Beyond the Business Cycle:

The Need for a Technology-Based Growth Strategy

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February 2012

Although this paper is primarily an assessment of alternative economic growth strategies, implications for specific policy instruments are unavoidable. Any such statements are mine alone and do not represent official positions of NIST or the Department of Commerce.

*I am indebted to Stephen Campbell, Albert Jones and Phillip Singerman for helpful comments on previous drafts.

Abstract

Facing the worst economic slowdown since the Great Depression, efforts to reestablish acceptable growth rates in both Europe and the United North America are relying to a great degree on short-term “stabilization” policies.

In a structurally sound economy, the neoclassical growth model states that appropriate monetary and fiscal policies will enable price signals to stimulate investment. The subsequent multiplier effect will then drive sustainable positive rates of growth. However, these macrostabilization policies can do relatively little to overcome accumulated underinvestment in economic assets that create the needed larger multipliers. This underinvestment has led to declining U.S. competitiveness in global markets and subsequent slower rates of growth—a pattern that was underway well before the “Great Recession.”

However, the massive monetary and fiscal “stimulus” applied since 2008 in the United States has had only a modest impact on economic growth. The reason is that the prolonged current slowdown is a manifestation of structural problems. Thirty-five years of U.S. trade deficits for manufactured products cannot be explained by business cycles, currency shifts, and trade barriers, or by alleged suboptimal use of monetary and short-term fiscal policies.

High rates of productivity growth are the policy solution, which can be accomplished only over time from sustained investment in intellectual, physical, human, organizational, and technical infrastructure capital. Implementing this imperative requires a public-private asset growth model emphasizing investment in technology.

This paper assesses the limitations of monetary and fiscal policies for establishing long-term growth trajectories and then describes the basis for a technology-based economic growth strategy targeted at long-term productivity growth. This growth model expands the original Schumpeterian concept of technology as the long-term driver of economic growth where technology is characterized as a homogeneous entity that is developed and commercialized by large-firm dominated industry structures. Instead, the new model characterizes technology as a multi-element asset that evolves over the entire technology life cycle, is developed by a public-private investment strategy, and is commercialized by complex industry structure that includes complementary roles by large and small firms.

Beyond Stimulus and Debt Reduction:
The Need for a Technology-Based Growth Strategy

Gregory Tassey

Like Albert Einstein who spent the last half of his life trying to develop a unified field theory, the U.S. economy is locked in a seemingly perpetual search for a unified macro-micro economic growth model. The importance of this search has been accentuated by the persistent weak performance of the U.S. economy following the 2008-09 recession, which has created growing concerns regarding the ability to return to acceptable long-term rates of growth. These concerns have been expressed largely in the form of a debate over the right combination of monetary and fiscal policies.

However, "macrostabilization" (monetary and fiscal) policies have strong limitations with respect to stimulating long-term economic growth. This fact creates the need for a shift to greater emphasis on microeconomic growth policy—an imperative that has reached crisis proportions due to a decades-long underinvestment in productivity-enhancing assets, especially technology. At least Einstein realized that "we can't solve problems by using the same kind of thinking we used when we created them."

Introduction

The level of consternation over sluggish growth has been particularly high in the United States because in the decades following World-War-II, the United States benefited from a structurally superior economy, characterized by the accumulation of a set of economic assets that drove high rates of productivity growth. This fact enabled macrostabilization policies to be used successfully to maintain an environment sufficient to attain acceptable growth rates. Such policies (various forms of neoclassical and Keynesian economics) rely on stimulating some combination of investment and consumption until the economy attains "escape velocity"—that is, re-establishes acceptable and sustainable private-sector rates of economic growth.[1]

One explanation for the weak response to monetary and fiscal policies is the balance-sheet deterioration of both consumers and all levels of government during the preceding decade. However, this high-debt problem is manifestation of the underlying trends that are restraining the potential for long-term recovery. In fact, this paper argues that the root problem is years of accumulated underinvestment, reflected in numerous economic indicators, such as decades of U.S. trade deficits. The explosion of debt has been an unfortunate choice of a response to an increasingly rapid globalization of the world's economy, the result of which has been a rapid growth in the productivities of other nations relative to the United States. Therefore, a new growth paradigm is needed based on a greater reliance on investment across a wide range of assets. The "range of assets" is a critical dimension of the proposed growth paradigm, as this portfolio distinguishes "neo-Schumpeterian" from traditional neoclassical growth philosophies.

The core of a "national economic strategy" is a sustained, high rate of productivity growth. Yet, this central role of productivity is still questioned by some, who argue that the increase in output per unit of labor reduces employment. However, even though productivity growth typically reduces the labor content of a unit of output, the resulting combination of improved product and price performance yields larger market shares. This, in turn, creates a demand not only for additional workers but also for higher skilled and thus higher paid ones in order to produce the more technically sophisticated products demanded by today's consumers. The cost of inadequate productivity growth is seen clearly in a number of economies in the form of falling relative incomes.[2]

Advances in technology are the only source of permanent increases in productivity (Basu, Fernald, and Shapiro, 2001). In contrast, economic studies have shown that technologically stagnant sectors experience slow productivity growth and, therefore, above average cost and price increases. Rising prices increase these sectors' measured share of nominal GDP, thereby lowering national productivity growth (Baumol, 1967; Nordhaus, 2006).

In essence, the long-term growth paradigm is driven by a set of fiscal policies, but these policies must be investment oriented and transcend many business cycles. In contrast to stabilization policies, the emphasis must be on investment in a range of productivity-enhancing technologies, as opposed to the traditional (and current) reliance on an investment component that focuses largely on conventional economic infrastructure such as transportation networks. While such "shovel-ready" investment projects are having a positive impact and are essential for an economy with a deteriorated traditional economic infrastructure, the scope and

[1] Atkinson and Audretsch (2008) provide an excellent comparative assessment of the alternative dominant major economic growth policy philosophies in terms of their respective approaches to achieving allocative and productive efficiency. In addition, they describe a third growth philosophy, innovation economics, which adds adaptive efficiency as a third policy target. Audretsch and Link (2012) elaborate on the weaknesses of neoclassical economic growth theory and add an assessment of Schumpeter's innovation theory.

[2] A NBER study found that the average productivity advantage of the United States over OECD countries as a group accounted for three quarters of the per capita income difference (McGuckin and van Ark, 2002).

magnitude is inadequate for a long-term growth strategy.

Equally important, such a strategy must be based on a growth model that reflects the increasingly complex and technology-intensive nature of global competition. The development and utilization of technologies on a scale large enough to attain significant global market shares for domestic industries require investment in a number of other categories of assets. They include human capital, better channels for technical and business knowledge diffusion to firms of all sizes, incentives for capital formation, intellectual property protection, and modern industry structure (i.e., co-located and functionally integrated supply chains). These assets form the foundation of a broad ecosystem that functionally integrates R&D, capital-formation, business management, and skilled labor. The emerging innovation ecosystem is a far more complex and integrated complex of industries, universities, and government institutions than what characterized the industrial revolution. This model is emerging on a global basis and thus a domestic economy-wide response is imperative.

Demand-Stimulation Policies Are Not Working

From 2001-2010, American households increased their debt by $5.7 trillion (75 percent), state and local governments increased their debt by more than $1 trillion (89 percent), and, the Federal Government increased its debt by $6 trillion (178 percent).[3] This expansion of domestic demand should have ratcheted up the economy's growth rate. Instead, average annual real GDP growth was less than half (45 percent) of the average for the previous four decades.[4]

This apparent contradiction to conventional growth theory has been largely unnoticed. Instead, traditional Keynesian economists and policy analysts argue for more of the same monetary and short-term fiscal stimulus. The only "structural" problem regularly mentioned is the excessive debt of the U.S. economy; hence, the label "balance-sheet" recession. It is true that the huge debt burden is restraining consumption and hence recovery, but this debt has only been a device to maintain consumption in the absence of real growth driven by adequate investment.

Monetary Policies. The conventional Federal Reserve Board response to recessions is to lower short-term rates. Historically, low interest rates induce consumers to spend and, by steepening the yield curve, stimulate banks to lend. This, in turn, promotes businesses to invest. The resulting capital formation drives future growth. This is the basic neoclassical growth model.

To attain a steeper yield curve, the Fed lowered interest rates aggressively. This strategy has reached its limit since 2008 with rates approaching zero or even negative values in real terms. Yet, consumers increased consumption modestly at best and companies have held back on investment and hiring. Instead of responding to the steepened yield curve with increased lending, banks have bought U.S. Treasury bonds, in effect borrowing from the government and then lending back to it at a higher rate.

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[3] Federal Reserve Board, *Flow of Funds Accounts*, Table L.1 (historical tables).

[4] From BEA NIPA Table 1.2.1 (real average annual GDP growth rates were 3.5 percent for 1961-2000 and 1.6 percent for 2001-2010).

Sustained low interest rates cause individuals and companies to be indifferent between holding cash and short-term investments such as Treasury notes. This “liquidity trap”, as it is called in economic text books, slows the velocity of money and hence economic activity. In such a situation, monetary policy in the form of lower rates becomes ineffective. Moreover, in a balance-sheet recession, households are focused on reducing debt, not incurring it, which makes them insensitive to low interest rates with respect to propensity to borrow.[5]

In recent decades, economists have rejected at least the seriousness of the liquidity-trap effect, if not the concept itself. This view arises partially from the fact that when lowering short-term rates through conventional open market operations fails, the Fed can fight the liquidity trap with “quantitative easing,” in which the Fed purchases longer-term financial assets from banks and other private institutions with new electronically created money. The desired result is to expand the money supply and not only lower long-term interest rates but also inflate assets (particularly the stock market), thereby creating a positive wealth effect that ostensibly leads to increased consumption. In this case, the Fed initiated two rounds of quantitative easing, known as QE1 and QE2, which together pumped about $2 trillion into financial markets.

However, the longer the current economic slowdown persists in the face of this massive monetary stimulus, the weaker this strategy becomes. Quantitative easing aimed at lowering long-term rates is increasingly unproductive as these rates approach the risk premium for each maturity, in effect creating risk-adjusted rates of zero.[6] A second negative aspect of lowering long-term rates is that doing so flattens the yield curve, thereby reducing the incentive for already reluctant banks to lend. Yet, after QE1 and QE2 did not produce the desired results, the Fed did just that by initiating “Operation Twist” in another attempt to revive the moribund housing market. This policy instrument is not designed to add liquidity. Instead, it consists of selling short-term Treasuries and buying an equal amount of long-term Treasuries in order to lower long-term rates (and, in the process, flattening the yield curve).

At this point, the only option for monetary policy is more quantitative easing for the purpose of stimulating inflation. The objective would be to maintain negative real interest rates and thereby finally induce more borrowing. With American households now in a long-term process of restructuring balance sheets, such policy initiatives are likely to continue to be ineffective.

A final but little discussed negative impact of prolonged interest rate suppression is a substantial reduction in interest income for retirees and investors who depend on this income, which in turn reduces consumer demand. Of course, a reduction in consumer income must be traded off against the negative effects of higher rates on borrowing by both consumers and businesses. Still, it is counterproductive to stimulate demand in one sector while suppressing it

[5] As pointed out in a Council on Foreign Relations report, “In every previous postwar recovery, the stock of household debt has risen as the recovery has begun. In the current recovery, the collapse in home prices has severely damaged household balance sheets. As a result, consumers have avoided taking on new debt. The result is weak consumer demand and, hence, a slow recovery.” See Bouhan and Swartz (2011).

[6] The risk premium is the amount of a rate above zero that accounts for interest rate variability; thus, a 2 percent 10-year Treasury is the equivalent of a zero interest rate, assuming 2 percent is the risk premium.

in another, especially when the stimulus instrument is experiencing declining effectiveness.[7]

Fiscal Policies. After the large debt accumulation in the 2000s, fiscal stimulus became even more aggressive in the 2008 recession three following years with annual budget deficits for 2009-2011 well over $1 trillion. Of particular relevance for long-term growth strategies is the fact that this fiscal stimulus has included an investment component. However, as discussed in subsequent sections, the amount and composition of this component is too small, too short-term, and inadequate from a long-term economic growth portfolio perspective.

Many analysts have been frustrated by the fact that in spite of healthy balance sheets and large cash reserves, U.S.-based businesses have not aggressively invested domestically, while increasing investment in in other economies. For example, NSF survey data that show U.S. manufacturing firms' investment in R&D outside the United States has been growing at almost three times the rate of these companies' domestically funded R&D.[8]

U.S. companies have done so (1) as a response to increased global market opportunities and competition and (2) because the host countries are offering greater incentives not only for R&D but subsequent commercialization. The bottom line is that the U.S. government has provided neither similar incentives nor a multi-faceted long-term investment strategy to increase the rate of return on private-sector investment in the domestic economy.

The resulting consequences of inadequate long-term domestic investment incentives are evident in a wide range of indicators:

- Private nonfarm employment decreased 3.3 percent in the decade 2000-2010.[9]
- Average annual real GDP growth during this period was 1.6 percent.[10]
- Real median household income declined in this decade by 7.0 percent.[11]
- Over the past 30 years (1980-2010), government transfer payments have risen from 11.7 percent to 18.4 percent of personal income.[12]
- In the first half of 2011, new single-family home sales fell to the lowest level since 1963,

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[7] A study by Ford and Vlasenko (2011) estimates that one year after the end of the recession in June 2009, the volume of interest-sensitive assets held by U.S. households ranged from $9.9 to $18.8 trillion. At that time (June 2010), the average interest rate on Treasuries was 2.14 percent, compared to an average of 7.07 percent at the same point in the previous nine recoveries. The projected annual impact of the lost interest income on the conservative estimate of $9.9 trillion in interest-sensitive household assets is $256 billion in reduced consumer spending, a 1.75 percentage point reduction in GDP, and the loss of 2.4 million jobs.

[8] Sources: National Science Foundation's *Science and Engineering Indicators 2006* and *2008* and *Research & Development in Industry 2007*. Between 1999 and 2007, foreign R&D funded by U.S. manufacturing firms grew 191 percent and their funded R&D performed domestically grew 67 percent.

[9] Bureau of Labor Statistics, Current Employment Statistics, Series CES0500000001. Nonfarm employment (includes government) declined 1.5 percent.

[10] Bureau of Economic Analysis, National GDP Trends.

[11] Census Bureau, Historical Income Tables H-6.

[12] New America Foundation (based on Bureau of Economic Analysis data).

when records were first kept and when the population was 120 million less.[13]

- Nearly half of American households are viewed as "financially fragile."[14]
- In 2011, approximately 13 percent of the population received food stamps.[15]

The Federal Government's own estimates indicate that at least five years will be required to return to "normal" employment rates.[16] Yet, many Keynesian economists continue to claim that the reason for the sluggish response of the American economy was that the recent government fiscal stimulus was too little and incorrectly structured. In particular, they argue that it contained too great a reliance on tax cuts.[17]

In response, Paul Krugman (2009) and other macroeconomists have called for even larger and better directed government fiscal stimulus based on two premises. First, they argue that persistent slack in the economy's capacity utilization means that government deficit spending can continue without inflation as long as this slack remains.[18] Second, they continue to espouse the Keynesian view that such fiscal stimulation will eventually cause the multiplier effect to kick in to a degree sufficient to achieve an acceptable and self-sustaining rate of growth.

The core of U.S. fiscal policy aimed at achieving recovery from the Great Recession was the American Recovery and Reinvestment Act of 2009, funded at $787 billion. While ARRA was certainly a major stimulus program, only a modest share of the total funding was directed at investment. Specifically, $105.3 billion was allocated to traditional economic infrastructure projects (highways, bridges, public transportation, etc.). An additional $48.7 billion was directed at energy infrastructure and energy efficiency (including a small amount for energy research and manufacturing scale-up). Only $7.6 billion was allocated to support "scientific research."

Compositional issues aside, ARRA was an aggressive short-term fiscal stimulus strategy. However, it is over longer periods of time that investment strategies determine economic growth rates. To this end, an increase in national investment requires a similar increase in

[13] http://www.census.gov/const/soldann.pdf.

[14] Lusardi, A., D. Schneider, and P. Tufano (2009).

[15] U.S. Dept. of Agriculture, http://www.fns.usda.gov/pd/29SNAPcurrPP.htm. Approximately an additional 4-5 percent had incomes sufficiently low to qualify for food stamps, but for various reasons they did not apply for them.

[16] The Federal Reserve Board in November 2010, after over two years of aggressive U.S. fiscal and monetary policy and in the midst of second round of monetary base expansion ("QE2"), lowered its estimates of economic growth. The Fed minutes from the November meeting stated that "the economy would converge fully to its longer-run rates of output growth, unemployment, and inflation within about five or six years." One year later in a November 2, 2011 press conference following an FOMC meeting, Chairman Bernanke stated that the pace of economic recovery would remain "frustratingly slow."

[17] It is true that tax incentives are a weaker demand-stimulation policy tool in an economy where (1) household balance sheets are heavily burdened by debt and (2) the employment outlook is weak for an extended period. In such an economy, significant portions of general tax cuts are used to pay down debt or increase savings. Hence, the benefits to demand stimulation will be relatively weak.

[18] In January 2011, U.S. industry was operating at 72.3 percent of capacity compared to a long-term average (1972-2010) of 80.5 percent (http://www.federalreserve.gov/releases/g17/current/default.htm).

savings. The critical requirement is that these savings be directed into investments that yield productive assets, as this strategy is the only way to grow real incomes in the long run. Productivity is a growing imperative, as the world's economy is becoming increasingly technology based with the result that productivity growth rates in many countries are accelerating. The policy message is that only the most efficient existing or newly created economic assets will be viable in the future. To survive, companies, industries and entire economies will have to become more productive by rapidly assimilating existing technologies and developing new ones.

Unfortunately, the structural problems increasingly evident within the U.S. economy have taken a long time to accumulate and similarly will require a long time to resolve. Specifically, the needed paradigm shift will not happen automatically for several reasons. First, the "installed wisdom" that led to inadequate growth policies remains entrenched even in the face of accumulating evidence that change is imperative. Strategies that worked in the past are presumed to be just as viable in the future. Moreover, the trauma associated with learning new investment and management strategies becomes a second significant barrier to adaptation (acquiring new "economic wisdom").

Second, an "installed-base" effect exists, which is the result of decades of accumulated economic assets. The owners of these assets face considerable risk in writing them off and shifting to a new asset mix with the consequent short-term increase in expenditures and uncertain productivity gains, even though current economic conditions dictate it should be done. Thus, traditional businesses go to great lengths to maintain the continued viability of these assets by lobbying, for example, for relief from taxes and regulations (Tassey 2007).

A manifestation of this denial of economic reality is the blaming of competitors for American economic growth problems. China, by virtue of its size (now the world's second largest economy) and its position as the port of export for Southeast Asia is a frequent target. The Chinese are justifiably criticized for currency manipulation, intellectual property theft, forced transfers of technology and domestic content requirements to gain access to their domestic markets, etc. However, the proposed conventional remedy of imposing tariffs on Chinese exports will not reverse the growing contribution of structural decline to the huge trade deficit with China. The fact is that the United States currently has bilateral trade deficits with 84 countries.[19] It has not had an aggregate trade surplus in goods since 1975. Thus, the current economic malaise is not primarily a market-access or a business-cycle problem.

In addition to demand stimulation and increasing capital market liquidity (the latter being the main result of so-called quantitative easing), the macroeconomic strategy for a U.S. economic recovery is based on depreciation of the dollar to stimulate exports. Yet, although the dollar index declined 34 percent in the past decade (2002-2011) against a basket of major currencies, the United States is still incurring large trade deficits.[20] The fact is that no economy has ever

[19] http://www.census.gov/foreign-trade/Press-Release/current_press_release/ft900.pdf.

[20] The U.S. "major-currency" dollar index is the value (weighted geometric mean) of the dollar relative to a basket of foreign currencies (Euro, English pound, Canadian dollar, Swedish krona, Swiss franc, and Japanese yen). During this same period, the dollar decline 22 percent against an index of all currencies. See http://www.federalreserve.gov/releases/h10/summary/default.htm.

prospered by depreciating its currency. The cost of this strategy is import-price inflation. Its only legitimate use is to buy time by temporarily increasing domestic value added while the structural problems that caused the long-term trade deficit are removed.

The bottom line is that if the underlying structure of an economy is sound, then macrostabilization policies can return that economy to an acceptable long-term growth track when short-term destabilizations occur. Neoclassical and Keynesian economists assume a sound structure exists or can be imposed through competition policies, which enables the internal dynamics of the marketplace to respond to price signals. The main difference between the two schools of thought is the mechanism by which growth occurs. Neoclassical economists believe that growth is determined by supply-side capital accumulation, which in turn is driven by relative prices—totally a market response. Keynesians believe investment is a derived demand, i.e., stimulated by consumption, which is only partly endogenous to the marketplace (i.e., portions are created by government spending). Neither group seriously attempts to explain the sources of the productivity of capital other than to assert it increases as part of the private-sector investment process.

The closest traditional economics comes to recognizing the role of technology is so-called "endogenous growth" theory.[21] Here, technology is recognized as an asset (and, therefore, its investment process, R&D, is also recognized). But, technology is still regarded as a pure private good with the implied assumption that relative prices effectively distribute this category of investment capital. The resulting stocks of knowledge and physical capital are then asserted to enable attainment of the necessary rates of productivity growth (productive efficiency is achieved). If relative productivities change, then relative prices will reallocate resources efficiently, thereby moving the economy toward a new equilibrium.

In summary, the most important characteristics of neoclassical economics are (1) government intervention of any type that is internal to the dynamics of the private market is viewed as interfering with allocative efficiency, implying that very few market failures exist, and (2) allocative efficiency is maximized relative to a given productive efficiency through the price mechanism (Atkinson and Audretsch, 2008). However, neoclassical economics says little about how the existing level of productive efficiency is determined and how it changes over time. The dynamics of long-term growth and competitiveness are therefore left to the innovation economists who provide the elements of adaptive efficiency, which in turn drive long-term productive efficiency.

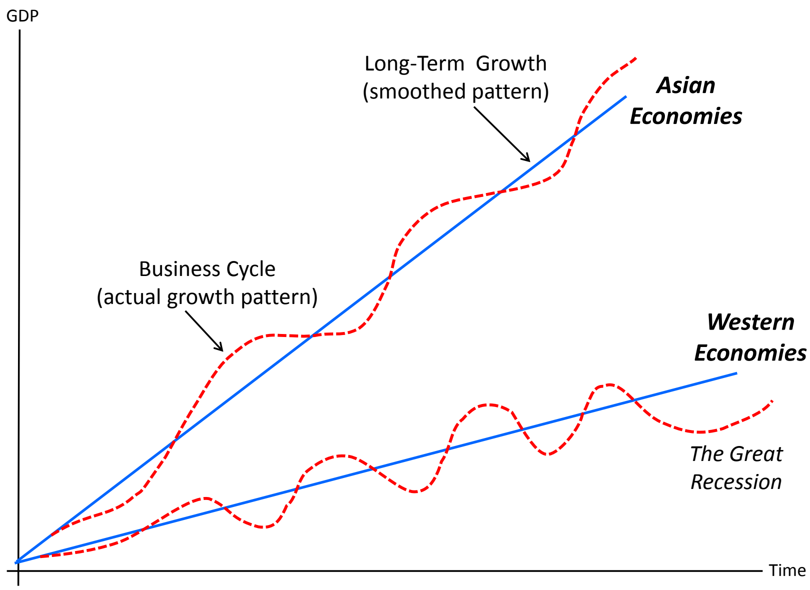
Structural Problems Should Be the Focus of Economic Growth Policy

A technology-driven and productivity-enhancing investment strategy is essential to enable the U.S economy or any high-income economy to compete successfully over time against other technology-based economies. Unfortunately, the United States has, for several decades now, failed to invest adequately in its economic future, with the result that its adaptive efficiency has declined.

[21] The evolution of the characterization of technical knowledge is assessed in Tassey (2005) along with a new model that recognizes the public-private character of modern technologies.

Long-Term vs. Short-Term Growth Strategies. A critical requirement for achieving acceptable rates of economic growth is that business-cycle fluctuations and the capacity for high long-term growth rates be managed by very different policy instruments. Fluctuations in economic activity always occur along a long-run growth trajectory, as shown in Fig. 1. The dashed lines represent these short-run oscillations resulting from business-cycle imbalances. The oscillations about the trend are managed by a combination of interest rates or monetary base control (monetary policy) and tax rates or government spending (fiscal policy).

Fig. 1 Long-Term vs. Short-Term Growth Trends



The solid straight lines represent different growth trajectories. Their relative slopes (growth rates) are determined by long-term investment strategies that result in unique portfolios of economic assets.

A sound economic structure actually facilitates the job of stabilization policies by enabling more efficient investment and productivity responses in recessions and a lesser tendency toward inflation in expansion phases. This has been evident during the last decade in Asian economies, where many nations have seen high sustained rates of growth and relatively subdued business cycle fluctuations, as exemplified by the top growth trajectory in Fig. 1.

During the last ten years, the U.S growth trend has resembled the bottom growth path and has been a manifestation of a much longer investment deficit. This substantial drop in the rate of economic growth had a pronounced negative impact on tax revenue, which was exacerbated by lower tax rates and higher government spending. The result was large budget deficits appearing almost instantaneously. In the mid-2000s, a quick reversal of easy monetary policy took place and the Great Recession followed.

Failure to Adapt. The U.S. economy boomed in the 1990s, not because of tax rates (which were higher than in the 2000s), but because years of investment in the development and assimilation of information technology by both government and industry finally paid off in the form of accelerated productivity growth.[22] The message is that the modern economy cannot grow over time simply by stimulating demand.

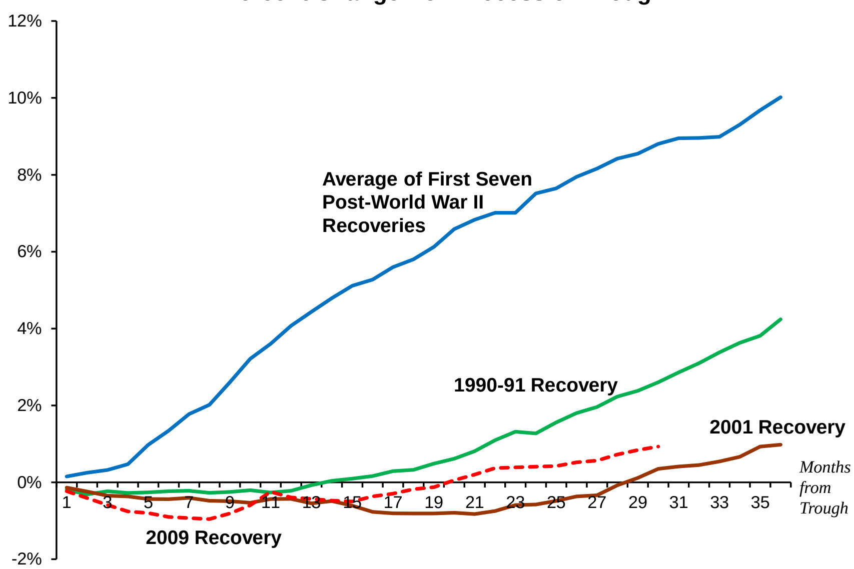
Yet, influential economists continue to deny this fundamental problem. The broader policy

[22] While three-quarters of US industries contributed to the acceleration in economic growth in the late 1990s, the four IT-producing industries were responsible for a quarter of that acceleration while only accounting for 3 percent of the GDP (Jorgenson, 2005).

debate has largely ignored those who argue for major structural reforms in education, investment in technology, more efficient industry structures, and government-industry partnerships, claiming instead that all the economy needs is more demand stimulation, specifically government spending.[23]

The movement toward unbalanced growth strategies in Europe and the United States is a response to globalization. The process of globalization began rather innocently in the 1970s and early 1980s, with a number of industrialized countries outsourcing low paying manufacturing and service jobs to poorer but aggressive Asian economies. However, in the mid-1980s, the Japanese economy demonstrated the ability to acquire advanced product technologies from western economies and combine them with its own improvements in process technologies.

Fig. 2 Non-Farm Employment Growth in Recession Recoveries: Percent Change from Recession Trough



Source: G. Tassey (2007, updated); BLS for employment data; NBER for recession trough dates

With modest differences, the Japanese growth model of the 1970s and 1980s has been adopted by other Asian economies over the past two decades. The result has been tremendous growth in the competitive capacity of China, India, Korea, and Taiwan. But this rapid growth in Asia has reduced rates of growth for most other industrialized countries. The macrostabilization policies implemented by western economies have been based largely on debt accumulation in a furtive attempt to maintain current levels of consumption. These high debt burdens are now perpetuating slow long-term growth rates by inhibiting domestic investment by government.

Ignoring strucutural problems makes effective selection of long-term employment recovery

[23] For example, Paul Krugman in several editorials in the *New York Times* stated that "all the facts suggest that high unemployment in America is the result of inadequate demand….structural unemployment is a fake problem, which mainly serves as an excuse for not pursuing real problems…." (September 26, 2010) and "talking about competitiveness as a goal is fundamentally misleading" (January 23, 2011).

In an interview with the Washington Post's Ezra Klein ("More from one of Obama's Keynesian all-stars," July 31, 2011), Lawrence Summers (former Director of the National Economic Council) challenged the view that "macroeconomics was about reducing the variability of output over time, not raising its average level." "Keynes," he argued, "focused on raising the average level of output through time by raising demand." He further stated that the current economic problem "is about demand, not some kind of structural factor in which there are mismatches between the kinds of workers available and the kind employers are seeking."

strategies unlikely. These barriers have become increasingly more severe as globalization has gathered momentum. Fig. 2 shows that the average recovery in employment from the first seven recessions after World War II occurred almost instantly. After approximately four months, employment growth accelerated rapidly. For three decades, this pattern held. Then, in the 1980s, significant technology-based competition began to emerge led by Japan. The subsequent 1990-91 recession showed the initial effects of globalization. 16 months were required to reach a positive employment level relative to the recession trough.

The situation deteriorated further in the 1990s, as the impacts of globalization deepened. Those impacts were offset temporarily by a short-term burst in productivity growth from several prior decades of investment in information technology (IT). However, as the benefits of IT diffused globally, competitive positions were once again based on who produced the best products and services relative to cost. The U.S. economy fell behind in a wide range of industries. This decline is evidenced by the fact that employment relative to the trough of the 2001 recession did not reach a positive level for 30 months. This was nearly twice the 1990-91 recovery time and seven times the average post-war recession recovery time. With respect to the current "recovery," after 30 months employment has only inched above the level at the 2009 recession trough—a meager return on historic economic stimulus.

The slower recovery rates during the last two recessions are due primarily to the massive number of manufacturing jobs lost to global competition. Table 1 indicates this process across a range of high-tech manufacturing industries. It also shows that high-tech service industries—often asserted by economists to be the automatic replacement for the loss of manufacturing value added—displayed little growth in aggregate employment during the past decade. In fact, two of the three high-tech service industries for which BLS provides data suffered significant employment declines.

Table 1 Rate of Employment Growth by Decade (percent change)

Industry (NAICS)	1990-2000	2000-2010
Total Private	21.9	-3.3
Manufacturing Sector	-2.4	-33.2
Computers (3341)	-17.8	-46.5
Communications Equipment (3342)	7.0	-50.5
Semiconductors (3344)	17.8	-45.3
Electronic Instruments (3345)	-23.2	-16.7
Service Sector	28.2	3.7
Telecommunications (514)	38.5	-35.6
Data Processing (518)	49.3	-23.3
Computer Systems Design (5415)	206.2	14.9

Source: Bureau of Labor Statistics, Current Employment Statistics Survey

In addition to job losses, globalization has also impacted the distribution of value added between workers and corporations. After World War II, the dominant position of the U.S. economy, which resulted from high labor productivity, led to a rising share of value added (GDP) for American workers. [24] However, the advent of globalization in the 1980s started a reverse shift

[24] With respect to economic growth policy, value added is the bottom-line metric. In economic accounting terms, it is largely the sum of payments to labor (wages and salaries) and payments to owners of capital (profits).

in that distribution from labor to industry, which continues today. This trend reversal occurred because U.S. companies began reallocating labor to other economies where the same skill levels could be obtained for lower wages and where the host governments were increasingly able and willing to provide technical infrastructure support and other important incentives such as a lower cost of physical capital. Overall, the failure to increase U.S. domestic labor's skills and the decline of unionization have resulted in an increasingly larger share of value added going to corporations in the domestic economy.[25]

Underinvestment in Workforce skills. In today's information driven and highly complex economies, labor is much more heterogeneous than was the case in the Industrial Revolution and hence substitution is more limited, not only across industries but within industries, as well. This heterogeneity has increased the potential for skill gaps in the labor force, which explains how aggregate U.S. unemployment in 2011 could be 14 million while 3 million jobs went unfilled.[26] One survey of skilled worker availability found that 32% of manufacturing companies were experiencing moderate to serious shortages in the availability of qualified workers, with certain sectors, such as aerospace/defense and life sciences/medical devices, reporting much higher levels of worker shortages.[27]

Globalization is increasingly solving this problem for corporations by greatly expanding the supply of skilled labor. In this context, it is ironic that such a furor was raised over the Boeing Company's decision to build a new plant in low-unionized South Carolina instead of highly-unionized Washington, given that the foreign content of Boeing's new 787 Dreamliner is 90 percent.[28]

Yet, while these indicators imply the need for a crisis approach to education reform and much more investment in worker retraining, the response so far has been highly inadequate. According to the College Board, the United States once led the world in the percentage of 25- to 34-year-olds with college degrees, but it now ranks 12th among 36 developed nations. And, according to the testing organization, ACT, fewer than 25% of 2010 high-school graduates who took the ACT college-entrance exam demonstrated the skills necessary to pass entry-level college courses.

More broadly, the entire school system is inadequate for today's modern technology-based economy. More incentives for students to choose science and engineering are needed and a much broader education and training infrastructure has to be developed to expand the skilled workforce. K-12 might have to become K-14 to truly upgrade U.S. workers' skills, with the

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[25] Work stoppages of more than 1,000 workers averaged approximately 300 per year for the first three decades after World War II. After 1980, however, the rate declined precipitously to an annual average of 16 since 2002. Source: Bureau of Labor Statistics (http://www.bls.gov/news.release/wkstp.t01.htm). The decline in impact of unions is partly due to the increasing heterogeneity of worker skills, but a major force has been the pressures of globalization.

[26] BLS data as of May 2011. See http://www.bls.gov/news.release/jolts.nr0.htm.

[27] *People and Profitability, A Time for Change: A 2009 People Management Practices Survey of the Manufacturing Industry*. Deloitte, the Manufacturing Institute, and Oracle.

[28] David Pritchard, Canada-United States Trade Center at the State University of New York at Buffalo.

additional two years being community-college level training in specific technical (vocational) job categories, including apprenticeships with high-tech small firms who often cannot afford the overhead associated with bringing young workers up to adequate levels of productivity.[29]

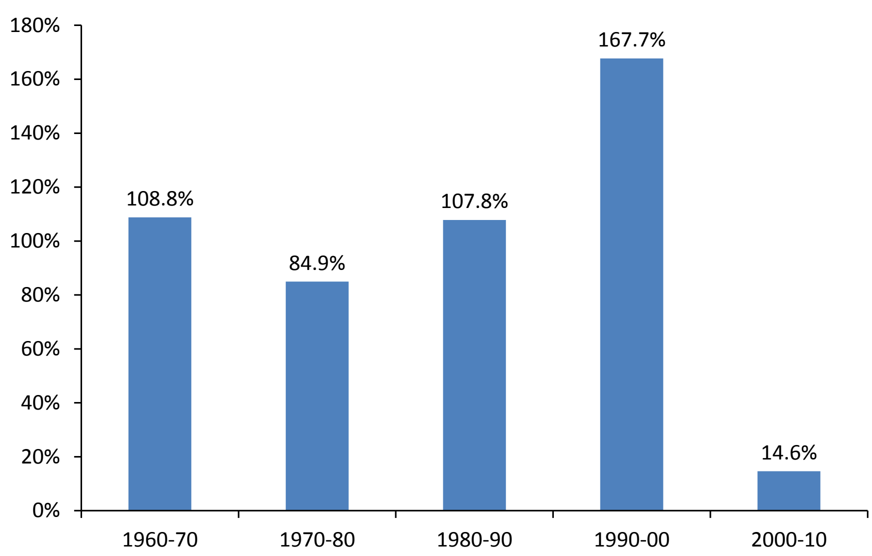
The track to "high-tech" vocational training must begin in high school to avoid the all-or-nothing decision now faced by American K-12 students: go to college whether or not it suits the student or the needs of industry or be relegated to low-paid trades, most of which are in declining industries or service industries with little upward mobility potential. Finally, the school year must be lengthened. At 180 days, graduating U.S. high-school students will have spent more than a full school year *less* in the classroom than the average for other countries; so, even if the quality of K-12 were competitive, American students would still be at a skills disadvantage.

Underinvestment in Productivity-Enhancing Physical Capital. Long-term underinvestment has been exacerbated for much of the past decade by a national savings rate that hovered around zero. This has meant that (1) virtually all investment was financed by foreign capital and (2) all growth was based on consumption. Neither provides a strong foundation for increased productivity growth rates.

If policymakers wanted to stimulate greater productivity in the domestic economy, one would expect a bias toward policies that leverage investments in the stocks of companies that either develop or use productivity-enhancing assets. However, Fig. 3 shows a three-decade decline in the rate of growth of fixed private investment in hardware and software (which are the primary types of investment by which technology has its productivity impacts).

Fig. 3 Fixed Private Investment: Hardware and Software

Growth by Decade (in 2005 dollars)



Source: Data from Bureau of Economic Analysis, NIPA Table 5.3.5 (includes both equipment and software) and Table 5.3.4 (price indexes for fixed private investment)

General tax cuts were tried in the 2000s as a means of maintaining the growth rates of the 1990s. However, even when general tax incentives are targeted at investment, the effect is to induce investment in the existing capital structure and thereby largely in the existing stock of technical knowledge. Moreover, general tax expenditures for industry are small compared to other categories of tax breaks. A study by

[29] The German Fraunhoffer Society model includes successful approaches to training and transitioning new skilled workers to small firms.

the National Tax Foundation estimates that generally available tax provisions will cost $54.8 billion in 2011. This amount is relatively modest compared to the projected exclusions for employer-provided health insurance ($177 billion), pensions and 401Ks ($142 billion), the mortgage interest deduction ($104 billion), and tax benefits for state and local governments such as the exclusion for bond income ($92 billion).[30] In contrast, the current annual cost of the R&D tax credit, which can help enhance the productivity of physical capital, is approximately $8.5 billion.

In fact, Congress has consistently done virtually everything conceivable to direct household savings into real estate—the most unproductive of all asset classes with respect to economic growth. In 1996, Congress changed the tax treatment of real-estate capital gains to favor investment in housing. Most households will never pay capital gains taxes on a real-estate sale. Moreover, housing is the only investment for which the interest on borrowed funds is tax deductible. An added incentive is the deductibility of property taxes from personal income subject to tax.[31] The flow of funds into housing has been additionally leveraged by the government-sponsored enterprises (GSEs), principally Fannie Mae and Freddie Mac. They create additional funds for home-mortgage lending institutions by buying home loans (thereby freeing funds for banks to re-lend) and by guaranteeing principal and interest payments. Together these two GSEs control 90 percent of the secondary mortgage market. So, if an asset class is tax preferenced on the purchase, tax preferenced on its holding period, and tax preferenced on its sale, funds will flow out of other asset categories into the favored asset class.

Not surprisingly, then, Americans have favored housing, making it their single largest asset. In turn, they have underemphasized investments in financial instruments that are used by corporations to raise investment capital. For example, the top 1 percent of Americans owns half of the country's investments (stocks, bonds, mutual funds), while the bottom 50 percent own only 0.5 percent.[32] As a result, the stated national objective of having all Americans own their own homes has resulted in policies that have collectively redirected household resources away from productivity-enhancing investments, in spite of a lower tax rate on long-term capital gains.

In summary, conventional stabilization and so-called growth policies ignore the fundamental causal relationship between the economy's structure and its ability to support sustained economic growth. It is true that investment is a component of fiscal policy. However, the current and, in fact, the typical investment content of fiscal stabilization efforts is too little, too narrow in focus, and too short-term. Unless addressed, the severe structural problems documented in this paper will constrain any recovery resulting from fiscal or monetary

[30] National Tax Foundation, "Putting Corporate Tax 'Loopholes' In Perspective." The report is available from the Foundation at www.taxfoundation.org/publications/show/26580.html.

[31] The Fiscal Times, a news organization funded by the Peter G. Peterson Foundation, estimates that these three major tax breaks accounted for $135.7 billion in reduced tax revenue in 2010.

[32] Source: Institute for Policy Studies.

stimulation alone.[33]

In contrast, investment in productivity growth offers the prospect of positive long-term returns from investment. The reason is that superior productivity results in larger shares of global markets, which, in turn, increases the demand for domestic labor. The economic growth potential is huge because, as previously noted, 95% of all future consumers live outside the United States. Moreover, the American consumer will likely not significantly increase consumption for the foreseeable future, as households work down debt, thus reducing domestic consumption as a source of growth for some time. The implication is that, the U.S. investment strategy must be designed to compete for global customers and must therefore be export oriented. Moreover, long-term productivity growth requires increasing the technological content of products, processes, and services. Technology investments demand higher skill levels, so that rates of compensation for the labor force will rise over time, as well.

The Core Structural Problem is the Failure to Emphasis the Core Driver of Long-Term Productivity Growth: Technology

The argument of excessive reliance on macroeconomic stabilization policies, especially when an economy has underlying structural problems, requires specification of a complementary set of microeconomic growth strategies to balance the policy mix. The imperative to either restructure or replace traditional industries over time requires (1) a consensus on the sources of growth for several decades into the future and (2) provision of the resources necessary to restructure the economy's stock of economic assets accordingly. Specifically, the structural changes occurring rapidly in the global economy demand that an investment-driven recovery be focused on a wide array of productivity-enhancing technologies.

The central role of technology in long-term productivity and output growth has been documented by economists over several decades. Yet, the still dominant neoclassical economic perspective, which emphasizes reliance on price-induced resource reallocation and which still dominates high-level policy advisory positions, gives little or no attention to complex public-private processes by which technologies are developed, assimilated and ultimately used to increase productivity. Not surprisingly, therefore, neoclassical economists, by ignoring the public-private nature of new technology development, its appropriability problems and long gestation times, can casually dismiss concerns over underinvestment—especially by the public sector.

Worker Incomes are Driven by Multifactor Productivity. Furthering denial of the limits of current macroeconomic growth strategies is the perception that U.S. productivity is growing at

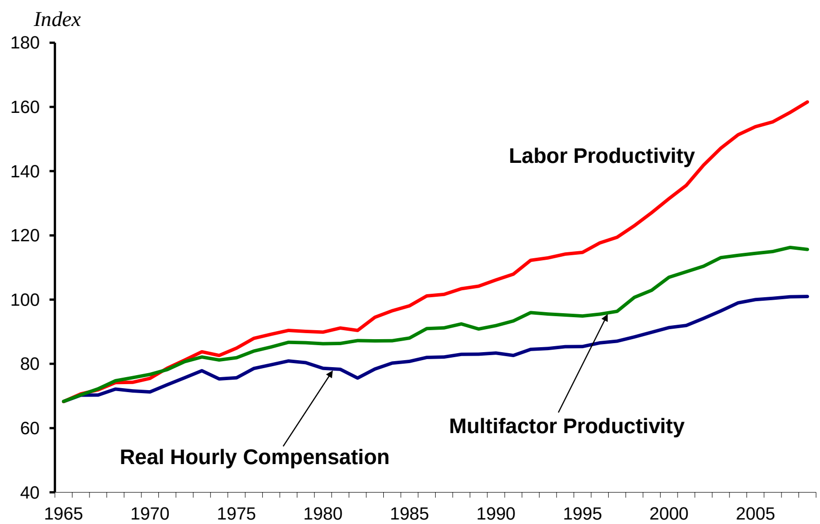
[33] Recent research has indicated that the fiscal multiplier is declining due to the effects of globalization. Important factors cited are increased trade (stimulated demand is used on imports), flexible exchange rates (deficit spending can lead to currency depreciation and hence inflation), and degree of indebtedness (government debt in excess of 60 percent of GDP reduces the fiscal multiplier to approximately zero). Also, the form of fiscal stimulus does not seem to matter, except in developing countries where the government investment multiplier is significantly higher than the multiplier on government consumption. See Ilzetzki, Mendoza, and Vegh (2010) and commentary by Nesvisky (http://www.nber.org/digest/mar11/w16479.html).

an acceptable rate with the implication that the fundamentals for future economic growth are sound.

The most widely disseminated and discussed productivity data are for labor. However, labor productivity is only a partial measure of the total productivity of an economic system. The more accurate metric is “multifactor productivity (MFP),” which includes the impact of capital and other inputs.[34] Nevertheless, because labor productivity is easier to calculate, it is available much faster than MFP and has the added advantage of being simpler and hence more easily understood. Thus, the media and the policy infrastructure both focus on labor productivity data.

In calculating domestic labor productivity, BLS only counts labor hours worked in the domestic economy. To the extent that labor input for a particular industry is offshored, the “measured” labor productivity is overstated. Thus, increased offshoring in the past 15 years seems to be a factor in the apparently faster rate of growth of labor productivity curve, as indicated in Fig. 4.

Fig. 4 Policy Focus on Multifactor Productivity
Trends in Productivity and Income Private Non-Farm Sector, 1965-2009



Source: Bureau of Labor Statistics

However, corporate managers recognize the relationship between labor and capital and thus pay domestic workers their “true” productivity, which is based on their interactions with physical and intellectual capital—the driver of MFP. This relationship is indicated in Fig. 4 by the fact that real wages track MFP, not labor productivity. These slower rates of growth in MFP and real labor incomes are a more accurate indicator of the rate of adaption to the growing pressures of global competition.

MFP has its own measurement problem: the use of inaccurate price indices applied to the cheaper imported inputs. Specifically, inaccurately high price indices result in lower imputed input quantities, which when distributed over the same labor in the importing domestic industry, causes in an increase in “measured” MFP (Mandel and Houseman, 2011; Houseman *et al*, 2011). To the extent inputs are cheaper, domestic corporate profits are enhanced.

[34] The Bureau of Labor Statistics defines multifactor productivity as “an index relating the change in real output to the change in the combined inputs of labor, capital, and intermediate purchases consumed in producing that output. Multifactor productivity growth measures the extent to which output growth has exceeded the growth in inputs, and reflects the joint influences on economic growth of a variety of factors, including technological change, returns to scale, enhancements in managerial and staff skills, changes in the organization of production, and other efficiency improvements.”

However, this does not result in additional domestic labor income, as corporate managers know where the increases in productivity are coming from. It does result in lower employment for the domestic supply chain as a whole.[35] For the long run, the major problems for future productivity growth are a stagnant national R&D intensity and a decade-long drop in the growth rate for fixed private investment.

The Technology Investment Option

The ultimate objectives of economic growth policy are to create jobs and to increase per capita income. With respect to employment, recent analysis shows that with one exception, "over rolling ten-year periods, employment and productivity growth have an almost perfect correlation".[36] Moreover, decades of research have demonstrated beyond a doubt that technology drives long-term productivity growth and hence incomes. BLS data show that in all but one of 71 technology-oriented occupations, the median income exceeds the median for all occupations. Moreover, in 57 of these occupations, the median income is 50 percent or more above the overall industry median (Hecker, 2005). The bottom line is that the high-income economy must be the high-tech economy.

The industries with high-skilled labor are also the industries investing in new technologies to combine with this labor. Thus, economic growth policy must place more emphasis on increasing multifactor productivity, which is the driver of value added (profits plus wages and salaries). Achieving this goal requires coordinated advances in science, technology, innovation, and diffusion (STID) assets.

This strategy requires investments in multiple drivers: technology, education, capital formation, and industry infrastructure. As shown clearly in Fig. 3, private-sector investment in hardware and software within the U.S. economy has stagnated, which does not bode well for future productivity growth. Equally important, investment in the driver of long-term growth in the productivity of capital—technology—has stagnated, as well.[37] So, a policy imperative is to increase national R&D spending in order to increase the amount of technology available to be embodied in new productivity-enhancing capital stock.

However, a major policy problem is the fact that R&D is not a homogeneous investment, as assumed by neoclassical economic growth models and even by innovation economists. Therefore, in addition to the *amount* of R&D, the *composition* of R&D is a critical strategy metric, and the *efficiency* by which each of these variables is managed is increasingly important in a global economy with shrinking R&D cycle times.

The *Amount* of R&D Investment. This has historically been the dominant STID policy metric.

[35] These same measurement problems may be resulting in an overestimate of GDP (Houseman *et al*, (2011).

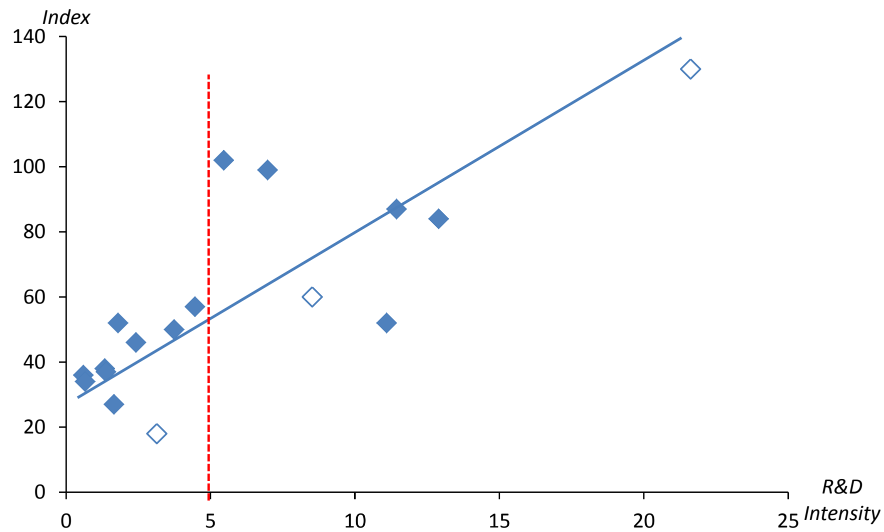
[36] Source: Bureau of Economic Analysis and McKinsey Global Institute. Data compiled by McKinsey (see Manyika *et al*, 2011)).

[37] A few noted economists, such as Douglas North and Paul Romer, have emphasized the critical role of technology in economic growth, but their views have been largely swamped by the dominant neoclassical and Keynesian economic philosophies (Atkinson and Audretsch, 2008, p. 2).

However, in spite of relatively long-term debate over the importance of investment in R&D, the U.S. economy has steadily lost ground with respect to the rest of the world. A major reason is that although the science, technology, innovation, and diffusion (STID) community has argued with increasing force that the United States is under-investing in innovation and subsequent market development (scale-up), the relatively small size of the "high-tech" portion of the economy (approximately 7 percent of GDP) has left it in a relatively weak position politically wither respect to getting priority status for needed major policy initiatives.[38]

The importance of the amount of investment in R&D can for the first time be demonstrated using product and process innovation data recently compiled by NSF for a broad cross-section of industries. Fig. 5 compares an index of industry innovation rates with industry R&D intensities for 17 industries.[39] The index is created by adding the number of product and process innovations for each industry in the NSF database and plotting this index against the R&D intensity for each industry. A positive correlation is clearly evident, underscoring the importance of R&D intensity as a major policy variable.

Fig 5 Rate of Innovation vs. R&D Intensity:
% of Companies in an Industry Reporting Product/Process Innovations, 2003-2007



Index = sum of percent of companies in an industry reporting product innovations and percent reporting process innovations. Sources: *Science and Engineering Indicators 2010* , Appendix Table 4-14; Boroush (2010).

The vertical dashed line in Fig. 5 indicates the minimum ratio of R&D to sales that typically qualifies an industry as R&D intensive. 10 of the 17 industries fall below this minimum.[40] Over time, these industries will become increasingly less competitive and provide

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[38] The other 93 percent of the economy does low-to-modest amounts of R&D but depends largely on the much smaller high-tech sector for most technology it uses. This dominant set of traditional industries is where the majority of jobs are being lost and profit margins squeezed. Its managers and workers are understandably worried but resist shedding increasingly noncompetitive assets and get retrained without aggressive government support. This "installed-base" effect is a major barrier to restoring an economy's competitiveness economy.

[39] R&D intensity is the amount of R&D spending by a firm or industry divided by net sales. For the economy as a whole, it is national R&D spending divided by GDP. It indicates the amount of an economy's output of goods and services that are being invested in developing technologies as a means of competing in the future. Larger economies have to spend more on R&D than do smaller economies to maintain an aggregate competitive position in global markets, so it is the ratio of R&D to GDP that should be the policy driver, not the level of R&D spending.

[40] The three un-shaded markers indicate service industries and the industry in the extreme upper right corner is software.

fewer jobs and lower rates of pay.

This positive relationship between R&D intensity and innovation is becoming increasingly important given that $1.4 trillion is spent annually on R&D in the global economy—a huge level of investment, especially given the substantial leverage of resulting innovations on subsequent capital formation for production and subsequent marketing operations. In fact, economic studies have estimated the return on R&D to be four times the return on investment in physical capital, implying that R&D investment should be increased by a factor of four (Jones and Williams, 1998, 2000).

This leverage on subsequent investment underscores the point that innovation is only the initial commercial application of a new technology. Over time, the majority of the economic benefits from investment in technologies are realized from scale-up and subsequent attainment of significant global market shares. In this regard, Table 2 provides a vivid demonstration of the importance of R&D intensity for manufacturing industries. The industries are segregated into

Table 2 Relationship Between R&D Intensity and Real Output Growth

Industry (NAICS Code)	Ave. R&D Intensity, 1999-2007	Percent Change in Real Output, 2000-07	Percent Change in Real Output, 2000-09
R&D Intensive:			
Pharmaceuticals (3254)	10.5	17.9	4.9
Semiconductors (3344)	10.1	17.0	1.1
Medical Equipment (3391)	7.5	34.6	39.5
Computers (3341)	6.1	109.9	147.0
Communications Equip (3342)	13.0	-40.0	-59.7
	Group Ave: 9.5	**Group Ave: 27.9**	**Group Ave: 26.6**
Non-R&D Intensive:			
Basic Chemicals (3251)	2.2	25.6	-7.8
Machinery (333)	3.8	2.3	-22.4
Electrical Equipment (335)	2.5	-13.4	-33.4
Plastics & Rubber (326)	2.3	-5.2	-28.0
Fabricated Metals (332)	1.4	2.6	-23.6
	Group Ave: 2.5	**Group Ave: 2.4**	**Group Ave: -23.1**

Sources: NSF for R&D intensity and BLS for real output.

high- and low-R&D-intensity groups for which the average rates of real-output growth are calculated for the periods 2000–07 and 2000-09. The difference in average growth rates between the two groups is remarkable.[41] Further, Table 2 provides a perspective on the relative effects of the 2008-09 recession on the two groups. While the downturn negatively affected

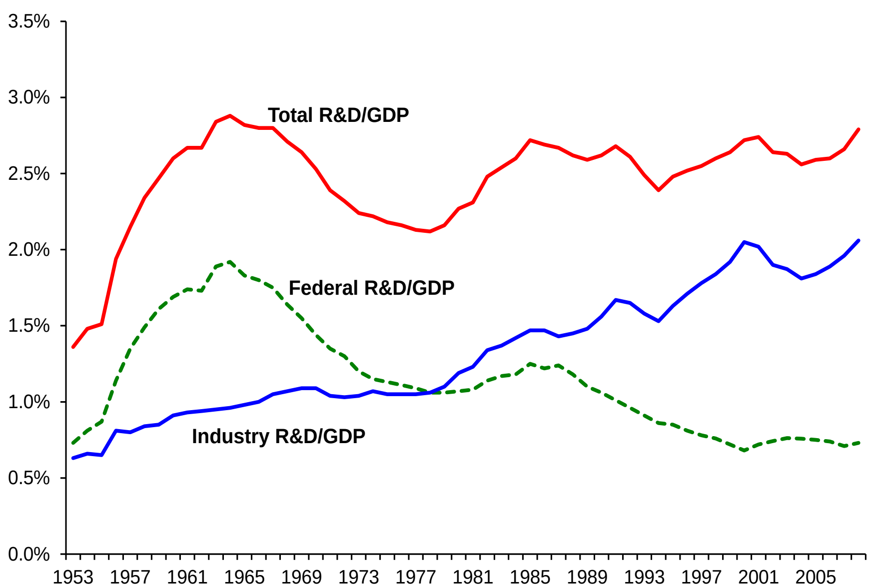
[41] This is the case even though one of the R&D-intensive industries, Communications Equipment, experienced a sharp drop in real output during these time periods due to significant offshoring.

several of the R&D-intensive industries, as a group their average grow rate remained effectively unchanged. In contrast, all of the non-R&D intensive industries suffered significant declines in output growth when the recession is included. The major policy implication is that when decision makers are looking for levers to stimulate output, job growth and worker incomes, high R&D intensity should be a primary target. But, such a policy target cannot be achieved through conventional macrostabilization policies.

Manufacturing industries are important to long-term economic growth in an advanced economy, not only because worker incomes are higher than the average for all industries but also because the manufacturing sector does a disproportionately large share of domestic industry R&D (67 percent) and employs a disproportionately large share of R&D personnel (57 percent). Allowing this sector to offshore would decimate the economy's R&D capacity and hence its overall innovation infrastructure. The problem is that the average R&D intensity for all U.S. manufacturing is only 3.7 percent—well below the lower end of what are considered R&D-intensive industries and, surprisingly, unchanged from the 1980s. However, as the dramatic negative change in the growth rate of the Communications Equipment industry (NAICS 3342) demonstrates, even a high R&D intensity is no longer a sufficient condition for maintaining domestic production content. The high R&D intensity of this industry indicates that the remaining domestic economic activity is competitive. However, it is also clear that other segments have been offshored, thereby reducing the domestic industry's share of the global industry's value added and consequently domestic jobs.

A total technology-life-cycle growth strategy is mandatory. Decades of economic research have shown clearly that technology is the long-term driver of productivity growth.[42] One would therefore think that technology investment would be the highest priority among the elements of an economic growth strategy. Yet, its role is hardly mentioned in current economic growth policy debates and, therefore, the migration to a new technology-based growth strategy has been stymied.

Fig. 6 U.S. R&D Intensity: Funding as a Share of GDP, 1953-2008



Source: National Science Foundation

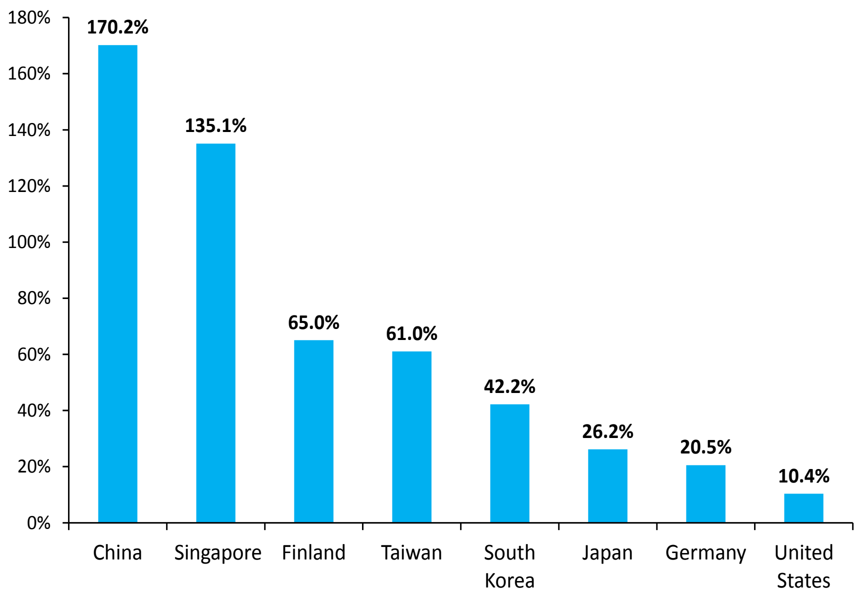
This investment myopia is shown clearly in Fig. 6, which depicts long-term trends in U.S. R&D

[42] See Tassey (2010, Chap. 3) for a summary of this literature.

intensity. The peak R&D intensity was reached in the mid-1960s and has not been exceeded in the subsequent 45 years, in spite of the relentless growth in R&D investment by other countries. The United States was once the most R&D intensive economy in the world, but its ranking has steadily declined. U.S. peak R&D intensity was reached in the mid-1960s and has not been exceeded in the subsequent 45 years, in spite of the relentless growth in R&D investment by other countries. As of 2008, OECD data show that the United States ranked seventh in R&D intensity.

The rapid expansion of national R&D spending in the early post-World-War-II period was driven to a significant extent by national security concerns, but the latter part of this uptrend was the result of a realization that the role of science and technology would expand rapidly in all segments of society. President Kennedy's 1961 speech calling on the country to greatly expand S&T investment was responded to for only a few short years (until the mid-1960s) and then largely forgotten. This trend indicates that the U.S. economy is no more committed to investment in technology today than 50 years ago.

Fig. 7 Changes in National R&D Intensity, 1995-2008



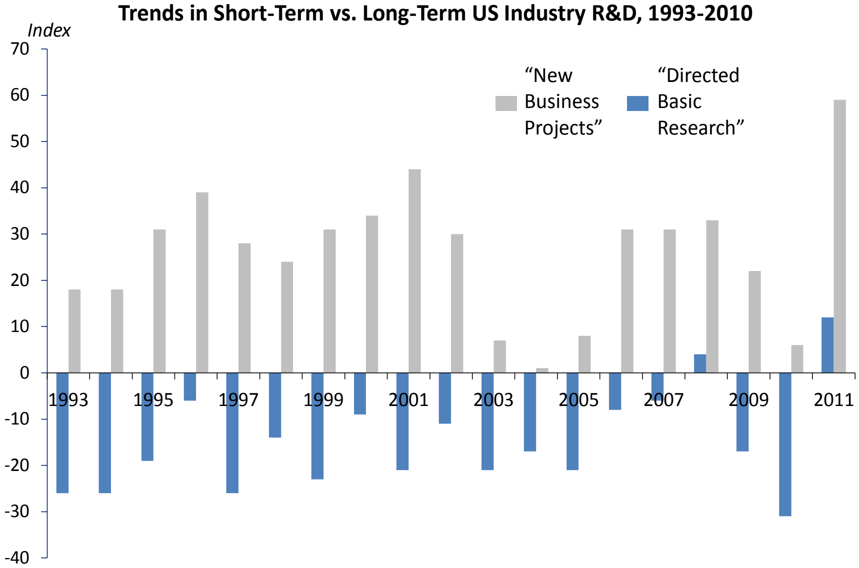
Sources: OECD, *Main Science and Technology Indicators*, 2010/1

Fig. 7 reinforces how badly the United States is lagging its competitors in responding to growing technology-based competition. This last place growth rate is not something an advanced economy can afford with the world's R&D spending continuing to expand rapidly. China's dramatic growth in R&D is coming off a low base of R&D intensity, but only apostles of denial will try to downplay its long-term significance, especially as it is a manifestation of a much longer national plan to attain technological superiority across multiple industries. The United States still conducts more R&D than any other economy (as it should being the largest economy), but its slipping R&D intensity foretells a constrained rate of economic growth that will continue until an aggressive national strategy is implemented to reverse these trends.

The *Composition* of R&D Investment. An accurate model of technology-based growth recognizes the several phases by which scientific knowledge is turned into successively more applied technical knowledge until the point of commercialization is reached. The earliest phase of *technology* research seeks to prove the concept of how the technology will eventually provide commercially viable products or processes. This "proof-of-concept" technology research typically occurs a long-time before commercialization. Its broad "technology-platform" character provides the potential for multiple market applications; that is, the aggregate potential economic growth impact is substantial. However, the higher discount rate applied by the private sector to adjust expected rates of return for time and also for both technical and market risk leads to significant underinvestment by industry in this early-phase technology research. Finally, the broad sets of potential applications (economies of scope) characteristic of modern generic technology platforms typically extend beyond the market foci of individual firms, thus further reducing the expected rate of return (Tassey, 2007).

Fig. 8 The "Valley of Death" is Getting Wider

Trends in Short-Term vs. Long-Term US Industry R&D, 1993-2010



Compiled from the Industrial Research Institute's annual surveys of member companies. Note: sample size is not constant from year to year.

The consequent trend toward less investment by industry in radically new technologies with long-term and large economic impact potential is demonstrated in Fig. 8. Using 19 years of data on annual planned company R&D expenditures from surveys of its members by the Industrial Research Institute, the bar chart shows trends in two "sea-change" indexes of R&D investment.[43] The light-shaded bars are the annual index numbers for "new business projects"; that is, short-term R&D aimed market applications within current technology life cycles. The dark bars are the annual index numbers for "directed basic research"; that is, investment in longer-term, higher-risk R&D projects that will define future technology platforms and hence life cycles.

The trends in the two indexes are starkly different. Over almost two decades, U.S. industry has regularly increased its investment in short-term R&D to respond to growing competitive challenges in the global economy, while regularly decreasing planned investments in the more radical research that provides the technology platforms for competing in future technology life cycles.

The Federal Government has not responded. As indicated in Fig. 6, the 50-year decline in government's R&D spending relative to GDP shows no sign of abating. In fact, government R&D budgets are under threat of absolute declines from current levels. Even the long-term growth in industry's R&D intensity topped out in the last decade, as increasing portions of domestic company R&D funding are allocated to other economies. Yet, seldom in the interminable

[43] A sea-change index is defined by the IRI as the difference between the number of companies indicating a planned increase of more than 2.5 percent (allowance for inflation) in a particular category of R&D in the forthcoming year and the number of companies indicating a planned decrease in spending in that year.

discussions in western economies of what to do about inadequate rates of economic growth are these and other indicators of technology-based investment discussed.

In addition to its inadequate size, the Federal Government R&D budget has historically been focused on specific mandated missions (national defense, health, space exploration, etc.) rather than on economic growth as a first-order objective.[44] In the past, many of the technologies resulting from mission-oriented research have eventually spun off into significant additional commercial applications (that is, economies of scope were eventually realized from government-funded the platform technologies). This funding strategy worked well for several decades after World War II when the U.S. economy dominated the world.

However, the indirect path by which mission-oriented technologies are developed and then later spun off to varying degrees into commercial applications draws out the R&D and hence the technology life cycles. The lengthy indirect process of realizing economies of scope from new technologies is no longer competitive in a world economy that conducts over a trillion dollars of R&D per year and is using increasingly efficient mechanisms for managing this investment. The result is that intense technology-based global competition is compressing all technology life cycles with the result that windows of opportunity are increasingly narrow. The severity of the composition problem for the U.S. economy is underscored by the fact that mission R&D spending comprises approximately 90 percent of the total Federal R&D budget.

Government, with a lower discount rate, the ability to undertake riskier projects, and the resources to support a broad portfolio of long-term research projects must be a major supporter of the elements of complex modern technologies with public-good content. Yet, as Fig. 6 demonstrates, government's capacity to contribute in the early part of the R&D cycle to next generation technologies has steadily shrunk relative to the size of the economy and even more so relative to the size and importance of technology assets in today's global economy.

A considerable portion of government-funded R&D is performed by industry. Thus, if government R&D budgets had grown in concert with the economy' growth, the decline in industry's own funding of breakthrough research (Fig. 8) could have been compensated for. Such research is critical to long-term rates of innovation because it focuses on the transition phase between basic research (which has no intrinsic commercial value) and development (which results directly in market applications, i.e., innovations). This transition phase (proof-of-concept research) plays the critical role of reducing technical and market risk sufficiently to encourage industry to invest the far larger funds required for applied R&D and then finally the

[44] For example, an examination of DARPA's research project portfolio shows a number of targeted technologies that clearly have commercial and hence economic-growth potential beyond defense applications, but other projects are just as clearly limited in potential for yielding economies of scope; i.e., market applications beyond defense. This is not a criticism of DARPA. It selects and manages a portfolio of technologies optimized for national security objectives, as it should. However, this portfolio is not optimized for economic growth in general, so relying largely on its substantial budget is no longer adequate as a national strategy for developing new technology platforms. Other agencies (e.g., DoE/ARPA-E) have programs targeting the same early phase of the R&D cycle, but their budgets are much smaller and their research portfolios have similar issues. The government–wide result is overlap in some technology elements and gaps in others.

development phase that creates innovations.[45]

Moreover, government funding for industry-performed (largely manufacturing) R&D is highly skewed with 75 percent going to two industries: instruments and aerospace (NAICS 3345 and 3364, respectively). Although receiving the dominant share of government funding of industrial R&D, these two industries account for only 19 percent of the value added produced by the high-tech portion of the U.S. manufacturing sector and 10 percent of the valued added from all of manufacturing.[46]

The trend in government applied research support is not reassuring in this regard. Federal Government funding for this phase of R&D has been unchanged in constant dollars for a full decade (since 2001). Other parts of the global economy recognize the need to help finance breakthrough technology research (for example, the EU's recently announced Seventh Framework Program for Research and Technological Development is being funded at a record level of $8.3 billion in 2011). These funds are targeted for universities, research organizations, and private industry (including small and medium firms) to leverage the development of new technology platforms and eventually new industries.

An important characteristic of technology development and subsequent innovation is that the amounts of R&D spending increase as the research becomes more applied. U.S. spending on development is approximately 3.5 times the amount spent on basic research and 1.7 times the amount spent on applied research. This leverage is normal, but the policy issue derives from the fact that industry hardly invests in basic research and is investing increasingly smaller portions of its overall R&D budget in proof-of-concept technology research. The reason is the difficulty for individual companies to project capturing adequate rates of returns on such long-term investments after adjusting for time and substantial technical and market risk.

The *Efficiency* of R&D Investment. R&D efficiency is a composite of three factors: (1) the portfolio of technologies pursued relative to the optimum one for maximum economic growth; (2) the distribution of R&D funding across the phases of the R&D cycle relative to the distribution that minimizes R&D cycle time (time to innovation) and maximizes innovation output, and (3) the organization of R&D relative to the structure that optimizes the return-on-investment impacts from risk pooling and complementary public and private contributions. The latter (complementary-asset benefits) includes the mix of participants (universities, government, and industry), the mechanisms by which public and private actors collaborate (ecosystem attributes), and the effectiveness of R&D infrastructure (research facilities, skills of researchers). These attributes of R&D efficiency require a complex organizational format, which is rapidly evolving among the world's technology-based economies.

The single most important emerging organizational format, the "regional innovation cluster,"

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[45] NSF classifies R&D by three phases: basic, applied, and development. The proof-of-concept technology research discussed here is only the first part of applied research.

[46] Gary Anderson, internal NIST memo using industry-performed R&D data from NSF and industry value-added data from BEA.

has become a global phenomenon.[47] The cluster model offers an approach to increasing the efficiency of technology-based economic growth strategies through the regional co-location of public and private R&D assets. Co-location synergies among these assets increase the productivity of R&D and enhance risk pooling at the R&D stage and even during scale-up for production of new technologies. Moreover, the research consortium element of a cluster facilitates effective management of intellectual property (IP).[48]

Clusters also provide concentrated labor pools with the relevant skills and promote technology diffusion and hence broader commercialization of research results. A fully functioning innovation cluster can facilitate management by the entire supply chain of successive technology life cycles through enhanced life-cycle investment coordination, including planning for and public-private co-funding of the transitions between life cycles.

The increasingly diffuse distribution of R&D in high-tech supply chains also requires more cooperation among multiple industries, universities and levels of government. Some clusters have built upon existing supply-chain synergies in which suppliers and customers were already co-located and interacting regularly to cooperate on innovation. However, “natural agglomeration” of related industries (supply chain) can take a long time to occur. Therefore, a pro-active policy approach is required. Without such synergies realized through the application of public-private asset growth models, individual companies will find themselves competing not only against firms in other countries but also against those countries’ governments that are partnering with their domestic industries.[49]

The New Global Competitive Strategy

For a good portion of the post-World-War II period, the United States was the dominant technology-based economy. Virtually all technologies currently driving the world’s economy originated in this country. R&D and technology assimilation efficiencies were not particularly important in the absence of significant foreign competition. Thus, individual companies and mission-oriented R&D agencies could operate independently. In spite of duplication, lack of economies of scope in R&D, and other inefficiencies, these agencies eventually produced technologies needed by their specific missions. Broader diffusion to the general economy occurred through inevitable but slowly developing spillover effects.

Today, however, growing global competition has shortened R&D cycles, requiring much more efficient technology funding strategies for both development and utilization. A major

[47] Geographic concentration of specific industries (“industry hubs”) is also on the rise. These hubs are not complete innovation clusters and therefore are formed largely through private-sector initiative with local government support. See, for example, Emily Maltby, “Where the Action Is,” *The Wall Street Journal*, August 23, 2011.

[48] Industry has complained about the difficulties in negotiating balanced IP arrangements with universities. This problem is evidenced by a 24 percent decline of industry funding of university research over the past decade.

[49] Each tier (industry) in a high-tech supply chain has its own synergies, especially between R&D and production. As Dow Chemical’s CEO Andrew Liveris put it, "when you build overseas your R&D will follow” (interview on CNBC, July 27, 2011). And, once an R&D capability is established in that country, its economy is set up to compete as an innovator in the next technology life cycle.

conceptual element of these new models is a characterization of the complementary roles of government and industry, especially in the early phases of a technology's development and in the provision of essential technical infrastructure (infratechnologies and associated standards). Thus, efficiency in both platform-technology and infratechnology development need significant upgrading.

Doing so requires growth models that include the major elements of an industrial technology, including the public-good components. However, in spite of overwhelming evidence from competing economies around the world, many Americans, including neoclassical economists, still argue that government involvement in *technology* development and utilization is "picking winners and losers" or "crowding out" private capital—implying a decision process that only the private sector is competent to undertake. In other words, no significant market failures are believed to exist in technology development and utilization, implying that allocative efficiency is a purely private-sector activity.

Moreover, allocative efficiency is regarded largely as a short-term (within technology-life-cycle) phenomenon. Longer term, the dynamics of global competition requires adaptive efficiency across life cycles, which in turn is based on government-industry partnerships derived from the public-private character of modern technologies and their supporting infrastructures. Once such a model is adopted, the picking-winners-and-losers argument disappears. Government co-funds the public-good portions of an emerging technology (technology-platform and infratechnology research) and industry funds the rest, in particular, the actual innovation efforts—where companies compete against each other domestically, as well as internationally.

The new theme is that, in the modern global economy, governments are becoming as much competitors as are their domestic industries. The globalization of most large and, increasingly, medium companies means that corporate strategies are less dependent on the internal markets of any single country. 95 percent of all consumers reside outside the United States, so companies' strategic thrusts are naturally aimed at the global marketplace. This trend increasingly leaves government as the single major economic agent that focuses entirely on the domestic economy.

In summary, the indicators discussed in the previous sections—declining rates of growth in fixed investment (hardware and software), R&D spending, workers' skills, and economic infrastructure (especially technical infrastructure), collectively convey a serious structural economic-growth problem. The installed-base and installed-wisdom effects have combined to block adaptation to the globalization of the technology-based economy. Failure to adopt and fund the right growth models will mean substandard rates of productivity growth, resulting in restrained output, tax revenues, and real incomes, thereby perpetuating the existing structural malaise.

Managing the Technology Life Cycle

Economic growth policy efficiency is not just a matter of determining private- and public-sector roles in a static market-failure context. The increasingly rapid pace of technological change requires dynamic policy support for the entire technology life cycle. The primary reason is that the nature of underinvestment by industry changes as technologies are created, mature, and finally become obsolete. The United States has lost enormous amounts of value added (and hence jobs) by ignoring the changing needs of domestic industries as their technologies and market opportunities evolve over time.

Once a new technology is initially commercialized, simultaneous scale-up of production capacity and product differentiation for multiple markets become critical issues. For the United States, scale-up has become a significant barrier to long-term economic growth. This is because the vast majority of the economic benefits from new technologies results from the growth of their markets after they have been first introduced. Early and substantial investment in process technologies and the actual scaling up of optimized production capacity are essential to attaining large market shares in the increasingly technology-based global economy. Supporting this stage of economic activity requires a different mix of policy mechanisms compared to the R&D stage.

A 2010 NIST study concluded that "U.S. leadership in invention has not been coupled with manufacturing success. Across a number of technologies—such as energy storage, power generation, and robotics—key invention and discovery have taken place within the U.S. innovation system, but manufacturing has moved offshore" (Ralston, 2010). Former Intel CEO, Andy Grove (2010), stated "Scaling isn't easy. The investments required are much higher than in the invention phase. And funds need to be committed early, when not much is known about the potential market."

Thus, setting aside the issue of the adequacy of U.S. R&D investment, the U.S. economy needs to augment its traditional focus on research that produces inventions and subsequent product innovations by increasing emphasis on the research needed to develop manufacturing processes capable of producing products that meet the quality and performance requirements of the global marketplace and yet also meet the cost targets needed for successful market penetration.

This problem is complicated by the fact that the $1.4 trillion currently being spent on R&D across the global economy by countries competing in a growing number of markets is resulting in highly differentiated demand and supply within product categories. The resulting pressure to at least semi-customize applications of generic product technologies is a fundamental change from the industrial revolution, where conditions for success were dominated by the imperative to achieve economies of *scale*. That is, markets in the past were driven by the need to produce large quantities of homogeneous products at low cost. This central tenet of economic growth required companies to become large enough to maintain capital structures sufficient to attain the desired economies of scale.

However, today scaling is becoming much more complex. Manufacturing processes increasingly must be flexible in order to achieve the economies of *scope* required to serve a heterogeneous set of sub-markets with the same generic production system.[50] Doing so

[50] For example, in the area of alternative energy technologies, the research focus is increasingly on the capability to convert waste and cellulosic feed stocks into a variety of fuels and chemicals. In fact, from 2009 to 2010, overall

requires flexibility while maintaining low unit cost, which can only be achieved through new processing techniques, massive use of information technology, and a highly skilled and heterogeneous labor force. The forthcoming "smart revolution" will attain this "mass customization" objective at least in the countries that make the required investments.

Thus, while scale-up—the process of achieving a minimum efficient scale of production—is still essential, the key attribute of advanced manufacturing will be the ability to achieve this minimum scale at a low output rates and do so for a range of differentiated products. This is a massive systems problem and will require increased funding of process R&D, manufacturing engineering education, and technical infrastructure that supports integrating process technology components into highly flexible manufacturing systems. More than ever before, productivity at the systems level will be a determining factor in future competitive success.

At the same time, the era of control of global technology-based markets by a single country is over. No one country, including the United States, will dominate a major technology again. The "next big thing"—nanotechnology—will be the first major technology in the last 60 years for which the United States is not guaranteed to be the prime mover. A number of countries in Europe and Asia have major research programs and their collective R&D investment is considerably greater than U.S. expenditures. While current assessments put the United States ahead in nanotechnology development, this is small comfort because it is the initial part of the technology life cycle (early technology development and innovation) in which American expertise is still competitive.

Perhaps the most challenging of all aspects of technology-based competition is the transition from the current to the next technology life cycle. Failure to plan for and efficiently execute life-cycle transitions in highly competitive global markets with shorter windows of opportunity can bring down individual firms, industries, and even economies, as cycle management failures tend to be systemic within national economic systems.[51]

In addition, offshoring can block compensating innovation in the domestic economy. Optoelectronics—an increasingly important industry because of the forthcoming migration of computers to photonics-based technologies—is in the process of transitioning from a discrete to an integrated technology format (a technology life-cycle transition). Monolithic integration has performance and cost advantages and could potentially be a growth industry for the United

investment (in companies) fell to a four-year low of $930 million, while the subset of investment in processes capable of making both fuels and chemicals reached an all-time high. Source: Lux Research.

[51] A decade ago, Nokia was the dominant supplier of cell phones. However, whereas the company once excelled by combining diversified offerings of handsets with efficient manufacturing and strong customer relationship management, all of its success was within one technology life cycle—the standard cell phone. The company failed, as many do, to plan for and thereby make the transition to the next major technology, the smart phone, where not just basic design and manufacturing are important. Operating and other software, for example, are now critical attributes. Research In Motion, Apple, Microsoft, Samsung (and Google with respect to operating systems) have passed them by. Nokia's supply chain (hardware and software components) has crumbled, making recovery even more difficult. Getting too far behind the evolutionary trend of multiple technology life cycles can present insurmountable obstacles. Nokia eventually reached such a state and had to partner with Microsoft in an attempt to catch up.

States.

However, at this early phase of its life cycle, the mature *discrete* technology can be produced more cheaply in Asia (Fuchs *et al*, 2011). This typical situation—the new technology having a lower performance-price ratio in the early phase of its life cycle—slows market penetration. Failure by U.S. firms to accelerate the evolution of *monolithic* technology and scale-up for initial markets in spite of the stretch out in cost disadvantage, may allow competing companies in other economies to eventually commercialize the new technology and gain first-mover advantages. The generic policy response is the cooperative dimension of the previously described public-private asset growth model, which promotes better strategic planning and life-cycle management, including the timing and supply of the risk capital required to accelerate R&D *and* scale-up.[52]

Corporate CEOs understand the complexity of the rapidly emerging global technology-based economy and the consequent need for more flexible and effective strategies. Such strategies go well beyond the frequent cry for more innovation and promotion of entrepreneurship. Corporations now pay considerable attention to their relationships with multiple high-tech industries composing their increasingly integrated supply-chains. These industries, composed of small and large firms, provide both complementary categories of innovation and scale-up capacity, which are needed to compete in the eventual high-volume markets where most jobs are produced. The dynamics of these relationships have motivated analysts to develop concepts such as "open innovation" (Chesbrough, 2004) and "user innovation" (Gault, 2011). The bottom line is that the failure to invest in efficiently integrated supply-chain structures and supporting technology infrastructures will lead to slow market penetration in the early phase of the technology's life cycle and almost guarantee low market share in the middle portion of that cycle.

Historically, the policy response to the loss of global market shares often has been subsidies to the existing domestic supply chain and/or to consumers (i.e., demand stimulation). In other cases, various forms of trade barriers are erected. Because of the stigma associated with traditional forms of protectionism, countries have at least partially turned to currency manipulation as a more subtle technique for adjusting the balance of trade in their favor. In 2010 and especially in 2011, many economies took steps to debase their currencies in an attempt to maintain favorable trade positions. None of these actions are acceptable solutions. While they may delay the inevitable, they cannot overcome structural problems and, in fact, make the problems worse by postponing the needed changes.

Equally discouraging, many economists still respond to cries for policy action with the neoclassical free trade argument. Free trade is admittedly the ideal format because it is theoretically the most efficient mechanism for the allocation of resources across global markets. Traditional economics argues that the resulting efficiency effect maximizes global welfare. By definition, all nations participating in free trade are "competitive" in one or more industries—namely, the ones they migrate to after trade ensues (Alic, 1987). Technically

[52] The S-shaped performance-price curve is a useful way of characterizing patterns of technology transition over a life cycle and the consequent policy implications. See Tassey (2007, 2010).

speaking, this is true even for economies that do not have an absolute advantage in any industry—hence, the economic concept of the law of *comparative* advantage.

However, this two-century-old view of trade requires the assumptions that technology is a relatively minor asset and, even more important, that it changes slowly. In fact, most of this time period has been characterized by relatively minor roles for technology with relative prices across countries still largely determined by endowed assets (arable land, navigable water ways, minerals deposits, etc.). The fact that these assets were available in at most slowly changing quantities facilitated the utilization of global resources in accordance with relative efficiencies (reflected in relative prices) based on this fixed-asset structure. That is, the traditional neoclassical focus on allocative efficiency through the market price mechanism was all that was needed for economic growth.

Hence, periodic applications of trade barriers aside, the historical pattern of trade is claimed by traditional economics to be determined largely by market dynamics, leading to the belief in a passive approach to trade by government. Even as manufacturing's share of world trade began to grow two centuries ago, technology life cycles were long enough to allow comparative advantages to last for extended periods.

The advent of technology as a major tradeable asset has radically changed the dynamics of trade among nations. What the centuries' old law of comparative advantage does not take into account is the fact that the basis for trade, i.e., a set of comparative advantages, can no longer be expected to remain fixed for very long. Increasingly, technological change alters relative prices and hence the absolute advantages or disadvantages across technologies. In fact, today most modern economic assets are created, resulting in continual shifts in comparative advantage among nations (Tassey, 2007, 2010). And, while global economic welfare may be increased, the different levels of adaptive efficiency among the world's economies result in both losers as well as winners (Samuelson, 2004).

Traditional economists do not deny the role of technology. However, they continue to assert that as one industry off shores, U.S. companies will somehow automatically shift to newer and higher valued-added industries. Because this process of "upward mobility" with respect to value-added was the norm for the U.S. economy for several decades after World War II, the process by which it occurred was hardly questioned or studied. This level of ignorance was not damaging as long as the U.S. economy was the dominant source of new technologies. Inefficient development and diffusion of technology still led to positive adjustments in comparative advantage because the process occurred largely within the domestic economy; that is, both the old and new technologies were domestically created and utilized.

Unfortunately, analysts and policy makers still only poorly understand the increasingly complex processes by which technologies are created, assimilated into economic systems, and ultimately drive long-term productivity and income growth. In the absence of a well-conceived and articulated growth model around which a consensus can form, frustration with the slow economic recovery and the historically negative view of government policies have fueled the reincarnation of past populist movements in the form of the Tea Party. As in past major economic crises, these movements arise based on the view that the problem is government and the solution, therefore, is to reduce its presence in the domestic economy.

Such trends run counter to the evolving global model of technology-based economic growth. In fact, other economies, being envious of the U.S. standard of living, have examined the technology-based economic growth process more closely and are progressively evolving public-private asset growth models. As a result, the current global trends in investment in the development and use of technology are exceeding those in the United States (Figs. 6, 7, and 8). The apostles of denial argue that the United States still leads other nations in total R&D expenditures, but the critical policy variable, as discussed earlier, is not the level of R&D but the ratio of R&D spending to GDP (R&D intensity). The United States is the world's largest economy, so it should do the most R&D—and, more and more, do it efficiently.

The broadest and hence most complex indicator is technology-based competitiveness. Success results only from managing entire technology life cycles. In this regard, in a study by the Information Technology and Innovation Foundation (ITIF) an index of attributes was created and then the rate of change in this index was estimated for the 40 leading industrialized nations. The United States was ranked 40th out of 40 countries in terms of "the rate of progress on innovation-based competitiveness in the last decade" (Atkinson and Andes, 2009). To be successful, a nation must have all of these attributes under management. However, the United States, along with a number of European countries, have neglected this imperative, overly relying instead on macrostabilization policies to create an environment that is expected to maintain sustained growth.

In summary, the highest order problem is the long-term inadequacy of productivity enhancing investments (technology, physical, human and organizational capital). Increasing the demand for housing does have a multiplier effect on that industry's supply chain, but this effect pales compared to the leverage from investment in technology for hardware and software that drive productivity in many industries. Equally important, the jobs created by a technology-driven supply chain are much higher paying—but, they must be sustained over entire technology life cycles.

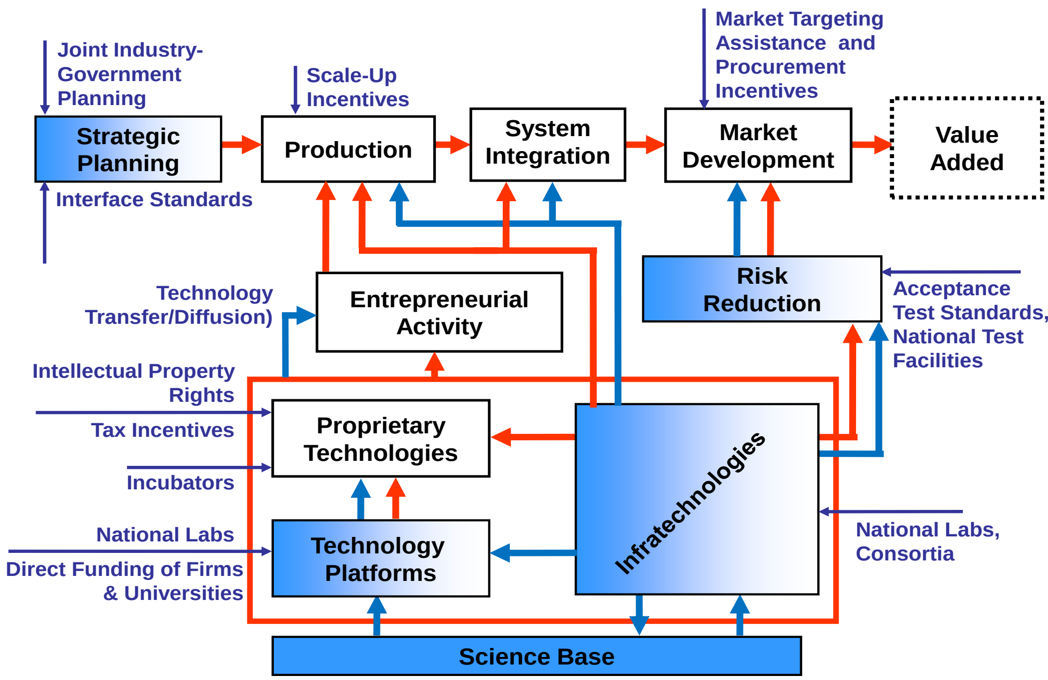
The Wrong Growth Model

The Black-Box Model. With respect to the "composition" and "efficiency" dimensions of the R&D cycle, a major problem is the failure of U.S. innovation policy to divest itself of the "black-box" model. This label refers to the outdated characterization of industrial technologies as homogeneous private goods, which implies little or no role for government. In contrast, innovation economics recognizes that reality is much more complex.

The United States has been the last among the world's technology-based economies to reject the black-box model of the innovation process. As a result, while it continues to adequately fund and thereby lead the world in basic science, it has relied largely on private capital to produce innovations directly from the resulting science base (e.g., biotechnology) or indirectly through spinoffs from mission agencies' R&D portfolios (e.g., electronics, materials, information technology). These mission agencies have varying degrees of freedom to support portions of a technology's development that go well beyond the range of investment support allowed for the small portion of the of the Federal budget (approximately 10 percent) that directly targets economic growth. This activity creates a relatively small set of modest-sized markets, and extensions (spinoffs) into much larger commercial markets typically involve significant delays.

This dichotomy within Federal R&D policy results directly from the neoclassical emphasis on allocative efficiency; that is, private-sector capital accumulation in response to market pricing signals. For the U.S. or any other government to adopt a "technology-element model" to replace the black-box version requires acceptance of the "quasi-public" good nature of several to these technology elements (Tassey, 2005, 2007). This, in turn, implies that modern technology-based markets suffer many more market failures than neoclassical economists realize (Atkinson and Audretsch, 2008).

Fig. 9 Managing the Entire Technology Life Cycle: Policy Roles in Response to Market Failures



The implications of multiple market failures for technology-based growth policy thereby the growth potential of a modern economy are shown clearly in Fig. 9. As previously described, the traditional technology "black box" is disaggregated into three technology elements: new technology platforms (also "proofs of concept" or "generic technologies"), infratechnologies (and associated standards), and proprietary technologies that are the basis for innovations (the black boxes).

These three elements are not arbitrarily chosen.[53] They perform distinctly different roles in the development and commercialization of new technologies and they respond to distinctly different investment incentives. The latter fact means they exhibit distinctly different market

[53] One need only examine the organization of large corporate R&D organizational structures to see that this is the case. Central corporate research labs draw upon basic science created in universities to prove new concepts (generic technologies). The resulting technology platforms are then provided to the applied R&D organizations in the company's line-of-business units to develop proprietary market applications (innovations). These research processes are enabled by a variety of infratechnologies, many of which are promulgated as industry standards.

failures. Public-good content and hence degree of market failure is indicated by the shaded areas. The science box is fully shaded because it is close to a pure public good and therefore basic research is funded by government through universities. Proof-of-concept (technology-platform) research and infratechnology research are quasi-public goods, which means their development is co-funded by industry and government—hence the overall rationale for the partnership mechanism. Proprietary technologies are largely private goods, but associated excessive risk and/or time discounting can still lead to underinvestment. The policy point is that each of these technology elements, having different investment characteristics, exhibit different market failure patterns and therefore require different policy responses.

Corporations understand the correct technology-based growth model, which is demonstrated in their organizational structure and conduct of R&D: technology platforms are developed in central corporate research labs and the applied R&D (that results in proprietary technologies and ultimately innovations) is then farmed out to the R&D facilities in the company's line-of-business units. Many companies also have dedicated laboratories to assimilate/develop infratechnologies and associated standards. Thus, the technology element model in Fig. 9 is derived directly from high-tech corporations' organizational structures.

The corporate application of this model worked fairly when the United States was the dominant technological power. Large U.S. corporations could apply lower discount rates to longer-term, higher-risk R&D projects because they faced relatively little competition and therefore long technology life cycles. The absence of significant competition also allowed projections of capturing multiple markets based on the new technology platform (i.e., achieving economies of scope). Finally, technological complexity was sufficiently low so that a single entity (a large R&D-intensive company) could be expected to have at least most of the R&D assets required to independently pursue major breakthroughs.

Today, however, virtually all high-tech companies are focusing more of their R&D spending on applied R&D in order to be competitive in the middle and later phases of technology life cycles, which now afford shorter windows of opportunity than in the past (Fig. 8). Their central research laboratories are receiving a declining share of corporate R&D investment and an increasing portion of these laboratories' budgets is allocated to supporting their business units' applied R&D or assessing external sources of new technologies.

Many economies are now compensating for these "market failures" by establishing public-private research partnerships to pool risk, improve the efficiency of R&D, and diffuse new technology platforms more rapidly within domestic supply chains. These economies are also investing increasing amounts in the supporting technical infrastructure (infratechnologies and standards) to increase efficiency across the R&D, manufacturing, and commercialization stages of technology-based economic activity.

However, the United States has only recently begun to move toward the technology-element growth model in which *each major element* is recognized as varying degrees of private and public components. Because of past resistance to microeconomic innovation policy, the U.S. government does not have the internal policy infrastructure in place to effectively design and manage such policies.

Co-Location Synergies. A second major problem is the failure of U.S. policy to understand the importance of co-location synergies inherent in today's high-tech supply chains. Claims by current economic thinking that an advanced economy can prosper solely as a service economy, ignoring the need for domestic sourcing of the large amounts of hardware and software needed by service firms. Short lead times for suppliers and the integration of new technologies into high-tech service systems require constant interaction between service companies and multiple tiers (industries) in the manufacturing supply chain. These interactions happen much more efficiently when these industries are geographically close to one another. Within the manufacturing sector, the increasing backward distribution of R&D in high-tech supply chains accentuates the need for close cooperation among multiple industries.

No one indicator can completely capture the macroeconomic effects of pervasive underinvestment, as described here. The one metric that comes closest is trade because it is in global markets that an economy's goods and services compete directly with those from all other economies. In this regard, U.S. performance has fared increasingly poorly. That the U.S. economy faces structural problems, not just business cycle destabilization, is underscored by the fact that it has not had a trade surplus in goods since 1975. Moreover, the high-tech portion of traded products, once viewed as the signature indicator of U.S. economic superiority, fell into a negative balance in 1982 and that deficit continues to widen.

As the majority of trade remains in products, not services, the manufacturing sector is a serious growth policy issue. The U.S. deficit in traded goods is 5 times the surplus in traded services. And, there is no guarantee that the U.S. economy will maintain a trade surplus in services in the future. The bottom line is that U.S. growth policies are not adapting to global competition, especially technology-based competition. 35 consecutive years of trade deficits for manufactured products cannot be explained by business cycles, currency shifts, trade barriers, etc. As stated succinctly by Pisano and Shih (2009), "restoring the ability of enterprises to develop and manufacture high-technology products in America is the only way the country can hope to pay down its enormous deficits and maintain, let alone raise, its citizens' standard of living."

Economists argue that free trade will result in rising incomes for all participants by allowing the law of comparative advantage to work. Presumably, these economists define free trade as the absence of currency manipulation, intellectual property theft, technical barriers to trade (such as domestic standards that discriminate against imports), and financial subsidies that directly affect relative prices. However, even with all of these restraints on trade are removed, trade does not create a rising tide that lifts all economic boats. Surprisingly, only a few economists including Paul Samuelson (2004) have argued that free trade is not a net win for all participants. In fact, some countries will experience falling incomes—even in the absence of trade manipulation efforts.

The major competitive problem is that the global technology life cycle is shrinking. However, it is not going to zero. Thus, policy makers who suggest that government funding of R&D is wasteful because the resulting technical knowledge spills over to competing economies are ignoring the essential dynamics of global competition; namely, the economy that innovates first and scales up the fastest will likely reap the largest share of the economic rewards because it is a distinct advantage to start out ahead of the competition over multiple life cycles, thereby repeatedly reaping monopoly profits and increasing returns to scale.

A Neo-Schumpeterian Growth Model

The previous section describes a growth model that is very different from the simplistic supply-side growth paradigm of neoclassical economics. A major difference is the recognition of the disruptive role of technology in the Schumpeterian tradition. However, the technology-element model also recognizes the complexity of modern technologies and the importance of competitive dynamics in determining comparative advantage among nations.

In this context, competitive position is determined by the relative efficiency of investment by both government and industry. Unlike neoclassical economic growth theory, comparative advantage is determined by the efficiency of public-private investment strategies. In fact, the increasing global scope of private industry's market strategies leaves government as the major differentiator of domestic competitiveness among nations, as it is public investment policies that determine the global flows of R&D and physical capital and the relative efficiencies of industry structures.

Modern technology-based competition requires two major modifications to Schumpeterian economics. First, the scope of potential market applications of today's technologies is much wider than in the 1930s and 1940s when Schumpeter wrote incredibly insightful works. As a result, the market structures that develop and commercialize them are more varied. As pointed out by Audretsch and Link (2012), Schumpeter first emphasized the role of the entrepreneur and hence small firms as the engine of innovation. This focus resulted from the need for small firms to find a way to disrupt the established markets dominated by large firms. However, Schumpeter eventually reversed his view and emphasized the superior capabilities and market strength of large firms, which enabled them to be more efficient and successful innovators.

Today, however, both large and small firms co-exist in the same technology-intensive supply chain. Each supplies complementary assets and thus components of the ultimate technology systems. This complex industry structure is seen in the emergence of innovation clusters all over the world, where not just a single industry but firms of all sizes agglomerate into new supply chains that deliver new technologies through a much more distributed pattern of R&D and subsequent innovation than characterizes the Schumpeterian industry structure.

Second, the complexity of modern technologies requires multiple mechanisms for a their development and deployment. Increasingly, these mechanisms include various forms of cooperation not only among competing firms by more and more between government and industry. In fact, the role of government in the technology life cycle has become varied, ranging from the early phases of R&D where the public-good content is high to the transition from the R&D phase to scale-up for commercialization.

In summary, Schumpeter's focus on the role of the large firm is understandable and, in fact, was a fairly accurate characterization of innovation economics until the last several decades. The current growth model increasingly evident across the global economy recognizes not only the complementary roles of large and small firms, but also the significant public-good content of technology platforms and the supporting infratechnologies, as described in the previous section.

The Policy Imperative

To compete in a global technology-based economy, the three types of efficiency discussed in this paper must be achieved at levels sufficient to grow per capita income over time. The three types are not independent of each other. Allocative efficiency—the major focus of neoclassical economics—is necessary but not sufficient. This supply-side approach views allocative efficiency as a static concept in that it is applied to the accumulation of an existing set of productive assets, which has a fixed maximum growth potential.

Whatever the pattern of asset accumulation dictated by relative prices, productive efficiency is also required. Its achievement is also traditionally viewed as an internal market problem. In a static growth model, productive efficiency is based on an underlying set of technologies, which determines a maximum efficiency level. Traditional growth models allow for technological change and its effect on relative prices and hence the directions for capital accumulation, but the process is not specified other than to assume a vague sequence in which scientific knowledge is obtained from a source exogenous to the private economy and then somehow turned into new technologies.

This situation was improved when Paul Romer (1990) explicitly included a "knowledge production function" into the neoclassical general equilibrium growth model. He also identified the "non-rival" and "partially excludable" characteristics of technology that contribute to systematic market failure. Such underinvestment characteristics lead to the technology-element growth model discussed earlier, which requires a more complex knowledge production function (Tassey, 2005). Most important, it is the primary role of the technology-element model to specifically characterize the three major elements of industrial technology so as to facilitate the selection of policy instruments that can accurately deal with these and other factors that suppress private investment in technology (Fig. 9).

Because technologies are created, used in economic activity, and then discarded when they become obsolete, the dynamics of managing the technology-based economy over time is an essential element of long-term economic growth. Thus, it is both the complexity and dynamics of modern technologies coupled with the increasingly intense global competition for technology-based markets that make achieving adaptive efficiency difficult and require multiple roles of government in support of investment by domestic industries.

At a general level, U.S. political leaders understand the imperative to invest in technology as the driver of long-term economic growth. Treasury Secretary Geithner has said that the United States should invest more in R&D.[54] In his January 2011 State-of-the-Union address, President Obama called for increased investment in R&D and innovation broadly to improve U.S. competitiveness. Several weeks later, the White House issued a revised innovation strategy

[54] "The Path Ahead for the U.S.-China Economic Relationship." Speech by Treasury Secretary Timothy Geithner to the John Hopkins School of Advanced International Studies (SAIS) on January 12, 2011, detailing the agenda for a forthcoming visit by China's President Hu Jintao.

document directed at implementing the President's goals.[55] Federal Reserve Board Chairman, Ben Bernanke, stated that "innovation and technological change are undoubtedly central to the growth process; over the past 200 years or so, innovation, technical advances, and investment in capital goods embodying new technologies have transformed economies around the world."[56]

Bernanke also points out that a growth rate in per capita GDP of 2-1/2 percent per year doubles average living standards in 28 years—about one generation—whereas per capita GDP growing at only one percentage point less (1-1/2 percent per year) leads to a doubling in average living standards in about 47 years—roughly two generations. That is, the technology-productivity-growth paradigm is the driver of long-term increases in the standard of living.

Thus, the central theme of this paper is that the only way to achieve higher rates of long-term growth in per capital income is through sustained investment in productivity-enhancing investment and that technology is the core of this investment. However, this general recognition of the growing role and importance of technology for competing effectively in the global economy has not resulted in a reversal of the long-term trend of underinvestment by the U.S. economy. Over the past 50 years, U.S. R&D intensity has remained flat (Fig. 7) and in the last decade fixed private investment hardly grew (Fig. 4). In contrast, many other countries have steadily increased their R&D spending relative to GDP and their overall rates of investment.

China has increased its R&D intensity by 170 percent over the past 15 years for which data are available (Fig. 7). In December 2010, the Chinese government announced a plan to invest up to $1.5 trillion over five years in strategic industries of the future (energy-saving and environmentally friendly technologies, biotechnology, new generation information technology, advanced manufacturing, new materials, alternative-fuel cars). This huge sum amounts to about 5 percent of China's GDP and will be supplied by both government and industry. Even if this level of expenditure turns out to be too large for Chinese industry to absorb in that period of time, it demonstrates a commitment to dramatically increasing the Chinese economy's innovation capacity. The Chinese five-year (2011-2015) plan calls for "cultivating and developing" these industries and the government plans to provide targeted tax incentives, including cutting the income tax rate in half for investors in the relevant technologies.[57]

The European Union has shown an increased recognition of the need to systematically plan and manage technology life cycles to increase long-term rates of economic growth. Robert-Jan Smits, European Commission Director-General of Research and Innovation characterized Europe's new "Innovation Union" strategy as the "first time that Europe has implemented a counter-cyclical investment policy in support of research and innovation during an economic

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[55] See *A Strategy for American Innovation: Securing Our Economic Growth and Prosperity,* an update to the administration's innovation report from September 2009 (www.whitehouse.gov/innovation).

[56] Chairman Ben S. Bernanke, "Promoting Research and Development: The Government's Role," speech at the Conference on "New Building Blocks for Jobs and Economic Growth," Washington, D.C., May 16, 2011.

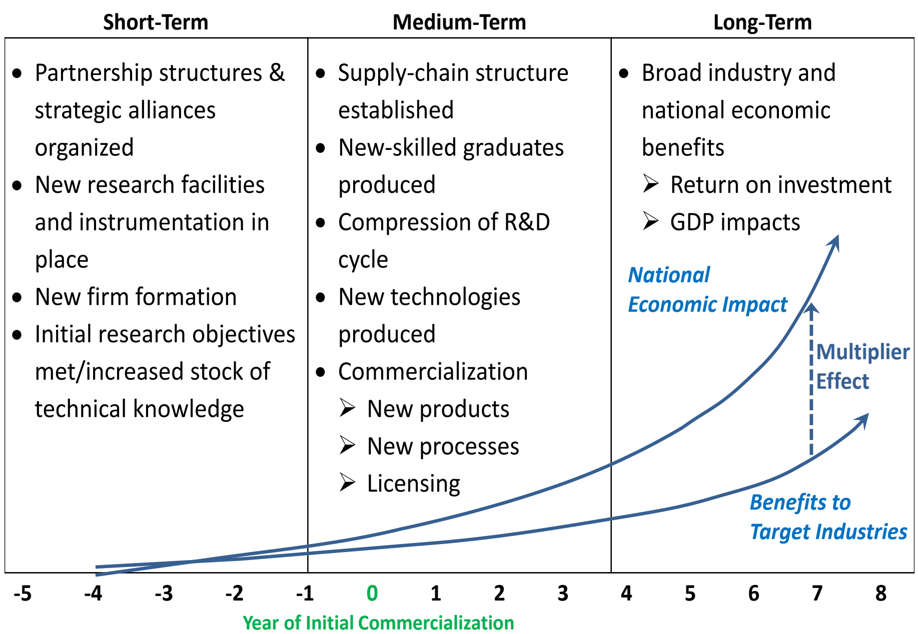
[57] "China Mulls $1.5 Trillion Boost for Strategic Industries" (http://www.cnbc.com/id/40483753/).

downturn."[58] Europe has adopted an EU-wide R&D-intensity target of 3 percent by 2020.[59]

The U.S. economic growth policy infrastructure needs to embrace the critical role of technology in response to several decades of research that shows it is the major long-term driver of productivity and income growth.[60] Government policy also must construct new policies addressing the scope of public and private economic assets that drive the evolution of high-tech supply chains.

However, even if the correct technology-based growth model were to be adopted, a major barrier to implementation remains. The accumulation and effective use of the complex set of technology-based assets required to achieve desired long-term rates of economic growth take a relatively long time to accumulate, integrate, and achieve fully functional system status. Using regional innovation clusters as an example, Fig. 10 shows that the long-term desired impact of large increases in value added (more jobs and higher profits) can only be realized after a number of short-term and intermediate-term goals are achieved. Thus, policy makers not only must understand the long-term nature of economic growth policy, but they must also track, measure, and report on short-term and intermediate-term indicators in order to maintain support and manage the entire technology life cycle.

Fig. 10 Timeline for Economic Impacts from STID Policies: Accelerated Economic Growth through Technology-Based Clusters



[58] Presentation by Robert-Jan Smits entitled "Prospects and Challenges for the European Innovation Union", February 18th, 2011. For a summary, see post by Stephen Ezell at http://www.innovationpolicy.org/european-commission-director-general-of-resea.

[59] This may be too low as a long-term strategy, but given the fact that the EU's current R&D intensity (2 percent) is even lower than that of the United States (2.8 percent), it is probably a reasonable intermediate goal.

[60] See Tassey, 2007 (Chap. 3). A partial annotated bibliography of studies of the economic impacts of technology is available at http://www.nist.gov/director/planning/upload/economic_impacts_of_technology.pdf.

Conclusion

The global economy is experiencing unparalleled expansion, characterized by an enormous influx of new workers. The skills of these workers are increasing rapidly, leveraging the convergence of emerging economies. This process of convergence has been repeated to varying degrees for centuries.[61] The difference this time is the breadth and size of the converging economies, whose workers are increasingly providing intense competition for labor in industrialized nations.

Making an economy more technology intensive is a challenging systems problem. The United States undertook the greatest technical systems challenge of all time by setting out to put a man on the moon in less than a decade. Similarly, restoring a competitive economic system based on technology development and commercialization will be a daunting challenge, requiring greater investment in a number of critical asset categories.

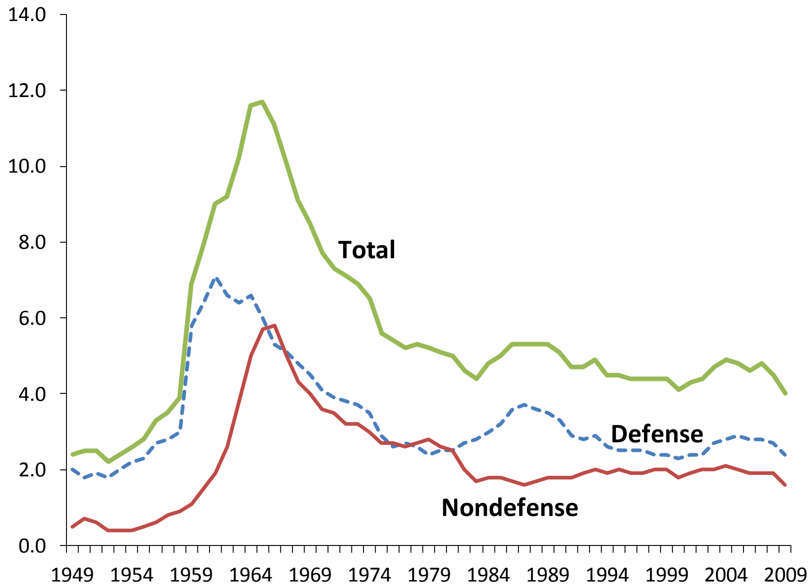
The transition to sustained competitiveness will require upgrading all categories of economic assets: technology, labor, plant and equipment, organization, marketing, and a broad technical infrastructure to support all the other categories. Because many of the world's economies have already adopted new technology-element growth models and are making substantial investments to implement them, the U.S. response can be neither small nor inefficient. R&D spending, for example, must now be managed by the metrics defined earlier: amount, composition, and efficiency of conduct.

In terms of the amount of R&D, the major requirement is to upgrade the currently inadequate incentives for both U.S.-based and foreign-based firms to locate R&D in the domestic economy by providing a competitive R&D tax incentive and an adequate supply of skilled R&D workers. R&D composition inefficiencies must be addressed by (1) reversing the Federal Government's declining spending relative to GDP, and (2) creating a holistic and economic-growth driven Federal R&D policy. Finally, efficient national R&D strategies will be dependent on new public-private research infrastructures in the form of regional technology-based clusters.

When a society decides to increase the portion of its government's budget allocated to developing new technologies, it happens. The Russian space program in the late 1950s was a wake-up call, which elicited an immediate and substantive response in terms of increased U.S. R&D spending. This was followed by President Kennedy's 1961 speech on the need to invest more in science and technology. Kennedy recognized that the United States was being challenged technologically for the first time and that this pressure would grow and expand its scope in the years ahead. Congress responded, as shown dramatically in Fig. 11 by the large spike in R&D's share of government spending. Unfortunately, this priority status lasted for only a few years and then government R&D spending intensity went into a half-century decline.

[61] This process of convergence has been well documented over the last several centuries encompassing two industrial revolutions, as technology became an increasingly significant factor in international competition. In the last four decades of the 20th century, convergence accelerated significantly with a number of emerging economies doubling national income in 10-20 years compared with the 30-70 years required to double in the 19th century (Lucas, 2009).

Fig. 11 Federal R&D as Percent of Total Outlays, 1949-2009



Source: OMB Historical Table 9.7

President Obama in his 2011 State-of-the-Union address repeatedly called for a return to innovation as the engine of U.S. competitiveness. Since that speech, government policies aimed at reviving and expanding the technology-based sector of the U.S. economy, especially manufacturing, have begun to form. Unfortunately, budget deficits and the consequent ratio of U.S. debt to GDP are much higher today than in the 1960s. This fact combined with the installed-wisdom effects from past economic growth strategies are providing substantial barriers to adaptation.

While “macrostabilization” efforts work reasonably well in normal economic downturns, more serious declines that are the manifestation of underlying structural problems will not be adequately mitigated by these policies. In such cases, macroeconomic stimulus efforts generate at best weak multiplier effects. The globalization of markets further reduces the fiscal multiplier traditionally expected from short-term stimulus. The result is that the economy does not attain self-sustaining growth. Debates over amounts and types of government spending become increasingly bitter, as political factions argue over how to divide up a stagnant economic pie.

Self-sustaining growth can only result from investment in productivity-enhancing assets based on regular advances in technology. However, the modern industrial technology is a complex system exhibiting multiple potential market applications. Even the largest R&D-intensive companies will not have the total complement of internal research and production assets to capture the full benefits of investment in new technology platforms. Further, new technology platforms are typically developed years in advance of initial commercialization. Thus, the higher discount rates now applied by companies to R&D investments are leading to declining investment in the radically new technologies that will drive the industries of the future.

The overall policy response is to create a national innovation system that will be characterized by (1) increased joint industry-government strategic planning at the technology-platform and infratechnology phases of the R&D cycle, (2) a more elaborate and better defined set of public and private roles through application of the technology-element growth model, and (3) movement toward a holistic innovation system, which supports the complete technology life cycle; i.e., the science, technology, innovation, and diffusion/scale-up (STID) phases of modern technology-based economic growth.

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