I was recently asked an original and provocative question by an interviewer in China. She wanted me to explain, looking back from the world which had emerged in 2050, what had been the key factors that had permitted the successful management of climate risk achieved across the first half of the 21st century. After reflection, I discovered that my answers surprised even me, principally because they were simply outside the accepted concepts, language and debate about climate change risks as they had emerged between 1992 and 2020. Perhaps this should not be so surprising looking ahead, in as much as scholars often recognize retrospectively that what characterized fundamental transitions of economy, politics and society was a full blown shift in the terms in which problems, especially those most challenging from an embedded perspective, become tractable only when the initial framework through which they are organized is shed in the dynamics of the passage that is already in play. Or, at least, this is what I want to argue is how we should approach climate change now.

**2050: LOOKING BACK**

Looking back from 2050, three factors stand out that facilitated and shaped the victory over more cataclysmic, climate-driven deterioration in the quality of the earth’s ecosystems. These three can be summed up as: (1) macroeconomics, (2) digital infrastructure; (3) Asian governance.

**Macroeconomics**

Macroeconomics refers to the relatively early (2020-2030) escape from the structural conditions that had sharply reduced productivity gains in both advanced industrial and emerging economies for more than four decades after the 1970s. The escape from prolonged stagnation marked a resumption of economic growth at levels much closer to those that had generally prevailed between 1870 and 1970 in Europe and North America, and then spread widely in Asia (if more sporadically across Latin America and Africa) from 1960 through 2010. This recovery of significantly higher rates of growth generated capital stocks to be invested at scale in redesigned infrastructure systems platforms, better adapted to emergent technological and organizational systems across the economy that were characterized by a critical shift from resource-intensive to sustainable production. In effect, it was
gradually recognized that climate change was less a discrete environmental problem than a symptom of the running down of an extended period of macroeconomic growth that had been installed as the normal condition of advanced economies across the late 19th and most of the 20th centuries. As the marginal productivity gains associated with the extensive employment of land and fossil fuels in key economic sectors declined, the environmental liabilities imposed as the byproducts of the dominant production technologies that characterized structural stagnation increased.

**Digital infrastructures**

The acceleration of economic transition away from pre-existing structures of production became the thread that tied development and sustainability together. In each of the key sectors—energy, mobility, agriculture and construction-- in which climate damaging side effects of natural resource consumption marked the global diffusion of long established industrial and agricultural models of economic growth, there were credible demonstrations of better productivity impacts of investment in technologically advanced infrastructures, incentivized by targeted fiscal incentives and complementary public policies. The efficiencies derived from these innovations deployed at scale restored constrained supplies of public finance, reduced the competing demand for income transfers and security expenditures that attend low growth, and mitigated the macroeconomic risks that constrained mid and long term private investment expectations and portfolios. At the same time, the rising demand for the services of these core sectors reduced the stranding of existing financial asset values that had discouraged and deferred policy and business reforms consistent with the new direction of technology change.

The application of new general-purpose digital technologies to dedicated infrastructure platforms across the core sectors of the economy proved the source of precipitous declines of costs. These cost savings were driven by advances in information processing in the areas of data monitoring and organization, storage and security, and control systems based on computational analysis and automated machine learning. Although these productivity effects were initially hidden for some decades by the lags in re-optimizing policy, business models and finance around the emerging technological capacities, the new growth frontiers were both more widely exposed and reinforced by expanding public investment and incentives to mitigate the transition risks private investors were unwilling to take on at all, or without prohibitive interest premiums in the cost of capital. In turn, as revised investor expectations about productivity mitigated constraints on public and private finance that had become, in the face of deep macroeconomic uncertainty, increasingly aversive to longer term and less liquid investments, the pace, scope and sustainability impacts of transition accelerated and diffused.

The rising wave of digital innovation proliferated through sector specific applications in each of the climate relevant production systems, substituting knowledge (software) and capital (platforms) for intensive reliance on semi-skilled labor and natural resource consumption that defined the embedded economic development model. Contrary to a long-standing popular belief that economic development was the primary source of climate risk, stable macroeconomic growth, built on a foundation of information-intensive infrastructure platforms, was recognized to be the precondition for ecosystem quality, rather than its antithesis. Sustainability remains the undeniable benefit that has been achieved since 2020, even as polities still wrestle with the disruptive effects on labor markets, on how properly to measure (tax, invest) well being derived from the zero marginal cost goods and services new infrastructure systems provide, and how to ensure equitable access to this value.
Asian Governance

The third and final factor that drove the acceptable management of climate and sustainability risks was the trajectory of governance and political institutions in Asia. Asian development had dominated global economic change and associated infrastructure investment in the years between 1980 and 2020. It equally imposed particular obstacles to the transitions that macroeconomic slow down and the displacement of resource intensive growth required. In Northeast and South Asia, the driving flagships of Asian manufacturing-led expansion, the baseline fuel and cheapest source of energy was coal. Natural gas, conventional or unconventional, was scarce and far away. Electric and industrial power plant investment, most often managed through state owned enterprises and financed by state owned banks, was geared up at unprecedented levels that left a huge, relatively efficient, highly functional, and largely unamortized asset values of recent vintage, fossil associated infrastructure on the state’s balance sheet. Know how and organizational capital were concentrated, and defended by politically influential elites, in heavy manufacturing sectors even as economic transition implied the transfer of productivity growth to service sectors that threatened to strand substantial financial values in already credit constrained public finance systems and require disruptive innovation in patterns of economic organization.

Even as continued dependence going forward on the familiar Asian development recipe came under increasing question, in part because of the shocking scale and speed of its impacts on local health and urban lifestyle and in part because of a coincident unexpected macroeconomic fall off in growth that lagged slightly the financial crisis in the advanced economies around 2008, it became increasingly apparent that if the answer to prolonged stagnation and low productivity lay in the prospects for technology led restored growth levels and if Asian investment for growth was institutionally wrapped up in state incentives and financing channels, then Asia had become too large a player in the world economy to retrace its prior successful experience with a strategy of late development through the import of established development models. In spite of the multiple hard challenges implied and widely recognized, the scale sufficient to sustain and diffuse productivity gains (and investor expectations of growth) that would not be curtailed by nationalist protection of essential markets depended on Asian participation in the leadership of transition, and the environmental benefits it would entail. Alternatively, an Asian failure to take the steps to leave behind the model of growth that had served it so well in the late 20th century would have surely condemned the global ecosystems to the most severe forecasts of risks they would run.

Looking back from 2050, it would have been perfectly reasonable to suggest that the commitment of Asian institutions to restructure production systems was the most problematic aspect of avoiding dramatic declines in ecosystem stability. The predominant Asian, particularly Chinese and Indian, patterns of governance that drove rapid growth in the late 20th century were distinct and local adaptations of historical legacies of demography, late development, embedded inefficiencies of collective organization, and exposure to colonialism and other Western institutions that more demanded adverse reaction than imitation. Across Asia, the first decades of the 21st century were colored by strong nationalist and populist trends. Religious and ethnic communalisms were tools for popular mobilization of political support. Economic organization was explicitly dualist: while the bulk of the economy was organized around markets for goods and services, the core energy, transport, heavy manufacturing, telecomm, financial and security sectors were reserved for, or closely guided and supported by, state enterprises and banks. In these
pillar industries, the Western experience of separation of production, finance and policy into independent firms and government agencies was incompletely realized. The reforms of these sectors, even under the high tide of global privatization, were partial or formal in extent. Urbanization proceeded at a pace that strained the administrative capacity of states to monitor and control decentralized institutions so that governance through selective campaigns or carefully targeted hierarchical mandates coexisted with generally weak enforcement of national policy instruments from taxation to pollution control. Patronage, often through state financing of large infrastructure projects, was common.

Perhaps the most significant feature of Asian exceptionality to an orthodox model of Western advanced economies was its commitment to collective units of social organization, well represented at the apex by state firms and at the base by local, particularly urban, governments/communitys. Identity and legal status were accorded by membership in these state chartered entities and behavioral control and incentives to shape norms of social practice were favored mechanisms for coordinating public order. Under this alternative model of institutional organization that combined growing competition in national and international markets with often individually restrictive forms of control within the collective competing units—they themselves always seeking advantage through the channels made available by a pervasive political hierarchy—Asian development had prospered beyond all expectations. Not wholly unlike the emulated or illiberal capitalism of externally competing and internally constraining city states of early modern Europe, these distinctive benchmarks of Asian social organization, in spite of their endless variations within the vast expanse of modern Asia, had assembled a machinery for development that at once surprised the world and rendered ambiguous its prospects for conceptual revision or political reform as the linked challenges of macroeconomic deceleration and unsustainable lifestyles emerged.

The institutional attributes of the Asian development model potentially offered both advantages and obstacles to the successful navigation of a rapid transition from manufacturing to technology-led growth. On the positive side, there were established political practices that gave priority to collective and populist interests. These preferences, often instantiated through large scale public works projects or infrastructure programs that served simultaneously as growth stimulants and political prizes, were far easier to implement and finance through governmental channels, which escaped legislative or regulatory deadlock more prevalent in political systems with less concentrated, or more dispersed, institutional powers. Moreover, the favored status of behavioral campaigns or state incentives as a policy tool could better be deployed against objects like energy efficiency or suburban design around drone delivery and shared transport, whether cars or bicycles, than in the West where individual comportment could normally at best be nudged along transition paths. Across Asia, the comfort, indeed preference for, political instruments like lifestyle or educational socialization and identification associated with macroeconomic or collective advance contrasts sharply with Western appeals to (micro)economic pricing or technology efficiency as justification for consequential change. Finally, it would appear that the mechanisms for coordination and alignment of evolution within the pillar industries, many of which lay at the heart of polluting sectors, would facilitate the process of systemic change (e.g. the integration of flexibility services, including demand side management, with the variable supply generation of clean energy; integration of transnational or regional power systems built out under state led initiatives like One Belt, One Road).
On the negative side, as the global and Asian economies slowed, the periodic bailing out of stranded state investments that was tolerable under high growth became more contentious and a source of macroeconomic risk. Key state firms and financial institutions had acquired monopoly power that resisted asset devaluations, the declining relevance of their knowhow, or the administered quotas of production hours or prices that would fall with the rapid introduction of more efficient technologies. Where the national economy was mandated to shift production patterns, the spare capacity left in the hands of state firms was often cheaply exported with state subsidy or trade support to other locations, delaying the transition of importing polities. Frequently as market-based reforms were grafted on to administratively based allocations of price and quantities in the pillar economy, the results of partial measures (e.g., markets for interprovincial grid connections; cap and trade regulations) would yield perverse results because they were implemented through the exercise of political power in non-transparent domains such as intra-governmental financial transfers and closed negotiations between the collective entities that dominated these core activities.

The ambiguity of the evolution of the institutions of governance with which Asia confronted its peculiar challenges of transition, growth and sustainability did not initially imply any deterministic answer to the outcomes achieved on the road to 2050. There were good reasons ex ante to be either optimistic or pessimistic about the odds of the joint growth and sustainability agenda. The principal lesson, looking back, is simply that Asia had become the central locus where the future shapes of technology-led growth would be hammered out, and where the derivative impacts on sustainability or its absence would be measured. In the end, the dynamics of transition had to be resolved in ways consistent with Asia’s principal forms of social organization, as adapted to the shifting technological context that enveloped them. With hindsight, it could be argued that the dominant effect was played out in the intersection between technologically enabled network identities and Asian social organization. As information everywhere became increasingly deployed and interpreted in a proliferating landscape of networks, the major determinant of social, economic and political choice became the networks to which one belonged. Networks at a global scale had to be gated and membership inside or outside these gates the principal source of opportunity and status. Geopolitics became a competition between an hierarchy of gated networks, with innovation in their capacities the metric of prominence and power. To have seen this from 1990 or 2020, or even to have grasped the broad outcomes of transitions of social action, was never possible from within the boundaries of worlds in motion.

Two points looking back are clearer. Asia was well equipped by the social base with which it entered this transformative process to act as a principal agent of its realization. Other countries, advanced and less developed, had learned they had to make significant, and perhaps more disruptive, adjustments in their own social organization that might once have been described as convergence to an Asian model. More important is the conclusion that, faced with one hand the demands of a largely exhausted model of growth with accumulating, if unintended, liabilities for the natural and human environment and, on the other, the emergence of the technological regimes that required non-linear structural change, the requisite strategy was to build into that technological and organizational future. The world of 2050 is qualitatively different from the world of 1990. To move toward the former armed with the conceptual and institutional apparatus of the latter was bound to be insufficient and likely to have been ineffective. The task of 2020
was to take some measure of the changes on the near horizon as they started to become more distinct and to revisit the framing of problems then salient in terms consistent with the foreseeable context in which they would be resolvable.

1990: LOOKING AHEAD

To take intellectual hold of the scope and pace of the changes on the horizon that leads to 2050 and to build sustainable production systems into the formidable practical challenges the world of 2050 demands, I have found it useful to consider these issues from three benchmark dates in the political discourse that frames debate over climate change and other dimensions of sustainability. In 1990 the world was marshaling its efforts in anticipation of the Rio Earth Summit that would define multilateral regimes for climate, desertification, biodiversity and associated elements of ecosystem deterioration. 2050 was specified as the target date at which the goals laid out in Rio had to be realized. 2020 is the halfway point between the worlds of 1990 and 2050, a signpost of the progress that had by then to be under substantial construction, if the 2050 objectives were to be achievable. However, in distinction from any linear conceptualization of the passages from 1990 to 2050, the major political, economic, technological, financial, social and geopolitical conditions that describe the worlds of 1990 and 2020 now seem as different from one another as do my imagined transitions between the worlds of 2020 and 2050 that pave a plausible path for the successful management of the 1990 sustainability risks.

Step back into the world of 1990 and recall the framing of climate change and sustainability as constituted in that context. In substantial ways the prevailing commitment to neoliberal political economy defined a highpoint of belief in markets. The Soviet Union was in collapse. The European Union was on the verge of the completion of the integration of a Single Market. The United States and the multilateral financial institutions it influenced packaged development models under the Washington Consensus of privatization, price reform and enhanced competition. In the domain of political diagnostics, the emerging markets and ex-planned economies were caught up in the “third wave” of democratization that predicted convergence around transparent elections, mobilization of inclusive political parties, and effective rule of law. Expectations about long-term growth trends were rising against a background threat in the advanced economies of stagnation that had appeared from the early 1970s. In the U.S. productivity indices were inflated by hardware and software sector gains and a peace dividend was due with the end of the Cold War. Europe was about to benefit from the efficiencies of both market integration and enlargement through the accession of post-Soviet states. The developing world, particularly in China and East Asia was on the brink of double-digit expansion. In geo-politics, international regimes had been recently agreed for the Law of the Sea and the Montreal Protocol against CFCs, with promising negotiations underway for a comprehensive and upgraded World Trade Organization.

The momentum of these multilateral processes seemed fluidly extensible to the multiple environmental issues on the Rio Earth Summit agenda for 1992. The level of collective confidence that reflected greater wealth and extensive competence for specialized institutions of multilateral governance embraced engagement with environmental risks conceived as economic externalities that were to be analyzed and managed
under market driven mechanisms. The major debate in the run up to Rio was between second generation economic instruments like cap and trade systems (US Clean Air Amendments of 1990) or pollution (carbon) taxes that moved beyond command and control regulation into general equilibrium modeling of the impacts of estimated costs and benefits that justified optimal pricing interventions consistent with neo-liberal theory. It is notable that 30 years after 1990 these same frames, methods, and tools still reign in theoretical debates about completing the imperfect multilateral regimes that have been constructed, including correcting the problems in operation of the now orthodox pricing instruments deployed to monetize externalities. While a less than hoped-for record of emissions mitigation is reflected in more extensive calls for rising levels of public resources to avoid the accumulating risks of unsustainable growth, it remains notable that these escalating demands rely on the political capacities of the same institutional agencies, processes and expertise that were in 1990 invested. The stability of the framework with which the challenges recognized in 1990 are envisioned is particularly remarkable precisely because the world of 2020 has lost all resemblance to the world in which these representations emerged.

2020: LOOKING AROUND

As we approach 2020, very few of the expectations prevalent around the origins of the climate change regime describe the background conditions in which the Paris Accords of 2015 are to be executed. Global trade is down from earlier peaks and manifestations or threats to strengthen border controls and tax barriers to the free movement if goods and services are frequent and widespread. State enterprises and banks have been re-chartered and in many cases are increasingly the favored and empowered vehicles through which geopolitical power is extended transnationally. Universal democratization has showed itself an illusion ever harder to articulate as media adept leaders in advanced industrial and developing nations have proven themselves quite capable of turning elections into the formal machinery of regime mobilization, reproduction and control that turns upside down the directions in which popular authority was intended to flow. The promised convergence of institutions no longer fits either the empirical record or announced ambitions of significant polities across the globe. The advance of multilateral governance has been frozen in the WTO, and deadlock in the climate negotiations at Copenhagen (2009) forced the restructuring of the Paris agreements to surrender the pretense of compulsory regulation for what remain voluntary and unsanctioned pledges of actions yet to be delivered. Inside the multilateral climate regime there has been little effort to conform policy to the announced ideal of imposing carbon prices anywhere close to the analyzed value of marginal damage costs in any nation or group of cooperating states. Success in reducing emission levels has generally come through the imposition of regulatory mandates for renewable power generation, whether in North America, Europe or China, and this at quantities of carbon free electricity that that can be technically accommodated within the margins of the installed fossil driven power systems.

And yet, perhaps the greatest deception of the promise of the 1990s has been the depressing story of macroeconomic stagnation since at least 2004 in the advanced industrial economies and since 2010-11 in the major emerging markets. Productivity remains trapped on the plateau to which it descended in the 1970s as economists and investors wrestle with the specter of radical uncertainties about credible or bankable futures in which technology and institutions might escape what are increasingly characterized as
structural instead of cyclical problems. In this altered and darkened 2020 perspective, we might categorize the changed state of play in the world that 1990 ushered in through four transitions underway that define the salient questions and issues that do, and should, preoccupy the new topography of the sustainability field that public and private actors face today. They suggest alternative framings of the problems originally to be solved through the lenses and mechanisms conceived and crafted in the world of 1990.

In the world as viewed from 2020 the arrows of a shifted framing ought to account for both the gains and losses that separate and reorient 2020 from 1990, and at the same time redirect us toward the world of 2050, however indistinct its clarity and however indirect the logic of our getting there intact seems to be.

1. From micro → macroeconomics
2. From public → private (finance)
3. From projects → systems
4. From environment → growth.

While drawing out and working through the explanations and implications of these four emerging transitions is less meaningful as a task than as the program of thought, analysis and practice it is meant to get off the ground, let me provide some sign posts for each that may be useful for further development.

**From micro → macro**

The central issues that dominated the quarter century of climate debate and multilateral negotiation from Rio to Kyoto, Copenhagen and Paris debated how much more did it cost to produce food and fuel in Green than in Brown (or business as usual) ways. These incremental costs set the degree of difficulty associated with the leap into lower carbon, had been assigned by the Rio Agreements to be borne by the advanced industrial economies when incurred by other polities, and were the topic of unending analyses from cost curves through convergence forecasts. It is arguable that the willingness of nations to pledge substantial cuts in their emissions at Paris followed the empirical demonstration that the spreads between renewable and fossil energies, not long ago estimated in the $10-20 range per ton of carbon saved, had largely collapsed in wind and solar technologies—a rapid trip down steep learning curves incentivized by substantial subsidies and market segregating mandates (not carbon prices) enacted in a limited set of major industrial nations allowed significant economies of scale in production in equipment exporting states in Asia following the induced demand.

As the microeconomic gaps that populated the political discourse of burdens and transfers vanished in the poster child sector of electric power, other concerns vaulted into the fore. Some of these concerned the greater sensitivity of capital availability and cost, especially in emerging markets and developing countries, associated with adding new forms of energy that were much more capital intensive than were the more familiar fossil fuel facilities. In addition, from the recent transitions in telecommunication systems, it was apparent that licensing, siting, know how and other learning needed to traverse the last mile of operationalizing the new facilities would demand time and practice. It also soon became clear that the reduced incremental costs of low carbon generation technologies did little to induce behavioral changes that continued to frustrate the materialization of economic savings long postulated in many applications of energy efficiency. Nor would lower spreads in renewables drive fossil fuels out in space heating and industrial processes where increasing electrification might have limited reach. There were even faint warnings from those few jurisdictions where the penetration of zero
carbon power was deep that disruptions of system design and business practice might pose policy and scaling risks with uncertain cost consequences.

Still, on the whole, Paris signaled that the microeconomic hole at the heart of the first period of climate action was falling behind the curve. The bend in the road ahead reappeared as macroeconomic. As the capital surpluses, public and private, that characterize periods of strong economic growth evaporated around the years of financial turmoil and investor horizons shortened, from where would the vast increases in capital allocations to sustainable infrastructure, with its peculiar package of public and private risks, be coming under horizons of prolonged low growth?

**From public → private**

For nearly all of the 20th century, in nearly all countries, infrastructure design, finance and operation were the domain of government departments. Monopoly provision of energy, transport, water and sewer services by local or national state entities with public budgetary resources was explained both by the economics of declining costs and the public responsibility for economic growth, security, distributional fairness of tariffs, and, later, environmental goals that were infused into the administration of these activities. In the final decades of the last century this logic was amended by arguments for privatization of management and finance, with some competition in supply, following the recognition of systematic inadequacies in the performance of government agencies as infrastructure planners, funders and operators in the West and through greater autonomy of corporatization of state enterprises and banks in emerging Asia and Latin America. At the same time, the assignment of responsibility for infrastructure management and finance remained complex. Multi-objective regulation of privatized firms and the designation of SOEs as pillar industries in Asia continued to infuse public purpose into infrastructure services, and economic theory still suggested that the efficient investment should align with those interests who could best manage the particular risks that prevailed across the value chain of developing, operating, and exiting from these projects. And infrastructure risks, especially in policy intensive sectors like energy, remained often more political and regulatory than commercial.

After 1990, as many governments began to adopt austerity measures that constrained fiscal budgets or debt capacity that had been the source of public finance for large scale infrastructure programs, the turn to private capital markets to supplement public incentives or mandates became increasingly common in both advanced and emerging economies. The turn to off-(public) balance sheet investment through independent power plants and public-private partnerships in power, transport and water resulted in the proliferation of hybrid enterprises of all possible combinations of corporate structure, along with the usual introduction of financial engineering, multiplication of innovative financial products and the consequent demand for financial regulation by Central Banks or special purpose regulators that invariably go along with these institutional shifts.

The trend toward financial regulation for fiscal incentives as a favored tool of public action complemented the more far ranging turn toward the substitution of monetary for fiscal policy that became pervasive in the widespread turn to quantitative easing and stimulation initiatives as macroeconomic shocks set in after 2008. Central banks were demanded to move more deeply into the management of sectoral risks through macro-prudential supervision of not only systemic risks to the financial stability but risks of asset mispricing, fiduciary standards, or investor fraud in capital markets subject to risks associated
with sustainability or income distribution. As reduced growth levels held down fiscal capacity, dissatisfaction with the behavior of private investors driven further into liquidity by macroeconomic uncertainty about the long run performance of economies, central banks had to respond not simply to systemic risk and macroeconomic performance, but demands to compensate for sectoral economic performance normally managed through fiscal measures from policy through investment. In effect, the proper balance between public and private financing, as well as the governance mechanisms through which public interventions in sectors like infrastructure, was called into question, along with weighty arguments that the business models of private investors and governance mandates of central banks were wisely constrained by the more conventional models of asset valuation and institutional competence they routinely followed. In such circumstances, the primacy of growth policy and improved efficiency of the fiscal instruments it afforded were moving center stage by 2020.

**From projects → systems**

At the leading edges of the 2020 sustainability front, there were rumblings of disturbance as well as disruption around deepening penetration of sustainable infrastructure projects. Rising electricity costs in Germany— an acknowledged pioneer whose programmatic stimulation of renewable energy served as a global attractor for exporters of equipment in Asia through regulation that guaranteed suppliers constant price, long term feed-in tariffs (with enhanced credit terms through provincial Land banks) that exceeded the price spreads between wind or solar and fossil generation plants provoked political turmoil among power consumers and taxpayers bearing the increased costs. Over time, even as the formulas to set the incremental system charges that supported low carbon energies evolved toward more cost-effective standards, inadequate attention to matching new grid and storage capacity; expensive curtailment of renewable facilities, reliance on polluting coal facilities for reserve power for inter-day and seasonal network balancing; exemptions from system charges for firms in energy intensive, competitive industries and falling demand due to declining growth testified to the gap that could arise when power markets designed to manage efficiently the risks of the variable costs associated with fossil fuel prices and time on the grid were operating with large and fixed quantities of zero marginal cost electricity.

Reconfiguring energy systems around the different technological and economic context of renewable power suggested reform of policy designs that distinguished generation from reliability (flexibility) markets with different pricing, capacity and innovation incentives. At the same time, business organization that had long been associated with utility models discovered holes in their revenue flows arising from large scale installations of distributed generation by households and commercial firms, and confronted new demands for system integration and consumer interface services they were historically unequipped to deliver. The changes in risk patterns between fossil and renewable energy also suggested the introduction of new financing instruments and the recruitment of investor groups with risk profiles better fitted to the new generation and balancing services. In short, all of the system features adapted to a century of reliance on fossil energies were ill fitted to the efficient deployment and use of the emergent technology facilities that were being hammered into its margins, resulting in both reduction of productivity realized on the new frontier and increasing risks of loss of financial asset value on the old. The dynamics of transition suffered from the embedded political power of established energy providers strategizing how to minimize the extent of
asset stranding on their weakened balance sheets. In the frequent case where these financial risks fell on state enterprises, state banks, or state commitments to bail out failed infrastructure built under state regulation, significant impacts fell upon the sovereign risk of the very governments whose policy reform was supposed to be the motive force behind system change. By logic and early experience, similar expectations about the opportunities and challenges first experienced in the technical, policy, business and financial practices of energy sectors would soon reproduce the dynamics of systemic transitions in the mobility, agricultural and construction sectors at the core of sustainability ambitions.

From environment → growth

In 2020 the impacts of extended productivity stagnation were taking their toll. The supply of public revenues and risk capacity were severely stretched. Yet demand for these resources was everywhere politically mobilized. Public responsibilities to reduce income inequality, increase security, and support faster formation of human capital through health and education all claimed senior priority to the much discussed, but little funded public investment in depreciating infrastructure, whether or not sustainable. Sustainability-oriented strategies that originated under higher expected growth rates and depended on the availability of abundant capital for illiquid investment in new infrastructure at the expanding economic margins faced the reality that with slower expansion transition would more likely require the substitution of new for existing infrastructure – a process of overturning what were perceived usually as entitlements to embedded flows instead of more contestable choices at the growth frontier. Macro-risk pushed private investors into more frequent turnover of their portfolios to maximize their ability continually to readjust returns against an increasingly uncertain and volatile longer term. And, within these constraints, public finance officials in treasuries, central banks and development banks adhered more closely to their core mandates to return the economy to stable growth rates that would relieve the threat of deflation that cast shadows across their policy options.

In this context and consistent with these mandates, public investment in sustainable infrastructure of scarce monetary or risk budgets, or of the diminished stocks of political capital that economically stressed constituencies will support, will be ranked against competing allocations in good part on the credibility of its claims to lift productivity toward economic “normalcy”. Yet, in spite of widespread political bromides that pronounce infrastructure expansion as a primary remedy for most economic ills, the empirical record of infrastructure productivity is notably uneven and mixed. Over thousands of studies of roads, rail, power and other major infrastructure projects, across all stages of development and geographies, there are few generalized conclusions that hold up consistently about the relationship between infrastructure investment and economic output at the margin. While it is evident that economic growth demands the build out of domestic transport, power and port systems, there is little that can be credibly demonstrated about the impacts of specific levels of investment, complementarities between types of investment, or even the causal direction between expenditure on infrastructure and national or regional income. While there are good reasons to suspect that much discussed inefficiencies in the planning delivery and operation of infrastructure come from poor or corrupted governance in the public processes that reign in the major infrastructure sectors, scientific caution in the face of such scattered data might restrict accepted wisdom to the propositions that investments at scale in infrastructure necessarily have: (1) short run macroeconomic gains, (2) uncertain longer run macroeconomic effects that vary with infrastructure derived revenues (direct or wider social/economic
returns) and the dynamics of dealing with the increased debt with which infrastructure is generally funded, and (3) a seeming correlation between infrastructure productivity and increased distance between the initial state of the economy adding infrastructure and the production frontier it aims to reach.

If the productivity returns of infrastructure as a class are complex, the nexus between sustainable infrastructure and growth is at least as opaque. To the extent that we might hypothesize that sustainability in infrastructure is associated with a reduced resource intensity derived from efficiency gains won through digital technology and control systems, the immediate problem for meaningful productivity improvement is tied to the more general question of why recent GNP statistics, paradoxically, do not seem to reflect the gains that the increasing diffusion of these new technologies would suggest. This conundrum has been carefully analyzed and debated in numerous empirical papers trying to explain the plateau in productivity growth in advanced economies since 2004, and has emerged as a principal topic for theoretical clashes over the causes of prolonged stagnation in a period where technological innovation is endlessly cited as its solution. Economists of great quality and originality go back and forth about whether persistently low productivity growth results from various supply or demand factors, the end of a uniquely productive century (1870-1970) based on a particular set of innovations whose equal is not likely to be replicated, the rising cost of unit R&D that afflicts the new information technologies, measurement errors in the calculation of national income, or the nature and length of lags that have historically deferred the realization of productivity gains in practice until adapted behavior complementary to technical changes catch up with developments in science and engineering.

Final Thoughts

Although I have proposed one variant of a productivity lag hypothesis in this paper under the discussion of transition system dynamics, this is only one example of a wide portfolio of guesses and intuitions whose viability must be seriously and programmatically tested. The working through in practice of the open 2020 issues that have taken on increasing intellectual and political economic salience could confirm more credible prospects that would subsume the recognized problems of sustainability in a technologically and institutionally transformed system constituted around zero marginal cost, resource saving, energy, mobility and agricultural services. But this world in 2050 would still be struggling with re-conceptualizing the public and private management of pricing, investment incentives, taxing mechanisms, the proper measurement and equitable distribution of well-being, and the classical links between jobs, identity, and status. The hypothetical integration of structural economic transition and sustainability is not intended to erase the multiple questions of environmental quality or justice under a quest to of seeking satisfactory answers to all the foreseeable dilemmas that come along with growth enhancing technological innovation and the necessary adaptations that enable it. A far more capital intensive, zero marginal cost economy is rather a loadstone for sustainability than a unique solution thereto.

The passage from 2020 to 2050 requires functionally and politically independent campaigns to improve the delivery of public goods, including infrastructure, by rationalizing the structure and practice in multiple public channels (budgets, development banks, financial regulators, line ministries and sectoral agencies, special purpose guarantee and insurance vehicles, import-export and development assistance programs), and mechanisms (taxes, subsidies, regulatory mandates, credit enhancements, Pigouvian taxes) that now form
an misaligned portfolio of public finance. We would not escape the challenges of inquiring into particular explorations why selective targeting of investments and incentives to direct funds to them might be more efficiently administered in China through the Peoples (central) Bank than by the Ministry of Finance or local environmental regulators. And China is not Europe, America, or India. To reframe environment as growth does not relieve us of the obligation to work through the comprehensive 2020 agenda piece-by-piece, place-by-place.

In the end, the intuition that growth and sustainability ought be more explicitly and programmatically associated is neither more optimistic nor more pessimistic than the now familiar (1990) framings of climate risk and management it could amend. It suggests optimistically that with great skill and good fortune there is a possible pathway from 2020 to 2050 to a sustainability that would come wrapped up with the formidable problems that an imaginable, if not inevitable, future of technical and institutional change implies. It recognizes pessimistically that there are long odds, implicit in an underachieving environmental record in the thirty years from 1990 to 2020, against the chances the performance of the same governing institutions charged with climate responsibility will next time be different. To put more of our money on updated frames simply resonates better with the perception that we have rarely solved critical problems with the same concepts, terms and actors through which we have become aware of them. More often, we get ahead by displacing them and substituting new dilemmas in the space they had occupied.
APPENDIX

THE AFG NARRATIVE
The availability and efficiency of finance are key challenges in facilitating systemic transitions in the energy, transportation, and agricultural sectors that are critical to fostering sustained economic growth, social inclusion, and environmental protection. While the current focus of much analysis and experimentation has been on innovative instruments blending public and private finance, the real need is to verify which policies can actually enhance economic growth to generate sufficient investable funds to support the required structural transitions of energy and land use systems. New ways to frame the political strategies and public sector capacity to support the design and implementation of potential solutions to address these challenges are thus urgent.

In this context, a plausible growth theory worth exploring would combine (i) technology innovation, (ii) political dynamics of sectoral system transitions that diffuse and scale productivity gains across core sectors, and (iii) the quality of institutional delivery of public investment. Assessing how such a model could be applied and implemented in different geographies and stages of economic development would require (i) a connected network of local and regional actors with practical public finance responsibilities (which AFG works to convene), (ii) a common conceptual framework, and (iii) coordinated capacities to adapt credible methodologies to variable conditions. These are the objectives of the AFG.

2017-2018 AFG AGENDA
TOPICAL DESCRIPTIONS OF CHARTERED ANALYSES
The AFG operates through regular convenings, often coincident with semi-annual meetings of the World Bank & IMF, of public finance authorities who are, or have been, high-level officials of Treasuries, Central Banks, or multilateral or national Development Banks. The AFG prioritizes and explores the questions associated with the four emergent trends most salient in 2020 by chartering analysis by AFG partner organizations, independent researchers, or bespoke teams to draw together dedicated and leading competence in these areas. Exemplary work products underway in the 2017-2018 AFG work program include:

Sustainability Metrics. With the World Bank and the analytics group Climate Policy Initiative (CPI), the AFG is broadening and generalizing the stranded asset work to develop tools for financial institutions to evaluate the stability of national financial systems to the entire range of sustainability shocks. This work is meant to fill the gap in assessment of financial stability beyond purely economic shocks to evaluate how financial sectors, and the loans to these sectors, would perform when a previously unpriced risk or externality – such as toxic waste depleting arable land, regulation required to combat deteriorating health due to local air pollution, or commodity price changes due to global climate change efforts – is suddenly or gradually priced in through damage, commodity pricing, insurance costs, or regulatory costs. The project develops a methodology
to identify and value potential shocks and the cost of remediation, as well as how these costs would be allocated to segments such as taxpayers, investors, consumers, and lenders, as well as a scorecard for use by financial institutions in evaluating the robustness of loans with sustainability threats.

Project risk assessment; off-take risk. Beyond evaluating the potential financial downside risks of climate change and sustainability, AFG is assessing how finance can be targeted more effectively to develop clean energy systems. At a general level, CPI and AFG have developed a framework that looks at infrastructure projects, including clean energy infrastructure, to assess which of these risks are most effectively handled by private players and which by socialized/public players. This assessment is matched with various types of private/public and regulatory finance mechanisms and evaluates how additional financial support - such as loans, risk guarantees, investment vehicle development - or policy or regulation can optimize the finance of the projects. In this broader area of work, the Green Climate Fund has identified off-take risk for infrastructure projects in less developed nations to be one of the most difficult barriers to overcome. Within this mandate we are evaluating a number of programs, policy, finance and regulatory options to understand the lowest cost and most effective means of mitigating this risk under different conditions, including different state utility industry and competitive market structures, as well as independent producer options, and new options that are developing.

India electricity system flexibility. The AFG linked is working through the London based Energy Transition Commission on new financing and policy options to encourage clean energy development is in the study and development of pathways for integrating clean energy into national energy systems at a lowest cost. In India, evaluation is beginning of the flexibility and clean energy integration needs that the Indian system, and 3 typical state electricity systems in India will have in the medium to long term as they extend clean energy ambitions. The analysis compares the micro-economics and finance of technology options for the range of integration needs and assessing how investment and technology development can work together to ensure that the best, lowest cost, technology and market design options will be in place in time for increasing clean energy ambitions in the medium term future.

South African stranded assets. In South Africa, in partnership with the Agence Francoise de Developpement (AFD), AFG analytical partners are working to assess the impact that a global transition to would have on the financial stability of one specific country. This analysis begins with the impact that a lower carbon economy would have on the value of fossil fuel exports, including, in this case, coal exports. The evaluation then moves into evaluating the impact on domestic energy and infrastructure costs as South Africa responds to the loss of coal export volumes and revenues, which support port and rail businesses, among others, and is required to build infrastructure to meet its own low carbon transition targets, including clean energy, transport, and related infrastructure. The analysis focuses on the national level, but also on the impacts of the finances of state owned enterprises, such as the national utility and the national pipeline and port company, as well as commercial enterprises including miners and refiners, and regional governments. Methodologies applied to this work is derived from ongoing CPI-led studies on US utility transition finance, using financial innovation to further clean energy ambitions in developed countries. These
analyses support utilities, regulatory commissions and advocates to develop financial and regulatory systems that overcome barriers to phasing out of coal plants and replacing them with clean energy that is in many instances less expensive than the fuel and variable costs of coal plants. However, current financial obligations and commitments lead to negative impacts in the short term for utilities, ratepayers, workers, and sometimes municipalities when plants are closed and require financial and regulatory innovations and models that can spread the near term costs over longer periods, mitigating the impact on utilities and ratepayers, while creating enough additional value for transition assistance to workers and municipalities.

Risk weighted inclusive landscapes. International and national capital flows to low carbon energy have been developed since 2010 to inform multilateral negotiators and governments alike of implementation of climate commitments. The present value of these data is limited due to failure to account in normalized terms for the multiple channels and instruments through which public expenditures, regulatory mandates, risk guarantee/insurance mechanisms and taxes on high carbon energy consumption are allocated and delivered. Development of normalized valuations across these alternative measures, particularly if risk weighted, will improve the efficiency of public portfolios and alignment between the institutional channels through which public resources flow. Focus on Brazilian policies targeting conservation of ecosystem services in agricultural development, infrastructure and logistics investment, and concessional credit allocation.

Productivity of public investment in hydroelectric and renewable energy plants in Brazil. The National Development Bank of Brazil has made available data relating to investment in all hydroelectric dams in environmentally high value biomes and to its financing of renewable energy facilities. Econometric analysis of comparative growth impacts on municipalities of such subsidized capital allocations qualified as environmentally sound and financed with taxpayer funds. Impacts on labor (jobs) and human capital stocks will also be measured and evaluated. Partnership with the Faculty of Economics, Pontifical Catholic University of Rio de Janeiro.

Productivity and environmental impacts of green finance investment; Central bank macro-prudential regulation in China. New regulation and transfer policies in China have attracted 50 billion US$ in qualified Green bonds in 2016 and are on track for comparable sums in 2017. In collaboration with the World Bank-China and the Peoples Bank of China, AFG will develop analysis of compliance of investments of bond proceeds with the legal terms and intent of regulations, environmental impacts of projects financed, and economic risk/return outcomes projected and realized in these projects. In addition, outcomes will be examined and evaluated with reference to the assignment of governmental jurisdiction through which public resources are implemented through the Central Bank, a monetary institution customarily responsible for monetary policy. Productivity results may also be applied to developing a portfolio strategy for a fund developed around a consortium of public and private investors.

**NOTE: PROGRAM SKETCH FOR STANFORD UNIVERSITY**

In addition to the world-renowned strength of Stanford in a wide range of fields in sustainability and climate science and engineering, the mobilization of Stanford’s leading expertise and institutional capacities particularly relevant to the AFG research agenda would fit particularly well with its several subjects not usually associated with climate and sustainability knowledge. In the terms of an AFG framing of climate-central
issues, Stanford collects globally recognized faculty, programs, and student quality at the undergraduate and graduate levels in macroeconomics, the new digital technologies and their socio-economic implications, and multiple dimensions of Asian social and cultural Studies. In addition to faculty specializations and high quality student abilities and focus in these core AFG areas, Stanford already has marshaled extra university networks and facilities around which new sustainability and climate dimensions and modules could be implemented. The most evident of these are the intricate and pervasive networks through which Stanford is uniquely woven into the fabric of Silicon Valley and its worldwide outreach. But there are also less visible, but still deep and effective ties to emerging Asia, some of long-standing like the academic connections to Tsinghua University and the India Institutes of Management and Technology, some more recent like the Asia-Pacific Research Center or the Stanford facilities inside the cultural heart of Peking (Beida) University. There may well be extraordinary options to build AFG related ties into incipient Presidential Initiatives such as innovative and problem-oriented public policy curricula with applied practice components in contemporary public policy.

A Stanford program that was in good part conceived and organized in climate finance and policy as re-framed through an AFG agenda could be structured around four elements that encompassed a wider, innovative domain of external, faculty, graduate and professional school, and undergraduate curricular activities. In brief outline, these dimensions might compose:

1. Direct association with the sponsorship and governance of the continuing work of the AFG itself, both as a meeting site and a location where AFG high level participants or their delegates might spend periods of time in their careers with fellowship status that would allow them more prolonged opportunities to reflect on and advance the issues at the core of AFG consideration and practical application. Stanford’s association would capacity, insight and stability to the commitments of those institutions already engaged with the expanding AFG including the World Bank, the Bank of International Settlements, and leading development banks like Agence Francaise de Development. Stanford activities would also benefit to the extent there were interest in any potential Bank of America role in AFG program development.

2. The type of in-depth, time-constrained and nationally or regionally applied analysis characteristic of AFG chartered analysis most usually demands concentrated efforts of geographically specific work that is poorly adapted to the constrained capacities of leading university faculty. However, the production of such work products by dedicated analytical organizations, whether of global scope, local specialization, or tailored partnerships between groups, would in many cases be enhanced by advisory or other limited participation in the design, execution and review of such programs and products by Stanford faculty. Especially in newer fields of sustainability and climate analysis stressed in the AFG agenda, the value of adding Stanford economics and business faculty like Nick Bloom, John Taylor or Susan Athey (productivity analysis, macroeconomics, price theory); John Ferejohn, Francis Fukuyama, or Jeremy Weinstein (institutional behavior); or association with Jean Oi, Andrew Walder, Arun Majundar (Chinese or Indian industrial and policy development) would be practical and outstanding. Of course, where longer-term faculty agendas or sabbatical/leave arrangements allowed more sustained integration into AFG framed work, deeper links still would be favored. It would be equally wise to add Silicon Valley or international expertise and experience that are frequently connected to Stanford networks (Hal Varian Google; Qian Yingye Chinese macroeconomics) to a program roster.
3. Graduate and professional students with extended research time built into their academic training would present natural objects of attraction for an AFG agenda related engagement with a new Stanford program. Theses opportunities of high theoretical and practical value could be organized around AFG chartered analyses, both in specialized data work and on site work with AFG partnership organizations operating in Asia and other sites where applied work demands local knowledge and presence. Such engagements as have been specially developed with local institutions, such as that between the AFG partner Climate Policy Initiative, the Catholic University of Rio de Janeiro economics faculty and the Central Bank of Brazil have demonstrated the value of providing doctoral students with opportunities to do extended applied empirical work, both for student learning and the quality of the resulting work products.

4. A clinic and associated seminar for Stanford undergraduate and professional school students, which offers intellectual background and work opportunities on aspects of US and California salient applications of AFG related problems and issues. Such a clinic could be offered independently, as a dedicated module in proposed new curricular approach to public policy fields, or as a concentration in an existing program or amalgamated offering under the Woods Institute, Earth Studies, or the Freeman Spogli Institute for International Studies.

a. PhD time in location
b. California clinic for undergrads and professionals