). After demonstrating success, SBIR was extended from NSF to all government agencies with research budgets of more than US$100 million.

Researchers often use SBIR grants as the first step toward forming a firm, without needing to actually form a firm in advance of receiving a grant. The 'basic research' format of SBIR has had the unintended consequence of supporting early stage ideas with commercial potential, in contrast to programs that may require a firm to support 50% of a project, typically limiting the selection to close to the market ideas. Program officers set topics, extending from their remit into areas of potential industrial interest, often through informal consultation with users. SBIR fills some of the gap, the so-called 'valley of death' that business angels and private venture capital firms are typically unwilling to enter until a firm has demonstrated earnings (Wessner, 2008). Thus, public and private venture capitals are complementary, with government playing the role of seeding the private venture capital industry (Wessner, 1999).

### *The Advanced Technology Program*

ATP[3] was initiated during the 1989–1993 Bush administration in response to concerns that US multinationals would move R&D to Europe to take advantage of the EU Framework Programme support. ATP granted most of its funds to consortia of large firms, sometimes supplemented by university researchers. ATP projects often received only intermittent attention by their industrial partners. Even though some ATP projects, such as its automotive initiative, were in the tens of millions of US$, this was an insignificant sum for firms that spend many orders of magnitude beyond that on a new model. If an initial champion was transferred or firm direction changed, the relatively small ATP initiative might fall by the wayside.

However, the scale of funding, even if insignificant to large firms, was sufficient to catch and hold the attention of academic partners who moved the projects forward. Indeed, university researchers sometimes initiated projects by recruiting industry partners to take the official lead, through a Trojan horse stratagem of university entrepreneurs finding firms to front their proposals. Indeed ATP program officers were often the instigators of consortia, surreptitiously taking the more pro-active role of DARPA program managers in order to drum up sufficient interest among firms to apply. Political opposition to the ATP reduced its funding and led to a shift towards grants in the low millions of US$ for innovative start-ups, turning ATP into a useful follow-on to the SBIR. ATP is currently emerging out 'deep freeze' in the National Institute of Science and Technology, its sponsoring agency, as the Technology Investment Program, after having received no new funds in recent years.

## Intervention mechanisms and policy implications

A key question emerges from the four examples of successful government support to specific industry sectors or technologies described above: how can

they be replicated in the current economic context, moving beyond the ideological opposition that accompanied the concept over the last decades?

A set of general principles for 'picking winners' may be derived from the discussion above, which need to be further examined in specific national and regional economic and political contexts:

- *Accurately assess the scale and scope of the crisis in order to formulate a commensurate response*. In a downturn, there is a natural tendency to focus on retaining old areas of the economy for fear of worse to come, but the slowing economic shrinkage does not address the more fundamental issue of creating a future economy, more tied to technological than financial innovation. The creation of a civilian-oriented OSRD and DARPA, and an expanded SBIR may speed up the post-war model of stimulating the science base, supplemented by relatively modest efforts to assist the linear model and translate research results into use.
- *Define clear objectives and aggregate sufficient resources to achieve them.* Aggregating adequate resources becomes ever more difficult as the potential resource base decreases in size, as is typically the case in small countries. The problem is further exacerbated when there are strong pressures to simultaneously pursue a broad range of alternatives (e.g. the Netherlands, see Hekkert, 2009). Moreover, existing technologies are protected by strong lock-in mechanisms and subsidies, both direct and indirect (Etzkowitz, 1984). Even when R&D resources are made available in the early stages of innovation, government funding is rarely available on the scale necessary to bridge gaps in the later, more expensive, stages of the innovation process (Hekkert, 2009). If large countries, such as the US, may aggregate significant human and material resources for technology development, smaller countries need to act together to achieve the critical mass to match the scale and scope of the effort needed to bring a significant new technology on line that has heretofore largely been restricted to large countries. In this context, cross-national collaboration to aggregate sufficient resources is indicated to achieve a breakthrough that a single country may be unable to achieve.[4] In addition, increasing the integration of financial markets and improving access to finance is an important condition for the survival and sustained growth of start-ups and small and medium-sized enterprises, particularly in high-tech sectors. Countercyclical public venture capital is required to break the 'iron discipline' of the business cycle.
- *Carefully consider the strengths and weaknesses of the national, regional and local industrial structure* (large companies versus small and medium-sized enterprises, activity in traditional low- and medium-tech industries versus new high-tech ones, the number and potential of international versus domestic players, etc.), and its sectoral specialisation. A correct assessment of industrial characteristics is essential for successful support. The risk of making the wrong choices is much higher for a domestic industry at the technological frontier or in sectors fraught with technological and market uncertainties, while supporting a domestic industry catch-up towards a foreign technological leader can be a safer option. Nevertheless, advances in most high-technology industries such as biotech, nanotech or medical devices imply assuming high risks, as the nature and pace of technological progress in these areas is different than in low- and medium-tech industries (Maincent and Navarro, 2006).
- *Design a selection process with clear criteria and time frame* to insure that the technical choices are feasible and capable of scale-up within a reasonable period.
- *Incentivize university–industry–government collaborations*, so that a balanced approach may be taken without government having to be the sole actor.

A number of OECD countries have already adopted important innovation and entrepreneurship support measures in their economic stimulus packages, next to other measures such as improving the infrastructure (e.g. roads, mass transit, information and communications technologies), investment in human capital, education/training, including schools, teachers, promoting the investment in and uptake of green technologies and innovations to foster energy-efficiency and sustainable economic growth. In terms of financial weight in stimulus packages, infrastructure investments, education and sometimes green technologies are the first and second most important of these spending items, although in many cases these components are related, e.g. infrastructure overlaps with spending on R&D (new laboratories) and spending in education category (new schools) (OECD, 2009).

The effects of such policies may take a longer time to emerge. In the past, it often took considerable time to renew a failing economic base. For example, a half century intervened from the beginnings of the economic decline of New England in the early 20th century to its post-war revival, based on the invention of venture capital and the founding of the minicomputer industry. To address the current crisis, we must, like Moses, look over the horizon, to the promised land of the Knowledge Age, and be aware that the forces of 'creative destruction' identified by Schumpeter (1942) work at an ever more furious pace during a downturn. Expressions of concern over growing national debt may be answered by reference to the new productive forces, and future tax revenues created by investment in new technologies. If we develop a far-reaching plan and take effective action we may not be consigned to wander aimlessly for 50 years.

## Notes

1. On the one hand, the market became the organizing principle of social relations while, on the other, the Speenhamland Law of 1795 placed limits on exchange relationships and guaranteed workers a living wage.
2. This section draws upon Etzkowitz *et al*. (2000).
3. The ATP discussion is primarily based on interviews conducted in 1996 by the first author as part of an evaluation of the Information Infrastructure in Health Care ATP Initiative.
4. An example of such multi-country collaboration is the Six Country Program of the Innovation Policy Network, which is an international network of public policy-makers, business leaders, academics, and other experts working in innovation (available at <http://www.6CP.net>, last accessed 2 December 2009). The members meet periodically to discuss the latest developments in innovation research, policy and practice. Established in 1975, the 6CP provides a platform for open discussion and analysis of innovation policy issues and exchanges of experiences and best practices in the field. The movement to a European Research Area has also encouraged many other EU initiatives to establish a model of aggregating resources to undertake larger collaborative projects.

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