IMF RESEARCH perspectives

Volume 20, Number 1 Spring/Summer 2019

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NOTE FROM THE GUEST EDITOR

In the Spring/Summer 2019 issue, we explore how old questions are tackled with new technology. In recent years we have witnessed unprecedented technological progress—such as digitalization, automation, machine learning, and big data—and its applications for everyday life. At the same time, we are seeing a remarkable slowdown in global economic activity after a few years of steady upswing. Policy and political uncertainties in many parts of the world remain high, while challenges such as climate change loom over the longer horizon. The time is right for policymakers to work cooperatively both nationally and internationally to help ward off downside risks and ensure effective policy support.

How will policymakers tackle reemerging yet long-standing economic issues, such as productivity, market failure, and resource allocation? What insights do new data and methodologies offer? The articles in this issue discuss the many ways technological progress and increased data availability have helped, as well as remaining challenges to making the best use of new technologies for analysis and judgment. In this way, policy can be evidence-based, proactively address risks and vulnerabilities, and lead to sustainable growth. ***~Yuko Hashimoto***

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IMF Research Perspectives—the IMF online bulletin with news on research is a bi-annual publication in English and is available exclusively online free of charge.

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INTERVIEW WITH

GITA GOPINATH

New Director of the Research Department

Gita Gopinath joined us as our new chief economist and Research Department director in January 2019. She made her successful debut with the *World Economic Outlook Update* at the World Economic Forum in January. Heightened economic and financial risks and political uncertainty around the globe signaled the onset of a difficult time. Her eminent achievement in academia is already known.

Yuko Hashimoto interviews Gita on a personal note. In their conversation, Gita shared childhood memories, turning points in her economics career, and her passion for her work.

YUKO: Thank you very much for your time today. You mentioned in the recent Communications Department interview that you studied pure science in high school. Exactly which area did you study?

GITA: I studied physics, chemistry, math, and biology. I took economics in college because my parents wanted me to join the Indian administrative service, and someone told them that economics was a good subject for this purpose. I signed on to a three-year college in economics without knowing the first thing about it. So basically, I committed to a subject that I had no idea about. In hindsight that was a very risky move, but thankfully it turned out fine.

Y: Chemistry, physics, biology—everything is related to mathematics, which is fundamental for studying economics.

G: Yes. Thankfully I liked math the most. That was helpful. I liked how economics uses math to tackle social questions.

Y: Are those areas related to your dream job when you were young?

G: I don't think I had a dream job. It was basically the flavor of the month. For some time, it was joining the Indian administrative service. A few years before that there was this extremely successful female runner in India, and my father was, like, "Oh maybe you could be an athlete." I did then run competitively for a couple of years. Basically, I was not one of those who knew early on what I wanted to become. What was always true was that I wanted to do something exciting and important, even if it wasn't clear to me what it would be.

Y: Were you an energetic girl or you were more of an observer?

G: I was certainly more reserved. My sister was much more social. I was not very social; I was reserved. I grew up in a small town, Mysore. And I had a few very good friends, and we wasted a lot of time together. I have to say that I like small towns because people there tend to be more simple and less complicated.

Y: Then you perhaps enjoyed gardens or flowers outside, and a dog also?

G: Well, gardens and flowers not; I'm not an outdoor person at all. I have spent more time outdoors after I moved to DC than maybe the last 10 years of my life because my apartment here is close to the Fund, and I walk about 30 minutes to get to and from work! My indoor entertainment was Bollywood movies. We also had a small dog.

Y: Did your parents encourage you to read newspaper articles, and some specific readings?

G: Yes. My father tried to make us all very literate. He bought the old Britannica series, and we spent hours going through them. In terms of newspapers there were the local newspapers like the *Hindu,* the *Times of India*. I can't say I was a voracious reader back then. I took to reading more these last few years. At that time, I was primarily into my academic studies and a few very close friends.

Y: I know it sounds like a quite intriguing and very intellectual girl you were.

G: Intriguing…I don't know. I was certainly thought of as "different" because I fought for equal rights for girls and defied expectations of what girls were expected to do. I refused to accept anybody telling me that, as a girl, you cannot do this, you cannot do that. I was very strong-willed about it.

Y: You had your own views. That's pretty nice. You started studying economics when there was an IMF program to India. What were your experiences then?

G: The external account crisis of India in 1990–91 was what got me most interested in economics. I think the reason I ended up doing international economics was because of this crisis that I experienced as a college student. That was a time when we were having all these debates about the Indian economy: which policies should be put in place, etc.

"…I worked as a research assistant for Ken Rogoff and Maury Obstfeld writing solutions for their textbook—two predecessors of my current job!"

For India, the 1990s was a transformative decade that cut tariffs, delicensed many industries, and cut regulatory red tape and stimulated private enterprise. I believe these reforms changed India's growth trajectory in a very important way.

Y: And you continued economics. And then how did it go?

G: I came to the US to do my PhD at the University of Washington in Seattle. One of my professors, Richard Startz, strongly encouraged me to transfer to one of the top five PhD programs, which is how I ended up doing my PhD from Princeton. Startz played a pivotal role in my life, and I am grateful to him. My advisors at Princeton—Ken Rogoff, Ben Bernanke, Pierre-Olivier Gourinchas—were all hugely supportive. My first summer at Princeton I worked as a research assistant for Ken Rogoff and Maury Obstfeld writing solutions for their textbook—two predecessors of my current job! Given all the hurdles women face in economics I was lucky that I had three advisors who were very encouraging and supportive.

Y: And now you've moved to Washington, DC, to work for a totally different system from academia. How do you balance work and your own time?

G: I confess my "own time" seems almost nonexistent, but I will not complain as I am thoroughly enjoying what I do. I do like watching TV shows—like right now I am watching *True Detective* on HBO.

Y: Especially in academia, thinking about research and papers, it's just an ongoing process—weekday, weekend...

G: Exactly. Research is always on your mind, though I think I have gotten slightly better at compartmentalizing things. At Harvard I used to spend long hours working, but they tended to be mainly quiet hours. Here I spend a lot more time meeting people, talking to people, communicating through many platforms. That's one of the main differences. I have to say that one of the most important events in my life was meeting my wonderful husband, because of whose support and advice I am where I am. I think it's as simple as that. And I have a son who is 16 years old. He's quite independent and a lot of fun to talk to and spar with. I also have a little dog, a Maltese named Oreo, who is adorable.

Y: How do you see our research feeding into the operational work of the Fund?

G: The work the research department does is central to the operational work of the Fund. Our research department flagships—the *World Economic Outlook* and the *External Sector Report*, the modeling work, multilateral surveillance, our many publications—all directly feed into the operational work of other departments. There's a lot of important research work being done on market power, international trade and exchange rates, the integrated policy framework, and structural reforms and many more topics that form the basis for policy advice to our members.

Y: Thank you very much for your time.

G: Thank you for doing this.

Technological Change and the Future of Work

The Impact on Africa and the G20

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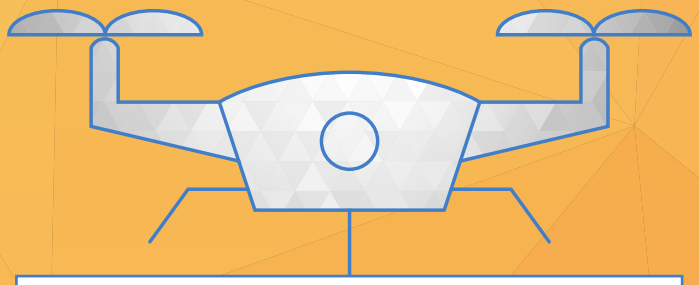


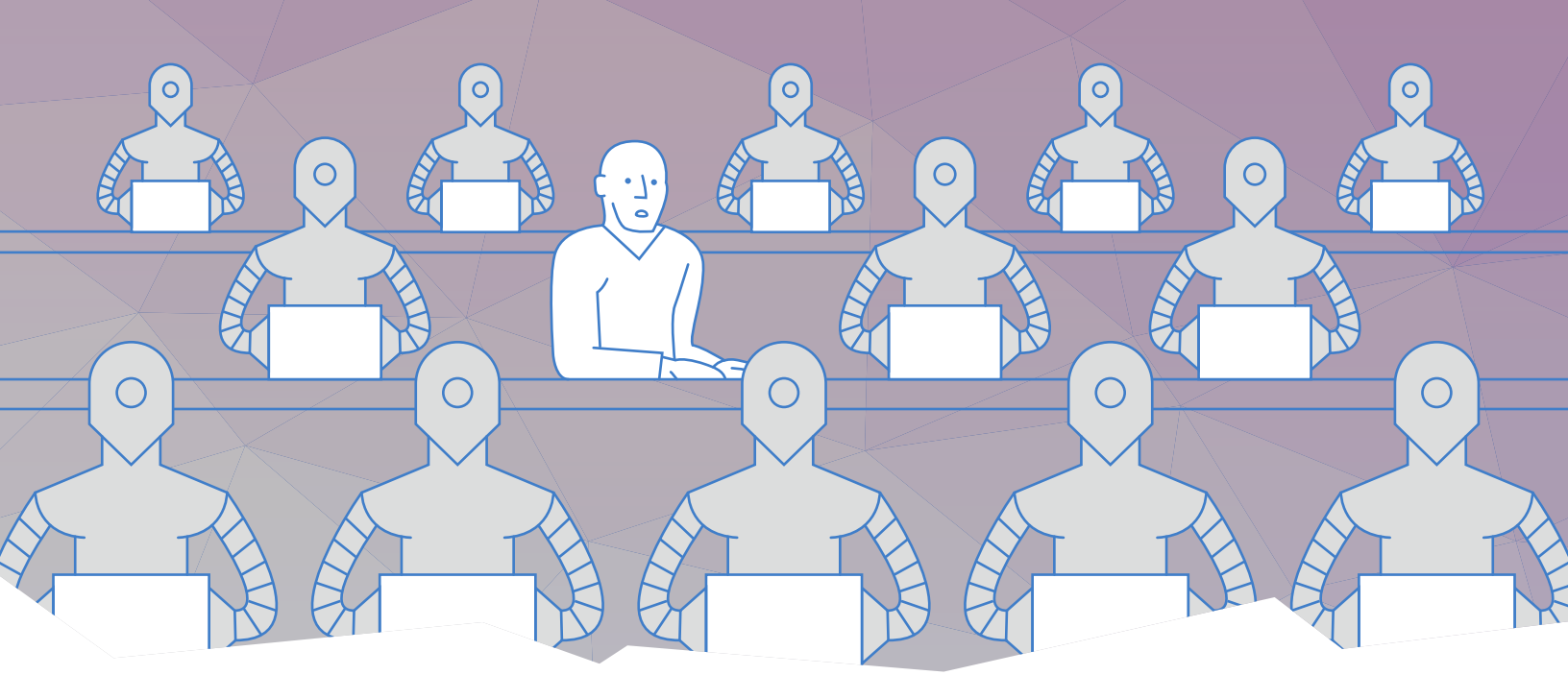
Robotics, automation, and artificial intelligence are transforming the production structure of countries and regions. This is not the first time such profound transformation has happened. At the turn of the 20th century, the industrial revolution moved 25 percent of the labor force from agriculture to manufacturing and related sectors over four decades. The adjustment was long (and painful). Protests involved displaced workers attacking factories and destroying machinery. The 20th century also witnessed political revolutions and two world wars until the stabilizing influence of modern welfare states and international cooperation emerged.

Will continued technological change benefit all? Or will it lead to even more polarization? The IMF has conducted research on these questions to distill policy advice for its membership: What policies are needed today to prepare for tomorrow?

Different Opportunities and Challenges for Different Country Groups

In G20 economies, automation provides opportunities to address the economic implications of demographic changes, but it also leads to job losses in some sectors and increasing income inequality. Countries with declining populations face the challenge of providing for a growing number of retirees with fewer people working. Here, replacing a shrinking labor force with robots can be a welcome opportunity to maintain living standards, as shown for Japan in Schneider, Hong, and Le (2018). However, in other G20 economies, the immediate challenge is to tackle the implications of job displacements and income polarization. The threat of new technologies replacing jobs across the skill spectrum is the key issue.

For sub-Saharan Africa, the challenges are different. The region's population is projected to increase from 1 billion in 2018 to 1.7 billion in 2040. To keep up, sub-Saharan Africa needs to create 20 million jobs a year over the next two decades. Some fear that automation could make this more difficult, though low labor costs may provide some protection. Alternatively, technological advances can provide opportunities for leapfrogging and can spur development. Indeed, we see many examples of this in sub-Saharan Africa today, including the rapid spread of mobile money, which originated in East Africa, the adaptation of ride sharing to motorbikes (for example "boda-bodas" in Uganda), and the delivery of blood to remote health facilities by drones.



Modeling Provides a Framework for Thinking about the Implications of Automation

IMF (2018) and Peralta-Alva and Roitman (2018) study the impact of automation on growth and income distribution in G20 economies. They turn to closed-economy models, with rich sectoral interlinkages capable of matching macro and household-level data. Their simulations suggest that for G20 economies the more easily capital substitutes for labor, the higher productivity and economic growth. At the same time, this leads to increased inequality by favoring income from capital and higher-skill work. Simulations suggest redistribution comes at the cost of efficiency, but with the right policy design, all income groups can gain.

Abdychev and others (2018) adapt the basic modeling approach in Berg, Buffie, and Zanna (2018) to a two-region setting. The two regions—think advanced economies and sub-Saharan Africa—differ only in their level of productivity. Labor and robots can either be substitutes or complements. If they are substitutes, an increase in robot productivity leads to a divergence in per capita GDP in favor of advanced economies—where it is more profitable to invest in robots because wages are relatively high. The labor share declines in both regions. However, if labor and robots are complementary, greater robot productivity helps sub-Saharan Africa—where it is more profitable to invest in robots combined with relatively cheap labor—progress toward convergence of per capita GDP with advanced economies. The labor share increases in both regions.

Scenario Analysis to Think about Fundamental Uncertainties

It is difficult to predict the relationship between robots and labor. Where will robots substitute for people and where will we continue to need people in jobs that currently exist or have yet to be created? Given this fundamental uncertainty, Abdychev and others (2018) turn to scenario analysis to explore what the future of work in sub-Saharan Africa might look like. They sketch three scenarios.

In the Africa Arisen scenario, technology increases productivity, and economies around the world remain integrated. These opportunities are successfully leveraged by sub-Saharan Africa, creating an emerging vibrant middle class. However, in a gig economy, frequent job transitions and income fluctuations are the norm.

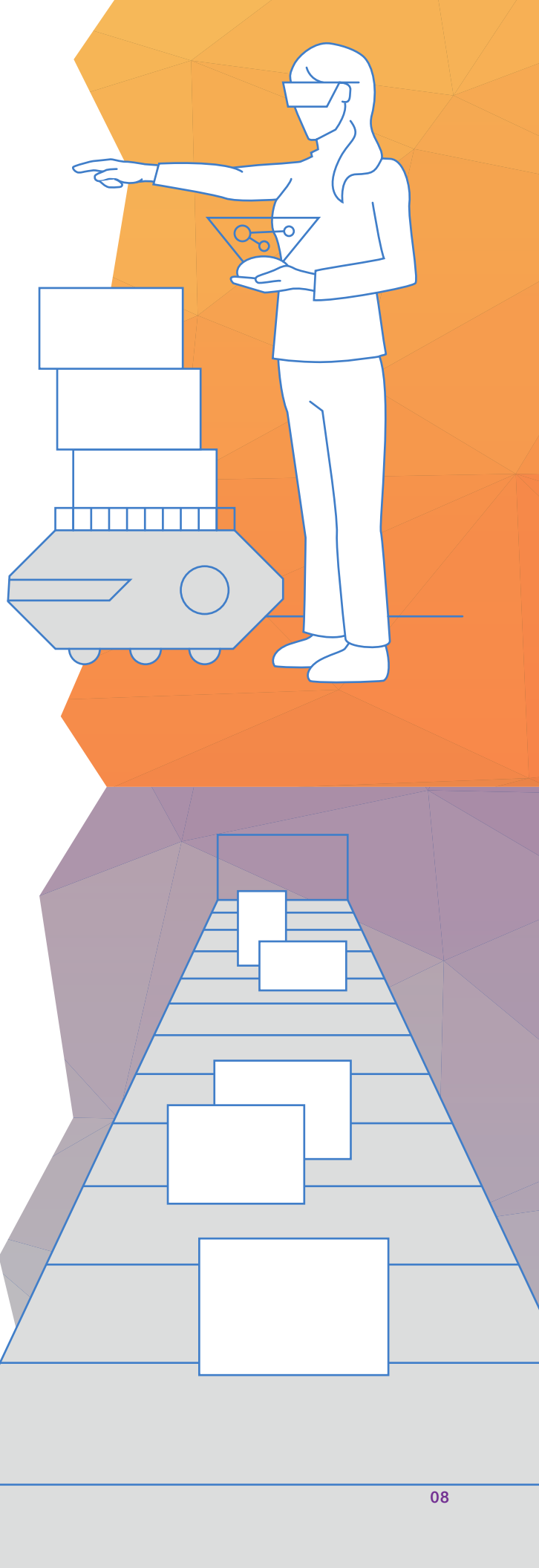
In the Africa for Africa scenario, advanced economies turn to protectionist policies demanded by technology-displaced workers. Sub-Saharan Africa charts its own course toward regional integration, which spurs growth. Low labor costs mean that automation proceeds much more slowly in sub-Saharan Africa than in the rest of the world. With limited tax revenue, governments struggle to keep up with education, health, and infrastructure needs.

In the Africa Adrift scenario, rapid automation leads to reshoring of manufacturing to advanced economies. In sub-Saharan Africa, development policies are thwarted by these global developments, leaving most economies stagnant and in debt. Informal jobs in subsistence agriculture and low-productivity services remain dominant.

Today's Policies for Tomorrow's Jobs

The future of work has already begun, but its direction can still be influenced by policy actions. Modeling and scenario exercises point to a few areas.

- Workers in countries at every development stage may face increasing job transitions and resulting income fluctuations. Hence, *social safety nets* will become even more important to help workers manage such transitions.
- Advanced economies could use the *tax-benefit system* to spread the gains from technogical advances.
- *Education* systems must be flexible to keep up with the changing nature of technology and teach digital literacy and skills that complement technology.
- Digital *infrastructure* is as important as physical infrastructure for job creation and development.
- In the case of sub-Saharan Africa, *smart urbanization* is needed to make cities drivers of innovation and growth.



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Is Misallocation Really MISMEASUREMENT?

When Models Meet the Micro Data

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Resource misallocation—which occurs when economic resources are not put to their best use—can arise for many reasons, including market failures (e.g. monopolies curtailing production) or policy failures (e.g. India's complex licensing system, China's support of state-owned enterprises, France's strict labor regulations).[1] Structural reforms are often motivated by the hope that shifting capital and labor to "better use" in more productive firms will give a large boost to aggregate productivity and GDP.

[1] Misallocation is generally an unintended consequence of these policies.

But how large are the gains from reducing misallocation? Put another way, is misallocation as bad as we instinctively think it is? The increasing availability of micro data, at the firm level, alongside advances in computing power, allow for new approaches to answer this decades-old question. In a seminal paper, Chang-Tai Hsieh and Peter Klenow argue that the dispersion of revenue productivity across firms (sales per unit of capital and labor) points to very costly misallocation in India and China. Consider a simple example: firm A has 10 workers and makes $500,000 a year ($50,000 a worker), while firm B has 50 workers and makes $1 million a year ($20,000 a worker). If one worker from firm B moves to firm A, the total number of workers stays constant but total revenue increases by $30,000: less worker misallocation and greater aggregate productivity! Based on this novel "dispersion approach" Hsieh and Klenow found that misallocation could explain roughly half the aggregate productivity gap between India and China and the United States. This approach to measuring misallocation has been highly influential.[2]

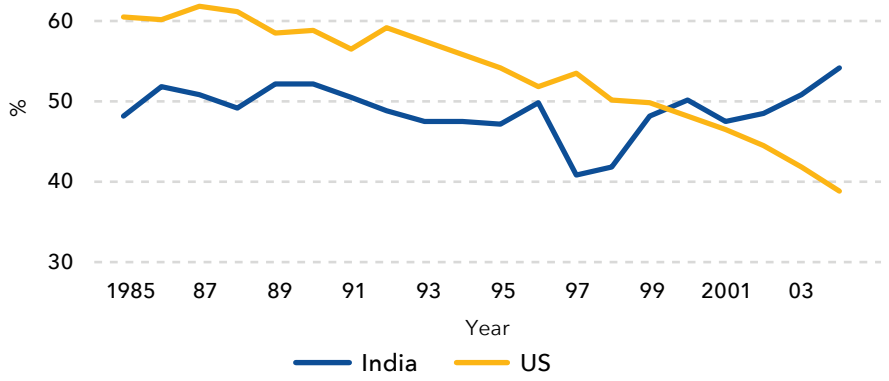
However, a recent paper by Mark Bils, Peter Klenow, and IMF economist Cian Ruane documents a dramatic rise in revenue productivity dispersion in the United States since the 1970s, so large that misallocation in the 2000s appears worse in the United States than in India (Figure 1). Could market distortions really have increased so much in the United States? The authors suggest a different explanation: the standard approach to measuring misallocation is inflated due to measurement error in survey data. This measurement error could have many causes: managers may not want to disclose information about their firm, surveys may not be completed by those with the most information, data may be imputed, and certain inputs in production are inherently difficult to measure. The authors find that "true" misallocation is not nearly as bad in India and the United States as it appears based on the data. In addition, misallocation in the United States has not grown as much as it seemed at first.

Measurement problems have always been ubiquitous in survey data, with low response rates and poor data quality causing problems for statisticians and researchers. But survey data quality might in fact be deteriorating over time. An article in the *Economist*, summarizing recent research, documented declining survey response rates in Canada, the United Kingdom, and the United States over time. These surveys inform policy questions regarding labor force participation, unemployment, inequality, misallocation, and the like, which means that this is an area of concern for all policy-oriented macroeconomists.

Another IMF economist working on measurement error is Ippei Shibata, who in a recent IMF working paper finds that misreporting in household surveys affects our measures of aggregate unemployment. "Evidence suggests that households misreport their employment status. Once we correct for such measurement error, the US unemployment rate could be close to a percentage point higher on average," says Shibata. But there is hope: "Fortunately, we can correct for misreporting in household surveys around the world provided that households report their employment status for at least three consecutive months."

There is no silver bullet for the problem of measurement error in survey data. But misallocation will continue to be relevant as policymakers struggle to make the most of their countries' resources. There has been good progress in the measurement of misallocation, thanks to the increasing availability of micro data, but there is a long road ahead when it comes to disentangling the sources of misallocation and its policy implications. Studying the impact of structural reforms and other policy "experiments" will be useful to gauge whether there are big gains from reducing misallocation.

Figure 1. Uncorrected Allocative Efficiency in US and Indian Manufacturing
(100 percent = no misallocation)



Source: Bils, Klenow, and Ruane (2018)

[2] The original academic paper gathered over 3,000 citations over the past 10 years (according to Google Scholar), and this approach to measuring misallocation was the focus of a chapter in the 2017 IMF *Fiscal Monitor.*

THE POWER OF TEXT

Measuring Sentiment in Financial Markets

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How do investors react to news? It's no surprise that this question has been at the core of the financial research agenda for several decades. But two forces have made this question even more pressing. On the one hand, innovations in information technologies have dramatically increased the reach of financial and economic news and the speed at which it travels. Real-time news wires, such as Reuters and Bloomberg, generate and diffuse information almost instantaneously and to an ever-increasing set of market participants. On the other hand, a growing number of countries, especially those whose markets are emerging, have opened their financial markets to the rest of the world. Among other things, this means that foreign news can affect local market conditions much more directly than in the past.

For a long time, however, studying the impact of news on investors' behavior and asset prices remained a daunting task. What is news exactly? What does it talk about? And how can we identify, in a systematic way, good (or bad) news? Fortunately, the past decade ushered in major advances in natural language processing, a field that mines and analyzes large amounts of textual information to extract its key features, such as topic and tone.

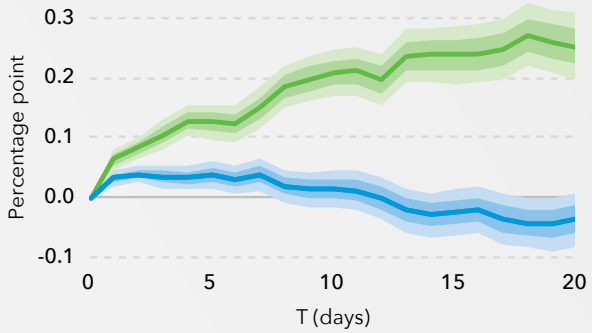
Since then, successful examples of text mining in economics and finance—using both traditional news sources and social media content—have flourished. Building on the most recent technologies, an IMF research project assessed the role of news in international asset prices using more than 4 million articles published by Reuters across the globe between 1991 and 2015. Using text-mining techniques to capture the tonality of news content, the project first constructed a daily "news-based" sentiment index for both advanced and emerging markets. Then it asked whether optimism (or pessimism) in the news today could help predict changes in asset prices.

The study first shows that sudden changes in news sentiment had a significant impact on asset prices around the world, confirming that media tone, in general, is a very good proxy for investor sentiment. It also highlights the role of foreign news (and foreign investors) rather than local news (and local investors) in driving local asset prices. Although sudden optimism in global news sentiment generates a strong and permanent impact on asset prices around the world, the effect of optimism in local news was more muted and only temporary (See Figure 1).

From a technical perspective, the study offers another example of the power of text as an input for cutting-edge economic and financial research.

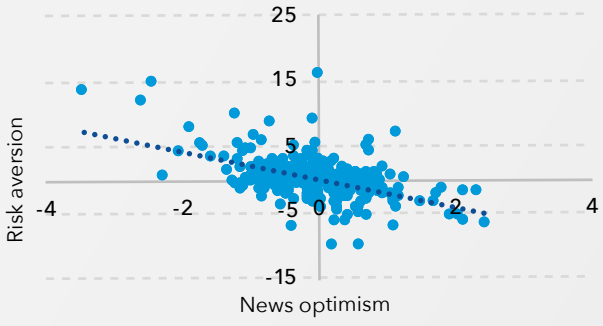
Importantly, the study also illustrates how new technologies—such as big data and text mining—can help institutions in their daily work. For instance, the mood captured in the news published around the world every day—the so-called global news sentiment index—mirrors other popular measures of global risk aversion, such as the Chicago Board Options Exchange Volatility Index (VIX; Figure 2). However, the news-based index is ultimately a better predictor of future movements in international asset prices than the VIX. "We are still in the process of understanding why news sentiment matters so much, and why it seems to capture much more information about investors' mood than other market-based indicators that are widely used. But the project already shows that monitoring news tone in real time is a very effective way to capture sudden changes in investor sentiment that would not be captured otherwise; which is key for financial surveillance" says Samuel Fraiberger, one of the coauthors of the study.

Figure 1. Media Tone and Asset Prices



Source: Fraiberger, S.P., D.Lee, D. Puy and R. Ranciere, 2018. "Media Sentiment and International Asset Prices," IMF Working Paper 18/274.
Note: The figure plots the response of equity prices around the world to optimism in global news (green) and local news (blue).

Figure 2. Global Risk Aversion (VIX) versus Media Sentiment



Source: Fraiberger, S.P., D.Lee, D. Puy and R. Ranciere, 2018. "Media Sentiment and International Asset Prices," IMF Working Paper 18/274.
Note: VIX = Chicago Board Options Exchange Volatility Index.

OUR COMMON ENERGY FUTURE

What Do 167 Years of Data Say?

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The consumption of energy services—heating, lighting, transportation, and the like—is essential to the functioning of modern economies. At the same time, since most energy for these services is supplied by fossil fuels, our high energy dependence triggers a multitude of environmental externalities, with climate change being the "greatest and widest-ranging market failure the world has ever seen" (Stern 2006, i). To curb carbon emissions, the world must reduce its consumption of fossil fuels. This could in principle result from an early *saturation* of total global energy consumption and/or acceleration of the ongoing energy *transition* toward low-carbon energy sources, such as nuclear, wind, and solar.

Energy Saturation

Recent work at the IMF analyzes the relationship between energy consumption and income per capita across countries and time. Our panel data analysis of more than 100 countries between 1850 and 2017 strongly supports the presence of an S-shaped relationship between (per capita) energy consumption and (per capita) income at the country level (Figure 1), with the income elasticity of energy consumption following an inverted U-shape pattern.[1] For the average country, the estimated level of income per capita at which energy consumption is expected to saturate is about $144,000 (2011 US dollars)—still far into the future. An economy with a $45,000 per capita income today (for example, Germany) growing at 2 percent a year would take almost 60 years to reach this income level.

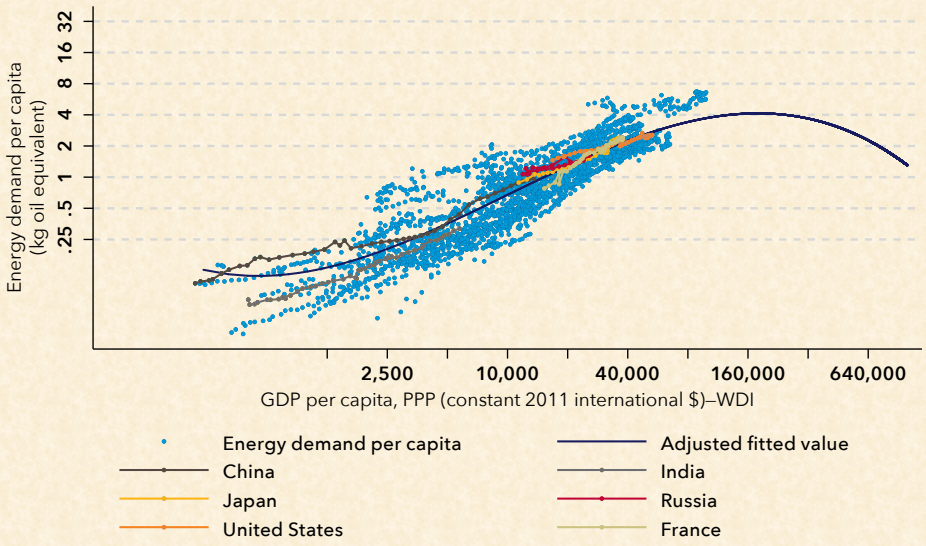
Energy-saving technologies, however, can push the energy saturation point forward by shifting the energy-income curve down, since provision of the same energy services requires less energy over time. Our findings show that, on average, energy efficiency improved approximately 1 percent between 1971 and 2015 (Figure 2). If we assume that global energy efficiency continues to decrease at its recent historical rate, we estimate, albeit with a substantial degree of uncertainty, that the saturation point will decline to about $87,000—already reached or close to being reached for some advanced economies. Currently, for example, it would take Germany only 33 years to get there.

The future of global energy consumption, then, depends largely on how low-income and middle-income countries will shape their energy systems. As of 2015, only 18 percent of the world's population had attained per capita energy consumption of 120 gigajoules a year—the bare minimum for a human development index score of 0.9, commensurate with the average Organisation for Economic Co-operation and Development economy (see Smil 2017, 416–17).

So global energy consumption driven by emerging markets is unlikely to saturate soon. Even in China, where energy consumption has grown more rapidly than it has anywhere else since the turn of the century—causing a boom in global commodity prices during the 2000s and a sharp and troublesome rise in domestic air pollution—energy consumption,

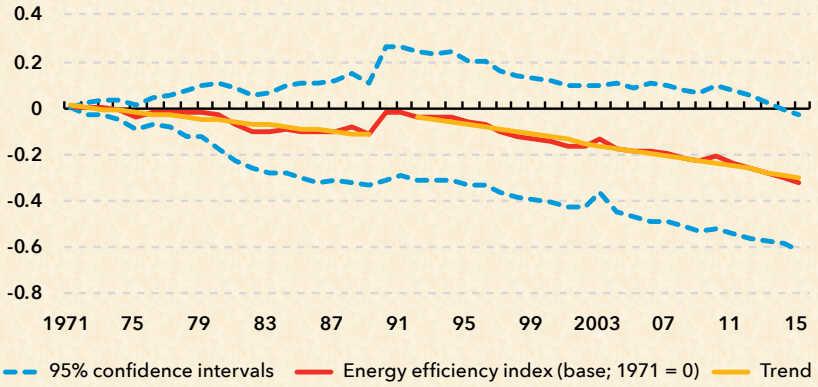
[1] A full analysis spanning the period 1850–2017 will appear in a forthcoming IMF working paper.

Figure 1. Energy per Capita versus Income per Capita



Sources: International Energy Agency; World Bank, World Development Indicators Database (WDI); and IMF staff calculations.
Note: PPP = purchasing power parity; WDI = World Development Indicators.
Note: Adjusted fitted values show the S-shaped energy-income relationship (constructed using the cubic polynomial), while energy demand per capita is adjusted for the estimated time fixed effects. Estimates are from the baseline specification.

Figure 2. Energy Efficiency, 1971–2015



Sources: International Energy Agency; World Bank, World Development Indicators Database; and IMF staff calculations.
Note: The red line represents the time fixed effects from the baseline specification with 95 percent confidence intervals (dashed lines). The yellow line is a linear trend estimated for the period 1971–1989 (1992–2015) with a slope of –0.07 (–0.11).

according to the World Bank World Development Indicators, is currently only 93 gigajoules per capita.

Thanks to continued efficiency gains, developing economies may leapfrog and saturate at lower income levels, which would help bring down the expected path of global greenhouse gas emissions. This scenario is uncertain, however, for several reasons. First, van Benthem (2015) finds little evidence of energy leapfrogging in the recent past: developing economies in 2006 grew at equal energy intensity as industrialized countries in 1960. This finding may in part reflect "rebound effects" (see Jevons 1865) through which some direct gains from higher efficiency are undone by increased energy consumption as a result of lower prices for energy services.[2] Earlier survey studies by Greening, Greene, and Difiglio (2000) and Sorrel (2009) are more skeptical, however, and find only small to moderate rebound effects.

Second, the falling income elasticity of energy consumption may depend on several other trends related to high income levels. These include outsourcing of energy-intensive production to developing economies, urbanization and structural change toward a service economy, electrification, and weaker aggregate consumption as a result of higher inequality. Some of these trends may be impossible to replicate or sustain at the global level (for example, someone must produce steel and mine cobalt).

[2] The discrepancy between our results and those of van Benthem (2015) can be explained by noting that he focuses on efficiency of end-use technologies, whereas our analysis also captures gains in fuel conversion efficiencies.

Energy Transition

The future energy saturation path of fast-growing emerging markets is paved with uncertainty, but there is hope. Changes in the global energy mix could increase the chance of timely mitigation of climate change. However, current mitigation pledges in nationally determined contributions—which are voluntary—even if fully implemented, would be consistent with a 3°C warming target, relative to preindustrial levels, rather than the 1.5–2°C target of the Paris Agreement. A quicker transition to a less-carbon-intensive energy mix is thus needed.

Policymakers are hoping that green investment will accelerate and will pick up the slack. Over the past few years, renewable energy has captured more than two-thirds of global investment in new generation capacity. This rapid growth came in part from the fact that, aided by regulatory pressure, technological innovations and learning by doing have substantially reduced the cost of wind and solar energy—once considered uneconomical. Further cost reductions are needed and appear feasible, at least for now. Take solar energy: for more than two decades the economics of solar have followed a predictable pattern—or learning curve— and costs have fallen 20 percent every time cumulative production has doubled. To ensure that positive learning externalities are fully internalized, government support remains imperative. Furthermore, eliminating fuel subsidies and increasing carbon taxes could substantially speed the transition by raising energy prices to reflect their true social costs.

Policymakers must also consider the temporary drawbacks to a successful transition. For example, some coal assets, such as coal-fired power plants, could become obsolete, and high-cost oil reserves could become unrecoverable (especially with acceleration of electric vehicle adoption). Or the transition may negatively affect pension funds whose balance sheets are highly exposed to these assets. To address the risks of stranded assets, countries and actors with high exposure to fossil fuel industries should seek diversification and stimulate the development of carbon capture technology.

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NEXT EDITION: DECEMBER 2019