Investment, Recovery and Growth

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Growth, Savings and Sustainability

If the international economy functions well, this decade could see substantial *growth* and improvement in the quality of life across the world with the possibility of lifting hundreds of millions of people out of poverty. There is, however, a great risk that this decade could see instability, stagnation and recession.

Europe is a key potential source of this instability. The electorates of France and Germany, and indeed the United Kingdom, have this month delivered a clear message that they insist on action to promote growth. Europe does indeed urgently need a growth strategy. But such a strategy must be founded on three basic economic realities: first, fiscal responsibility and growth are inseparable – the absence of one undermines the other; second, consumption-led growth on its own will not be enough in the long term and lacks fiscal credibility; third, long-term growth needs strong foundations in structural reform that can improve productivity and competitiveness but it takes time for the growth effects to come through.

Thus, Europe must have an investment-led recovery and one that carries the credibility of being a route to a sustainable future. That investment will be largely private sector but it will depend on clear and credible signals from government on its policies and on a strengthening of the capabilities of its financial institutions, including the European Investment Bank and the European Bank for Reconstruction and Development for the continent as a whole and national level institutions such as the Green Investment Bank in the U.K. For Europe, the priorities are energy efficiency and infrastructure for energy security and reduction of emissions. This would include a smart supergrid that can accommodate solar energy where it is sunny, wind where it is windy, and the efficient integration of different energy sources.

But beyond Europe further economic imbalances between the rich economies, between developed and developing countries, and among developing and emerging markets pose serious threats to the ability of the global economy to grow at the scale and pace required to meet the world's aspiration for growth and development.

Key large, fast-growing countries around the world have agreed on the need to direct some of the global *savings* to developing countries as part of the response to the current global imbalances.[1] Their huge exposure to developed country bonds now looks like a worryingly unbalanced portfolio. Simultaneously, the weak functioning of financial systems in developed countries was a central cause of a serious misallocation of savings toward risky financial propositions—including bets on inflated housing markets—and consequently of the current economic and financial crisis.

There is a further important imbalance that threatens the global economy: its resource productivity. High-carbon, low-efficiency growth leads to huge risks of potentially catastrophic societal and economic consequences from climate change. We know that over the next four decades, in order to have a reasonable chance of avoiding global warming of more than 2°C, we will have to cut total emissions from 50 billion tons CO_2e[2] per year today to less than 20 billion tons in 2050. This means, on reasonable assumptions on growth, prices of

natural resources and with sound management for economic growth, reducing the current emissions per unit of output by a factor of about 7 or 8 in order to reduce absolute global emissions by a factor of at least 2.5.

Developed and developing countries are realizing that growth and development should take a different path: a systemic transformation of the economy based on reduced emissions and higher resource efficiency. They are starting to lay out their green growth plans, which are the foundations for a new energy and industrial revolution that can bring decades of economic growth, help reduce poverty, promote stability and security, and help manage sustainability and the risks of climate change. Although it is insufficiently recognized, many developing and emerging countries are pioneers on this new path: this is where the bulk of infrastructure and other investment in coming years will be.

All this points to the opportunity and importance of channeling some of the flows of global savings to the emerging markets and developing countries where plans for growth are clear and sound investment opportunities with strong financial and social returns exist.

In the years before the crisis, there were complaints in some advanced industrial countries about a global "savings surplus"—so large that it was referred to as a "savings glut"—and several fast-growing emerging economies are indeed characterized by high saving rates. Some of these countries are now looking for investment opportunities to diversify their portfolio beyond U.S. or Euro bonds. Even before the crisis there was a feeling that something was amiss: there were better ways of deploying the world's savings, given the enormous needs for investments to promote development and to respond to the challenge of climate change. Today, the world is operating well below its potential. Something is wrong if, simultaneously, there are excess funds looking for uses, unutilized labor and capital, and vital needs that have to be satisfied.

The G-20, among others, has been calling for those countries with high savings to reduce their savings and to consume more. But the planet will not survive as a viable habitat if everyone aspires to the kind of *resource-intensive* lifestyles and production methods that have marked some of the advanced industrial countries. The solution surely is not discouraging savings, but rather recognizing that global financial intermediation has not functioned well, and there is a great misallocation in how savings have been "recycled". We observed massive flows of money going in the *wrong* directions—from developing and emerging markets to the advanced industrial countries—rather than taking advantage of opportunities for sound investment in economic growth and low-carbon and climate-resilient infrastructure in the developing world. Developing countries have been exporting their hard-earned savings and have often been importing risky portfolios that do little to advance the well-being of their own people.

Over the last few years, we have seen a substantial trend in developing countries pioneering a new approach to growth, focused on *sustainability:* growth that uses more efficiently natural resources and limits emissions. This contrasts markedly with past growth strategies in the more advanced industrial countries, which traditionally have focused on labor productivity, treating natural resources and the environment with abandon. This focus on the environment and sustainability is driven not only by the recognition of the planet's limited resources and by an awareness of the adverse effects of environmental degradation on quality of life, but also by the desire to be less dependent on fossil fuels and less vulnerable to sharp rises in the prices of natural resources.

These are initiatives of immense value to the world as a whole. They are based on the recognition that low-carbon growth and the new energy-industrial revolution is the growth story of the future. As we stand on the verge of a new growth model, it is apparent that there will be immense needs for investment in infrastructure over the coming years, to generate growth, overcome poverty and manage the risks of climate change.

A New Development Institution

Many emerging markets and all low-income countries require a major step increase in infrastructure investment to tackle growth constraints, respond to urbanization pressures and meet their crucial development, inclusion and environmental goals. In aggregate the incremental investment spending across emerging markets and developing countries is estimated at around $1 trillion a year more than what is currently spent.[3] Electricity, water (upstream and downstream) and transport are expected to account for the bulk of the spending needs.

In addition to the scale of the requirements, the financing of these infrastructure investments poses a number of challenges. Beyond the normal commercial and physical risks, greenfield infrastructure projects require large risk capital for upfront investment associated with the development and construction phase. Additionally, many projects face risks around revenue streams associated with policy uncertainties and affordability (e.g. water fees), making many projects unbankable unless policy risk is managed and reduced. Finally, many governments need support to ensure that there is a viable and high-quality pipeline of projects for investors to finance.

Infrastructure projects will have a large impact on ensuring the sustainability of future growth. Between 10-15 percent of the required infrastructure investment could be attributed to making such investment sustainable, by ensuring lower-emissions, higher efficiency and resilience to climate change. The returns to this extra investment are strong not just in the value of reduction in emissions but also in the many and faster appearing co-benefits, including a cleaner, quieter, safer and more bio-diverse production and the strong technological learning-by-doing that we are already seeing.

Current spending on infrastructure in developing countries is approximately $0.8-0.9 trillion per year, of which the majority is financed on domestic public budgets. The remaining annual financing is provided by a mix of private sector institutions, developed country overseas development assistance, multilateral development banks and, more recently, by emerging countries such as the BRICS—Brazil, Russia, India, China and South Africa. Annual infrastructure spending will therefore need to more than double by 2020, in the context of rapid urbanization and aspirations for growth and poverty reduction. Domestic budgets will continue to play an important role, but the amount they can take on will inevitably be constrained by macroeconomic considerations regarding sustainable levels of debt.

The existing architecture is highly deficient in providing financing on the scale and with the characteristics needed. It is conservative on the amount of debt it is willing to take on, often preventing economically productive investments from being financed and thus holding back growth prospects. Current institutions often also lack the ability to invest adequately in project preparation, a detailed enough understanding of local policy risks, and sufficient experience in infrastructure projects in similar circumstances. This means they often are unable to adequately assess risk-return profiles, deal with uncertainty of revenue streams, and hold assets in appropriately diversified, large portfolios.

The reallocation of global savings, in the context of tackling current macroeconomic imbalances, will need to play a key role in making finances available for investment in infrastructure. While initially the extra investment would come largely from the pool of extra savings worldwide, some would come from a recovery in demand and a better reallocation of savings. Given the scale of the gap and the complexity of the issue, a broad based effort is warranted to revamp global, regional and national institutions to enable them to play a role in re-channeling global savings. But as we have argued, a response to the challenge of a rapid increase in infrastructure investment cannot lie only in the reallocation of world saving, important though that is. It also requires management of the numerous market failures that are preventing investment to flow as well as the reduction of policy risk.

A new development bank as proposed by the BRICS could play an important direct and catalytic role in this effort.[4] It could serve as a vehicle that can reduce and absorb part of the up-front risk, finance key bottlenecks in the project pipeline, and generate sufficient knowledge and reputation through scale, could encourage investment flows in early stages and could unlock investment opportunities in later stages. The presence of such a bank in a project itself reduces project risk since governments are much less likely to behave inconsistently or irresponsibly if the bank is involved. This has been a clear lesson, for example, from the EBRD's experience in its support for transition to open-market economies in Eastern and Central Europe, and Central Asia.

Such a bank could also be a key convener and syndicator of programs in a way that closely involves the private sector and other public institutions such as development banks and sovereign wealth funds. It is much more likely to be treated as a convener than a single private sector investment bank or single government. Over time, it could develop the technical capabilities to support countries as they develop their project pipeline, by ensuring projects are high quality and bankable.

The way to recovery in Europe and to sustained growth in the emerging markets and developing countries have much in common: infrastructure investment for resource efficiency and a low-carbon economy. Many of the arguments overlap although they are not the same. Crucial to the investment being realized are clear, credible and consistent policies and greatly strengthening financial institutions, public and private. Part of the credibility comes from the understanding that low-carbon growth is essential for future prosperity and stability. Action is urgent both for Europe and for the developing world.

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Endnotes

[1] Fourth BRICS Summit (2012); G20 Communiqué (2011).
[2] CO_{2e} is carbon dioxide equivalent where other greenhouse gases are included in proportion to their effects on radiative forcing.
[3] Fay, et al (2010).
[4] Fourth BRICS Summit (2012).

The U.S. Economy: Sustaining the Recovery—Policy Challenges, Political Differences and an International Context

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The U.S. economy continues to expand, but the recovery from the deep recession remains slow and economic slack appears still to be considerable. The economy expanded at a 2-1/2 percent pace in the second half of 2011 and preliminary data indicate it grew at a 2-1/4 percent annual rate in the first quarter. Nonetheless, there are some signs that a stronger foundation for growth is being established. The labor market has strengthened and with it household incomes and spending—despite the sharp rise in gasoline prices this winter and spring. Balance sheets are being rebuilt: household debt and especially debt service levels have fallen relative to income, and banks and other lenders have rebuilt capital and are making credit more freely available, except in the residential real estate market. Relative to late 2011, financial conditions have eased considerably, with equity prices rising, volatility lower on balance, and credit spreads coming in. Headline inflation has been lifted by rising gas prices, but those prices are expected to level out or come off some, and core inflation rates are close to the Federal Reserve's new 2 percent target. Wage inflation remains quite damped—less than the rise in prices—suggesting that considerable slack remains in labor markets.

Some of the most recent data have been on the soft side and most forecasters are expecting only a gradual strengthening of the expansion over the balance of the year, despite the continued exceptionally accommodative stance of monetary policy, which the Federal Reserve expects to be in place "at least through late 2014." The growth of business investment has tailed off this year; the housing market remains quite weak, held back by tight credit and the overhang of houses that will likely come onto the market as borrowers and lenders cope with the still-considerable volume of underwater mortgages and economic distress; and fiscal policy is swinging toward restraint—perhaps by a considerable amount on January 1, 2013 when various temporary tax cuts expire and the spending cuts agreed on last summer come into effect unless action is taken on a long-term plan to restore a path to debt sustainability.

This is an environment in which policy action to sustain and strengthen a tepid expansion—at a minimum to avoid undermining the expansion—would seem to be required. But the political parties have such starkly contrasting views of the role of government in the economy that they have been unable to reach the required agreements. The Republicans favor small government, believing that the private sector will supply growth if the government gets out of the way; they are deeply skeptical of the efficacy of the government's fine tuning of resource allocation toward particular industries or of macroeconomic policy, fiscal or monetary. The Democrats believe that excessive reliance on private sector discipline was one cause of the crisis and government should compensate for what they see as substantial market externalities; they emphasize a collective responsibility exercised through government for a social safety net; and they see activist fiscal and monetary policies as providing needed support for the economy in the short to medium terms. No one expects the parties to agree on anything before the U.S. elections in November, and the outcome will shape the exact nature of the subsequent approach to the problems, but action or agreement on at least three policy areas as soon as possible after the election would seem to be required to sustain expansion:

1. Fiscal Policy

The U.S. faces a "fiscal cliff" in January 2013 in which, without a change in law, expiring tax cuts and new spending reductions are slated to tighten fiscal policy by an amount estimated from 3-1/2 to as much as 5 percent of GDP. This cliff comes about as a consequence of U.S. legislators and the executive branch being unable to agree on a medium- to long-term strategy to put debt and deficits on a sustainable track. Recognizing the long-term problems, policymakers have had to make tax cuts temporary and to require spending reductions to demonstrate their awareness of the longer-term issues and as a way of trying to force themselves to come to terms with the longer-term problems.

The economy is unlikely to be strong enough to sustain moderate growth—and could even go back into recession—if these scheduled tax increases and spending cuts go into effect for very long after January 1. The evidence from Europe suggests that fiscal restraint really does damp demand, especially when monetary policy is constrained from offsetting easing. The U.S. does not face the monetary policy constraints of eurozone periphery nations, but with short-term rates at the zero lower bound, monetary policy using unconventional methods is unlikely to be able to offset the adverse effects of such a sharp fiscal tightening. Many expect the deadlines to be extended if agreements can't be reached immediately after the election, but delay without signs of tangible progress risks declining confidence in the ability of the political system to come to grips with the problems and downgrades from the credit rating agencies with the potential for increases in interest rates. Although bond purchases by the monetary authority can keep rates low for a time and avoid overt default, at some point such purchases will clash with the objective of price stability, and giving up on that objective would entail default in another guise—unexpected inflation, would only work for a short time before the rates on government securities adjusted, and would be very costly in terms of longer-run economic stability. Moreover, the huge amount of uncertainty about future tax and spending of the federal government must be complicating the planning of households and businesses and, at the margin, damping spending.

The fixes are difficult and require some sacrifices relative to sustaining the current trajectories, but broad outlines of the path to fiscal sustainability have been clear for some time and embraced by several bipartisan groups: reduce the growth of entitlement spending and increase charges on higher income recipients for social security and Medicare; raise tax revenue by broadening the base through reductions in tax deductions and credits that favor particular types of expenditures. The election will help determine the mix of spending and tax changes, but the hard decisions can't be postponed much longer without running increasing risks of sudden fiscal tightening, eroding confidence, and, as the economy recovers, the crowding out of private investment.

Two critical issues are trajectory and commitment. Any credible plan for fiscal retrenchment will tend to damp aggregate demand to some extent as people adjust spending and saving in anticipation of higher taxes and lower governmental support in the future. But, with the expansion so modest, it will be important to phase retrenchment in very gradually so as not to cause a sudden pullback in near-term spending. Moreover, a gradual or even delayed phase in would give people a chance to plan for reduced support in retirement. At the same time, maintaining market confidence and facilitating planning will require that the commitments not be seen as likely to be reversed by future Congresses or administrations. And that will require some degree of bipartisan accord; this would be especially important for adjustments that are phased in slowly or with a lag.

2. Housing

Problems in the housing market have been a major impediment to a more robust economic response to extraordinarily low interest rates. The overproduction and over-pricing of houses earlier has left an overhang of houses coming onto the mar-

ket in the recovery, especially given the effects of the weak economy on household formation. The problems created by this fundamental disequilibrium have not been alleviated—and in some cases exacerbated—by government policies with respect to housing finance. Finding policies that facilitate loan restructurings for large numbers of households without engendering perceptions of unfairness and moral hazard has been extraordinarily difficult and is perhaps impossible. What may be most helpful now is to settle on some programs both parties can agree to and leave them in place for a while—without the promise of a new program around the corner— so both lenders and borrowers can work within their parameters. In addition, private lenders need to step up the pace of both restructurings and foreclosures to work through the overhang; this requires more private resources being brought to bear, but it also would be facilitated by more assurance that appropriately undertaken actions would not be subject to adverse government actions, such as forced repurchases of mortgages guaranteed by government sponsored enterprises (GSEs) or government lawsuits.

One reason residential real estate credit remains so tight is that private mortgage securitization has not revived. The authorities need to set the rules of the road for such securitizations—including the required "skin in the game" under Dodd-Frank, which remains pending. More fundamentally, the administration and Congress have not come to grips with the longer-term issue of what the role of the government should be in the housing finance market—how Fannie and Freddie should be reshaped or whether there should be any role at all for governmental entities in housing finance. Until those decisions are made, it will be difficult for private lenders to plan their own roles in the mortgage market and commit resources to the origination, holding or distribution of mortgages.

3. Financial Regulation

The buildup of imbalances and vulnerabilities in the lead up to the crisis and the necessity to use taxpayer resources to limit the damage from the subsequent collapse revealed deep flaws in the financial system and its oversight. The job now is to fix the flaws while impeding the recovery as little as possible in the process. It's not clear the latter objective is being met. The extent of the changes, the length of time to implement them, the possibility of global inconsistencies must be making it difficult for financial intermediaries to adjust business plans and commit resources. Moreover, rapid implementation of some new requirements—like higher capital levels in Europe—appear to be reducing the availability of credit.

The answer is not "repealing Dodd-Frank" or rolling back higher capital requirements as some have argued. Much in that legislation goes in needed directions—for example by requiring greater capital and liquidity for systemically important institutions, by giving the authorities new ways of resolving systemically important institutions while increasing the odds of preserving stability, by making derivatives markets safer, and by increasing the oversight of clearinghouses and other financial market utilities. And internationally agreed increases in capital and liquidity buffers are the most robust means to protect markets and taxpayers, reduce regulatory arbitrage, and set a level playing field for competition. But implementation of Dodd-Frank has been delayed and weighed down by the sheer volume of new rules to be written—a number of which are unrelated to the causes of the crisis; by the difficulty of applying cost-benefit analysis within the parameters of the law; and by the problems of coordinating across agencies in the U.S. and across countries.

Perhaps it is time to prioritize—concentrate on the most important aspects, especially the capital and liquidity buffers and risk management of the most important institutions and the possibility of their resolution in a global context, and strengthening the financial market utilities at the center of the markets. Get bipartisan support for these basic reforms, subject them to rigorous cost-benefit analysis, and speed up getting those rules in place.

International Dimensions of U.S. Policy

The most important responsibility of U.S. policymakers is to promote sustained, noninflationary growth at home in a stable financial environment. Deviations from any of those objectives would have negative implications for the global economy. And, as I have emphasized, the sooner the needed steps are agreed and taken, the better for the U.S. and global economies.

Relative to the years before the crisis, the U.S. will need to rely less on consumption and government spending to support economic activity and proportionately more on investment and net exports, with a much smaller current account surplus. The reliance of global growth on the debt-financed U.S. consumption manifestly was not sustainable. In terms of policy mix, as noted, the U.S. needs to embark on a gradual tightening of fiscal policy; unless private sector spending strengthens more rapidly than now, fiscal restraint will need to be accompanied by highly accommodative monetary policy in order to promote higher employment and inflation near the 2 percent target. This policy mix should support a shift of production toward exportable goods and services and a shift of expenditures toward domestically produced goods and services. Changes in relative prices are a critical part of the market mechanisms inducing such shifts and those changes may imply some further weakening in the foreign exchange value of the dollar, or at a minimum no significant reversal of the decline already experienced.

For the rest of the world, greater domestic demand and perhaps appreciating currencies, on average, will be required to promote sustained global expansion—less reliance on exports. Low interest rates in the United States may foster capital flows to countries with higher returns, most likely emerging market economies, reducing the "uphill" flow of capital from the emerging markets to the advanced economies. Thus, there will be spillovers from the policies of the U.S. into the rest of the world, just as there have been spillovers from the policies in the rest of the world into the U.S.—especially those policies that have blocked exchange rate appreciation in order to promote export-led growth.

Expectations—bordering on demands in some cases—that the U.S. shift its policies—for example run less expansionary monetary policies— to take account of these spillovers are misplaced. In the current circumstances, what is required for domestic growth and balance in the United States and in surplus countries is also required for global growth and balance—no conflict exists. What the U.S. must do will make the global economy less subject to disruption from debt-caused problems in the U.S. and from an erosion of confidence in U.S. government obligations, which play such a critical role in global financial markets, reflecting the reserve currency status of the dollar and the depth and liquidity of dollar financial markets. Moreover, it is not reasonable to expect U.S. residents to sacrifice their own economic welfare to benefit other countries, especially when those countries also need to rebalance and have the tools to do so. Greater exchange flexibility, macroprudential policies for their financial systems, greater reliance on domestic demand in surplus countries will also promote global and domestic growth and stability. Although there may be a theoretical "cooperative solution" that fosters even stronger global growth with U.S. sacrifices, there is no way to transfer the gains from the winners to the losers.

Countries must make macroeconomic policy with full awareness of the global context. Actions taken by one country—especially a large globally important country—will have wide ranging implications for other countries. Such a country needs to be cognizant of the effects of its policies on other countries and the likely response of those countries' policy initiatives. Some types of policies, such as those affecting globally integrated financial markets, must be harmonized and coordinated to a considerable extent to avoid regulatory arbitrage and to control externalities. The alternative would be interference in the free flow of global capital and less efficient resource allocation. With respect to fiscal and monetary policies, the need for this type

of coordination is much less clear. Discussions and analysis of macroeconomic policy spillovers are a valuable addition to the international economic dialogue. But in the end, countries have the obligation to stabilize their own economies and the means to achieve their own economic objectives in a variety of global economic circumstances without requiring sacrifices by their trading partners.

Global Growth and Adjustment: The Energy Dimension

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Various dimensions of the global energy system have been discussed by the G-20 leaders since the group was first convened in late 2008. The sharp spike in crude oil prices in mid-2008, just before the Lehman crash, and their volatility in the period that has followed impelled the French G-20 presidency to examine price formation and transparency in commodity markets. Climate change finance as a part of broader development finance has been a recurring theme, as has been the need to phase out subsidies on hydrocarbon consumption, something which is particularly prevalent among the emerging market members of the G-20. The links between high and volatile oil prices, the balance of payments, and food prices and affordability have been another preoccupation of the G-20 leaders. A healthy, resilient and stable global energy system is as important to strong, balanced and sustainable global growth as the global financial system.

Since February this year, I have been fortunate to obtain a deeper perspective on these issues in my new role as the chief economist of Shell International. I am grateful to Brookings and to Kemal Derviş and Homi Kharas for allowing me to remain a part of the Brookings Think Tank 20 (TT-20) group, and to continue to contribute to its series of reflections on policy coordination in the global economy. Accordingly, in this contribution I would like to reflect on adjustment in the global energy system as part of the overall adjustment of the global economy. I will concentrate on longer-term structural developments rather than concerning myself with the short term. I do so also because such structural analysis is the hallmark of work that Shell has been doing for 40 years as part of its global scenarios (www.shell.com/scenarios), and in which I am now immersed.

Shell's current published energy scenarios (labeled 'Signals and Signposts') date to early 2011 and were designed to take on board the global financial crash of 2008 as well as the outcome of the 2009 Copenhagen conference on climate change. The long-term perspective on energy demand and supply in those scenarios was, however, substantially based on work undertaken at the height of the boom in 2008. Using Shell's own World Energy Model, that work attempted to reconcile global growth, energy needs and environmental constraints in the period until 2050.

In this effort it was not alone. Particularly in the run-up to the Copenhagen conference a number of international, academic and policy organizations were similarly engaged in peering into the world's carbon future over the medium run. Being exposed now to the scenario process, what I personally find valuable about the Shell discipline is its willingness to examine alternative futures even-handedly, recognizing the inherent uncertainty of global developments. Once having systematically examined a range of alternatives, Shell as a business is obviously obliged to form its own view both for business decisions as well as in its advocacy. Through experience and practice, though, it has found that its corporate interests are better served if such considerations do not influence the scenario analysis.

To be helpful, even scenarios have to be grounded in a view of the future. Given the ebullience of that time, it is hardly surprising that the 2008 scenarios accepted that the economic growth of the major emerging markets was likely to be sustained into the foreseeable future. Given their earlier stage of development, this growth was likely to be both

faster and much more materials-intensive than growth in the mature economies, and would therefore put demands on a range of global resources particularly, but not only, the global energy system. A relook at growth prospects following the crisis concluded that the fundamental drivers of poor country growth remained largely intact, even as the prospects for growth in the rich countries had been harmed for at least a while. The prospect of key economies encountering a "middle-income trap" or encountering a financial crisis cannot be discounted. These at a minimum could affect the trajectory of growth, if not the end point.

Global demand for energy in 2050 could triple from its 2000 level if the energy intensity of the emerging economies were to follow historical patterns, including that followed by successful recent developers. Ordinary market forces and developments will of course respond to this enhanced demand, although most probably along a rising cost curve as cheaper sources of energy, particularly crude oil, are replaced by less easily accessed sources. Sensible policies on both demand and supply (on which more below) could help these trends to deviate from historical experience to a degree, but the finding of the World Energy Model is that, by 2050, there could remain a gap between prospective demand and supply equivalent to the size of the entire global energy industry in 2000. This gap, (dubbed a "Zone of Uncertainty" in the Shell work) could be bridged either through smart and purposive national and global policy actions, or by chaotic and disruptive economic and energy market adjustments. One implication was that there was little margin for choice among energy alternatives: coal, oil, gas, wind, nuclear, solar, all would need to be pressed into service if poor countries were to grow and to urbanize.

The Shell energy scenarios broadly accept the scientific consensus on global warming and its causal association with global concentrations of carbon dioxide. While a rising share of renewables in the primary energy mix is both desirable and likely, the transition will take a long time. Both policy and technology matter. Taking technology (and finance) first, the basic observation of the scenarios on the supply side is how slow change is likely to be, given the sheer scale of the global energy system, and the need for new technologies to go to competitive scale. Work done by Shell staff, and published in the peer-reviewed science journal *Nature,* examines the historical experience with the introduction of new energy technologies. It finds that it typically takes 30 years for a new energy technology to go from pilot-plant scale to the point where it constitutes even 1-2 percent of the world's primary energy resources. Emerging technologies studied since the 1960s include nuclear, liquid natural gas, bio-fuels, wind and solar photovoltaic. The scale of the global energy system implies that even this level of penetration requires a sustained compound growth rate of 26 percent per year.

Following this "establishment phase" which typically requires exceptional policy support, the technology in question enters the zone of "materiality". Thereafter growth moderates, and the technology in question assumes its long-term position in the energy mix based on considerations of commercial competitiveness and convenience. With the best will in the world, then, there are limits to the rate at which the supply mix can evolve, even in the presence of policies supportive of technological development. If we assume that the next 30 years are critical for the world's carbon future, an important implication of this work is that the technologies for shifting the world's primary energy mix are already known. The point is to rear them from youth to adulthood.

This then leads to policy, and the implications of different policy pathways for global warming. Interestingly, even as far back as 2008, well before Copenhagen, the Shell scenario team was not particularly optimistic about action by national governments being the principal driver of coordinated regulatory policies toward climate change. Instead in a scenario that it labeled "Blueprints" the spur to action initially comes from a patchwork of local initiatives which in turn stimulate business and government to back coordinated and

consistent global policies. The tipping point occurs as consumers and investors realize that "change is not necessarily painful, but can also be attractive". Success breeds success and ever more ambitious actions become politically possible.

The crucial variable is timing: policy actions are taken early on and the world is able to stay on a high growth, but economically sustainable growth path. The alternative (but equally plausible) scenario, entitled "Scramble" is one where the imperative of energy security in a world of apparently finite energy resources puts a premium on negotiation of bilateral agreements and incentives for local resource development, both bio-fuels and coal. This focus on supply leads to demand and climate action being postponed until supply shortages and climate events force drastic action. This delay imposes a larger, though later, growth penalty than under "Blueprints".

Even under the more orderly "Blueprints" scenario, there are expected to be immense difficulties in keeping greenhouse gas atmospheric concentrations below the 450 parts per million (ppm) threshold that scientists believe is the safe limit if global warming is to be restrained to the politically endorsed target of no more than 2^0C (above pre-industrial levels) by 2050. Achieving this goal would require, among other things, greenhouse gas emissions to peak before 2015; a zero-emissions power sector by 2050 and a near zero-emissions transport sector over the same period. Under "Scramble" the dynamics of adjustment are harder because of the later start.

This brings us then to the world of today and the prospects currently facing both the U.S. (the specific focus of this TT-20 volume) and the G-20 in the global energy economy. Here, important recent developments are the reappraisal of nuclear energy by the advanced countries, particularly Japan and Germany following the Fukushima failure a year ago, and the dramatic expansion in hydrocarbons extracted from shale, both gas and liquids. The former has not so far affected the nuclear investment plans of the developing countries and, as such, is more likely to have short-term rather than long-term effects, and is currently particularly affecting global liquid natural gas (LNG) markets.

Similarly, the shale revolution is also so far largely restricted to the U.S., for both geological and institutional reasons, and this is likely to remain so for some time before other parts of the world are able to replicate the U.S.'s success, even though promising geological structures do exist elsewhere, such as China and Argentina. However the U.S. is a big part of the global energy scene, so that these domestic improvements in gas and liquids supply, when coupled with moderation in demand resulting both from slower growth and improvements in efficiency, could affect global markets by reducing U.S. oil imports in the medium-term. The fragmented structure of the shale gas industry in the U.S. with a number of smaller-scale operators, has resulted in considerable volatility in natural gas prices (currently below the long-run marginal cost of supply), which acts as a disincentive for the huge investments needed for sustained LNG exports. There are also regulatory constraints on the export of such gas. Some investments in liquid natural gas for export (largely to Asia)from the U.S. Gulf Coast, based on these unconventional gas finds, are now beginning to be made, exploiting the huge price differentials that currently exist.

For the present, therefore the major application of this unconventional gas bonanza is likely to be within the U.S. itself, as a replacement for coal in the generation of electric power, with attendant benefits for reduced emissions of greenhouse gases. Some analysts have claimed that this cheap energy advantage will confer significant benefits both to the U.S. balance of payments (and hence the dollar); others argue that this additional source of cheap, locally sourced hydrocarbons will provide the basis for an American industrial renaissance particularly in chemicals. What is more certain is that, in the absence of exceptional government regulatory or financial support, hydrocarbons in the U.S. will continue to provide stiff competition for the expansion of renewable energy sources at commercial scale.

In many ways these developments in unconventional gas and oil are consistent with the fundamental supply adjustment mechanisms foreseen in the Shell scenarios. High oil prices, sustained by expectations of buoyant long-term demand from the poorer countries, have stimulated exploration and innovation, one outcome of which has been the unconventional gas revolution in the U.S. This should be seen less as the application of a new energy source than a dramatic expansion in application of existing technologies in response to attractive price prospects. The fact that this expansion has been largely in gas, at least so far, is also in line with the Shell 2011 scenarios, which predicted a steady shift in the global primary energy mix away from crude oil toward natural gas, both conventional and unconventional. The acceleration of this trend could mean a slight easing in the pressure on energy supply, so that the world may actually have a choice in reducing the importance of coal as a source of primary energy while maintaining the growth prospects of poor countries.

It also seems that another premise of the Shell scenarios will remain valid for the foreseeable future. Divergence in national resource endowments and differing environmental beliefs together with profound disagreements on international burden-sharing will continue to make it difficult to agree on a uniform, global long-term price for carbon, even though this is what would most efficiently encourage the massive investments needed to bring renewables to scale. While the world waits for a series of local initiatives to cumulate into a consistent global consensus, an important task facing the G-20 is to ensure that diverse local initiatives do not fracture the framework of global commerce, in pursuit of the ever-elusive "level playing field". While finance steals the headlines, rules-based trade is the true flywheel of the global economy. The G-20 must ensure that it remains so.

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