Measuring and Accounting for Innovation in the 21st Century
Editors' Introduction

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The National Income and Product Accounts and other economic statistics—designed in an age when the structure of the economy was vastly different than that of today—do not yet fully account for the wide range of innovative activity that is plainly evident in everyday experience. This limitation of our existing measurement system significantly hinders researchers, analysts, and policymakers. Better measures of innovative activity are necessary to understand the challenges and consequences of innovation and to inform the design of policies that best promote it.

In March 2017, the Conference on Research in Income and Wealth (CRIW) of the National Bureau of Economic Research (NBER) held a conference at the McDonough School of Business at Georgetown University in Washington, D.C. The purpose of this conference was to bring together academic researchers, staff from the statistical agencies, and members of the broader community studying and assessing innovation to advance the agenda of more completely and systematically accounting for innovative activity in national accounts and other economic statistics. This volume includes most of the papers presented at the conference. The papers have undergone review and, in some cases, substantial revision since their presentation at the conference. These revisions importantly reflect the excellent comments provided by discussants at the conference and two anonymous reviewers of the volume.

Before getting to a summary of the conference, the conference organizers and attendees would like to thank those who made the conference a success and the NBER/CRIW volume possible: the NBER and CRIW for financial support; Georgetown University's McDonough School of Business for hosting the conference; and NBER staff, especially Helena Fitz-Patrick for crucial assistance in compiling this volume and Brett Maranjian for exceptionally competent organizational and logistical support.

Background

This conference and volume focus primarily on the challenges of how best to measure innovation, track its effects on economic activity and inflation, and to understand how innovation has changed the structure of an increasingly digitized economy. At the same time, the papers also relate to challenges of economic measurement that long have been the subject of CRIW conferences.

Measuring innovation is a challenging task, both for researchers and for national statisticians. One approach statisticians use is to conduct a survey that measures innovation, and an international consensus has developed a manual and definition of innovation for this purpose. Published as the "Oslo Manual" (OECD/Eurostat, 2018), innovation is defined as "a product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)." This definition distinguishes between innovation as an outcome (an innovation) and the activities

through which innovations come about (innovation activities). It is difficult to measure the value (and thus the impact) of innovation outcomes using surveys, however.[1]

Another approach is that implicit in a simple macroeconomic growth model whereby, the fruits of innovation are subsumed in total factor productivity (TFP). This approach also is not entirely satisfying. Indeed, the concern about TFP growth as a measure of innovation is perhaps best captured by Moses Abramovitz's observation in a 1956 article that TFP in many ways is a "measure of ignorance" (Abramovitz, 1956). Digging deeper into Abramowitz's perspective, he showed that an index of U.S. output was 1,325 in 1944-53 relative to 100 in 1869-78 but that inputs were 381 relative to 100. From this, he concluded that almost all growth in U.S. output was over and above growth of measured inputs. He wrote: "Since we know little about the causes of productivity increase, the indicated importance of this element may be taken to be some sort of measure of our ignorance about the causes of economic growth in the United States…" Despite ongoing concerns sparked by Abamowitz, he actually provided what is perhaps the best response—one that has animated many CRIW conferences, including this one—in the part of his comment that is not often quoted. The full sentence is: "Since we know little about the causes of productivity increase, the indicated importance of this element may be taken to be some sort of measure of our ignorance about the causes of economic growth in the United State**s** *and some sort of indication of where we need to concentrate our attention* (our italics)."

The papers in this conference are in the spirit of the latter point made by Abramowitz, namely, the continued need to concentrate attention on sources of growth and innovation, including analyses of direct innovation outcome measures such as patents and "Oslo Manual" survey-based data. For those not familiar with work on innovation, four themes in this conference show what a very long way the innovation measurement literature has come since the time of Abramovitz's writing. First, consider that real output measures depend both on nominal output and quality-adjusted prices, and both are challenging to measure when there is innovation and structural change in an economy. Today's Census Bureau surveys cover virtually all services industries, whereas in Abramovitz's time, coverage of industry sectors outside of manufacturing was extremely limited. The development and implementation of firm-level databases based on linked waves of business registers and associated surveys has put a spotlight on the importance of new business formation and firm-level entry and exit as a channel through which productivity change occurs.[2]

Obtaining price measures that correctly adjust for quality change and the introduction of new goods remains as daunting a task as it was in Abramovitz's time, especially in sectors undergoing rapid change (e.g., digital services) and products for which defining a constant-quality unit of output is difficult (e.g., cloud services or semiconductors). But a huge literature has addressed these issues and illustrates the progress that has been made. Emphasis in recent years has been on whether changes due to digitization and whether some improvements in consumer welfare should be included in GDP, topics this conference directly addresses and advances.[3]

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[1] Surveys that follow the Oslo Manual aim to capture whether or not the organization has introduced new products or brought new processes into use during a reference period (e.g., two years). While this provides a "count" of innovation outcomes for the period, it does not get at their relative value or economic importance.
[2] See, e.g., Foster, Haltiwanger, and Krizan (2006) and Foster, Haltiwanger and Syverson (2008, 2016), for a survey, Syverson (2011).
[3] Recent reviews of these literatures include Byrne and Corrado (2017a, 2017b), Corrado, Fox, Goodridge, Haskel, Jona-Lasinio, Sichel, and Westlake (2017), Dynan and Sheiner (2018), Moulton (2018), and Sichel (2019).

Second, measuring value added at the industry, firm, or establishment level (as well as measuring TFP) requires better measured flows of labor and capital services—including quality-adjusted input prices for purchased inputs—to better isolate the spillovers (i.e., social returns) that should be part of TFP. This task entails many of the same issues confronted in accurately capturing real output (e.g., relevant disaggregation, and theory-consistent formulas for aggregation as exemplified by the seminal contributions of Jorgenson and Griliches, 1967, and Diewert, 1976), as well as keeping up with ongoing change in the economy. For tangible capital, a key challenge is obtaining quality-adjusted prices for capital goods undergoing rapid quality change. For purchased services and intangible capital, more fundamental definitional issues come into play as well. And, for both intangible capital and some types of high-tech capital, businesses produce capital goods on their own-account (rather than purchasing them in the market) and these new means of production will require new techniques of measurement. In each of these cases, much of the new activity is spurred by innovative activity, which only can be tracked fully if economic measurement can account for each of these pieces.

Third, the importance of intellectual property in market capitalization of public firms and of intangible capital in overall investment has increased dramatically in recent decades, as highlighted in Lev (2001), Corrado, Hulten, and Sichel (2009), Corrado and Hulten (2010), Lev and Gu (2016) and Haskel and Westlake (2017). Some types of intangible capital generally are captured in National Accounts as both outputs and inputs, including research and development (R&D), software, mineral exploration, and artistic and literary originals. Getting accurate measures of investment and capital (both nominal and real) for these assets is essential for tracking inputs to innovation. Some types of intangible capital that were identified by Corrado, Hulten, and Sichel (2005, 2009)—including industrial design, organizational capital, training, and brand equity—typically are not counted as business investment in national accounts. These assets are extensively deployed by businesses and so affect economic growth, though their effect on *measured* economic growth is confounded by their omission from measures of output (not counted as business investment) and from measures of inputs (not counted as productive capital). Because intangible capital often is connected to innovative activity, improving measures of intangibles will facilitate a fuller tracking of innovation. Moreover, because of the difficulties of measuring activities related to intangibles, it is important to derive alternative measures of innovation, such as counts of trademarks and self-reported innovation in addition to patents.

Fourth, as with the asset boundary related to intangible capital, the definition of GDP implicitly considers some activities in scope while others are considered out of scope. For example, most household production is not counted in GDP because GDP largely focuses on economic activity mediated by markets. This choice can create challenges when certain activities shift from households to market-mediated activity or the other way. For example, consider a worker who becomes an Uber driver. Some of her output is unrecorded as she drives family to school (non-market work). Some is recorded as output via credit card data when she drives paying riders, but her business capital input is not measured because she uses a household car. Or, the output of a part-time delivery person is recorded, but due to difficulties of reporting hours and self-employment status, labor input is not recorded. Similarly, home computers, tablets, and smartphones have boosted the "domestic capital stock" and have enhanced home production, either by using the devices directly (booking flights from home, writing Wikipedia entries) or enabling a marketplace to exist where none existed before (ride-sharing). These examples highlight the importance of thinking hard about the appropriate asset and activity boundaries for GDP and how appropriate boundaries may have changed over time.

This framework, while quite broad, provides context for the conference and the papers in this volume, summarized below.

SUMMARY

To set the stage for the conference, CRIW Chair Katharine Abraham and NBER President James Poterba opened the conference with remarks in the morning. Abraham highlighted CRIW's rich history and emphasized why now, in an era of fake news and alternative facts, it is more important than ever to get right basic facts about the economy. She also highlighted key challenges in economic measurement, including declining response rates to economic surveys. Poterba developed Abraham's broad measurement theme and suggested that intense public and business interest in economic statistics creates an historic opportunity for making progress on improving measures of the economy. To seize this opportunity effectively, Poterba highlighted the importance of bringing together statistical agencies from around the world, academics, and the business community. Poterba also put a smile on the faces of CRIW members with his comment that the CRIW is a jewel in the crown of the NBER.

The papers in the conference took different approaches to investigating our ignorance surrounding innovation, and they largely relate to four broad questions. First, how should current measurement frameworks be expanded to incorporate more fully the role and consequences of innovative activity? Second, what new approaches and data would be most useful to enhance our understanding of innovation? Third, how has innovation changed the structure of the economy, including production processes, labor markets, and financial activities? Finally, what changes within the current measurement framework would improve our ability to more fully capture innovative activity?

On the first theme of how current measurement frameworks should be expanded, one question of particular interest is whether and how the asset and production boundaries used in current measurement frameworks (such as in the National Accounts) need to be adjusted to more fully account for innovation-related changes in output and inputs. The issue of boundaries and definitions was taken up by the first paper in the volume. In **"Expanded GDP for Welfare Measurement in the 21st Century," Charles Hulten and Leonard Nakamura** make a powerful argument that GDP, as a measure of production, omits much of the benefits arising from the digital revolution. They highlight that consumer choices today are informed by far more information than in the past and with advances in communications technology that information is free or very low cost and readily available 24/7 in almost any location. In addition, many benefits of the digital revolution directly benefit consumers without ever appearing in GDP (including the significant inputs of consumer time that are required to produce them). Thus, they argue that there is a disconnect or wedge between growth in real GDP and that of consumer well-being. To capture this idea, they follow Lancaster (1966) and supplement the conventional growth accounting framework with a technology for consumer decision making. This approach yields an expanded measure of GDP (which the authors refer to as EGDP). With this framework, the authors analyze the wedge between real GDP and consumer well-being. Based on a series of case studies, the authors make the case that this wedge likely is large enough to be consequential and too large to be ignored.

Diane Coyle's lunchtime talk at the conference covered some similar themes. She offered insightful perspectives on several key issues for GDP and welfare measurement, including production boundaries, the provision of free goods, the role of outlet substitution as new ways of buying goods and services arise, the digitization of consumer goods, the role of bundling of goods and services and cross subsidies, and cross border issues. Coyle highlighted the need to think through the boundary between what should be counted as quality change or left as unmeasured consumer surplus and accounted for elsewhere, as in Hulten and Nakamura (above). She also

argued that even in conventional National Accounts the production/non-production boundaries are more fluid than often recognized: the treatment of owner-occupied housing for example.

The paper by **Javier Miranda and Nikolas Zolas ("Measuring the Impact of Household Innovation Using Non-Employer Administrative Data")** highlights a different aspect of how activity boundaries implicit in the definition of GDP lead to the non-measurement of certain categories of production and innovative activity within the household sector. In particular, they focus on patents obtained by businesses without employees as a proxy for identifying household innovation given that such businesses usually represent household entrepreneurs. They find that the value of household innovations patented between 2000 and 2011 is $5 billion. This estimate may seem modest, but survey evidence suggests only a small fraction of household innovations actually is patented.[4] This topic relates directly to the very engaging dinner talk on household innovation by **Eric von Hippel**. He made the case that household innovation is pervasive, creates substantial value, and contributes importantly to household well-being.[5] The paper by Miranda and Zolas, along with von Hippel's talk and contemporaneously issued book (von Hipple 2017), highlight efforts to better understand this area of household innovation and production.

Another way in which current measurement frameworks can be expanded is by digging more deeply into the detailed dynamism underlying economic growth, and the availability of detailed microdata makes this possible. In **"Innovation, Productivity Dispersion, and Productivity Growth", Lucia Foster, Cheryl Grim, John Haltiwanger, and Zoltan Wolf** draw on the literature on firm dynamics to investigate how micro dynamics feed through to aggregate or industry measures of productivity growth. They study the U.S. economy using the Longitudinal Business Database (LBD), an establishment-level database founded on the Business Register and consisting of the universe of employer businesses in the non-farm business sector of the United States (about 7 million establishments and 6 million firm observations per year for 1976-2013). The authors investigate how the dispersion of productivity at the industry level and the growth of productivity responds to a surge of entry, looking in particular at high tech and other industries. They draw on the idea of Gort and Klepper (1982) who suggested that an initial wave of entrants, who are experimenting and learning, will subsequently be selected out into leavers and stayers. This pattern would lead to a rise and then fall in productivity dispersion that, ultimately, would be followed by subsequent productivity growth. This outcome is the broad pattern the authors observe in the U.S. data: in the late 1990s there was an increase in the entry rate and productivity dispersion, but this was followed by falling entry and growth; although contrary to the theory, rising dispersion.

Another set of papers in this volume focus on the development and utilization of new data and approaches to measuring innovative activity and its economic effects. Measuring and tracking innovation and innovative activity is increasingly difficult yet critical from a policy and managerial perspective. In their paper **"Innovation Surveys—A Multidimensional Approach" Wesley Cohen, You-Na Lee and John Walsh** summarize key challenges with existing administrative and survey-based measures and propose that an expanded focus be taken when designing firm-based surveys to include richer data at the level of individual innovations. In their empirical analysis, the authors demonstrate the usefulness of this conceptual approach using their new innovation survey. They then suggest new or improved measures of innovation consistent with this approach that were not included in the survey. The authors show how shifting our attention from the firm as the unit of analysis to the innovation helps us assess the technological significance of an innovation, its likelihood of success and ultimately its potential impact on the state of current knowledge. The

[4] See Sichel and von Hippel (forthcoming).

authors argue that this complementary approach will allow policy makers and managers to make better informed investment decisions based on improved understanding of innovations and their markets.

Trademarking represents another unexplored source of information for tracking innovation, and in their paper **"An Anatomy of U.S. Firms Seeking Trademark Registration" Emin Dinlersoz, Nathan Goldschlag, Amanda Myers and Nikolas Zolas** make a strong case that trademarking is a valuable indicator of innovative activity. In particular, they construct a new administrative dataset that combines data on trademark applications and registrations from the U.S. Patent and Trademark Office Trademark Case Files Dataset (TCFD) with data on all firms from the U.S. Census Bureau's Longitudinal Business Database (LBD). The resulting dataset is comprehensive covering all employing firms regardless of size, industry or location between 1976 and 2015. It is the first effort to systematically link these data in the U.S. and provides a way to explore the value of the intangible associated with trademarks such as brand awareness and product loyalty as well as non-patented innovations and their relation to business dynamics. In their paper, the authors explore the relation of trademark application filing to firm employment, revenue growth and firm innovative activity as measured by R&D and patents. The authors show trademark registration is a precursor of firm success and is tied to innovation. Firms in the United States have substantially higher employment and greater revenue in the period following first filing for a trademark relative to control firms. The paper also finds higher average R&D expenditure and patenting by first-time trademark filers both before and after initial filing compared to control firms.

Regarding the sources of innovation, the paper by Nathan Goldschlag, Ron Jarmin, Nikolas Zolas, and Julia Lane (**"The Link Between University R&D, Human Capital, and Business Startups")** brings together several datasets to examine the linkages between university R&D, human capital, and business startups. The key underlying idea is that knowledge assets—typically not captured on a firm's balance sheet—are critical to understanding the value of a company, its ability to innovate, and ultimately its success. This paper explores how an employees' prior work and research experience affects the outcomes of startup firms including its growth, survival and innovative activity. The author's draw from a rich set of administrative data sources including payroll transaction data from the human resource files of 22 major research universities, Unemployment Insurance wage records underlying the Longitudinal Employer Household Dynamics (LEHD) dataset, IRS form W2, and the Longitudinal Business Database to construct new measures of workplace experience for U.S. workers including direct measures of research experience as well as experience in R&D labs, high-tech businesses and universities. The authors find evidence of the importance these forms of previous employee experience have on the outcomes of startup firms generally and high-tech firms specifically.

A third topic of the conference focused on how innovation is changing the structure of the economy, including production processes, labor markets, and financial activities. One area where innovation has had high visibility is the rise of the "gig" economy. **In "Measuring the Gig Economy: Current Knowledge and Open Issues" Katharine Abraham, John Haltiwanger, Kristin Sandusky, and James Spletzer** provide a typology of work arrangements and reviews how different arrangements, and especially gig activity, are captured in existing data, noting that a challenge for understanding recent trends is that the monthly Current Population Survey of households and administrative data (e.g., tax data) paint a different picture, with the former showing little evidence of the growth in self-employment that would be implied by a surge in gig activity and the latter providing evidence of considerable recent growth. The authors match individual-level survey and administrative records and find that a large and growing fraction of those with self-employment activity in administrative data have no such activity recorded in household survey data. Promising avenues for improving the measurement of self-employment

activity include the addition of more probing questions to household survey questionnaires and the development of integrated data sets that combine survey, administrative and, potentially, private data.

One of the key relationships that needs to be understood better in the modern economy is that between new types of tangible capital (notably ICT) and new types of organizational form: think of the revolution in the print media industry for example, or the effect of computerization on just-in-time style manufacturing. In the paper "**ICT, R&D and organizational innovation: Exploring complementarities in investment and production", Pierre Mohnen, Michael Polder, and George van Leeuwen** investigate whether ICT (hardware), R&D, and organizational change are complementary in production, and how much they influence total factor productivity. Such an investigation requires combinations of datasets (another theme of this conference). Typical firm-level datasets have information on outputs (such as sales) and on inputs (such as capital and operating spending), but do not typically have information on organizational change. Surveys of innovation and organization have the latter information, but typically not accounting data. Thus, Mohnen, Polder, and van Leeuwen merge together the Dutch Business Register and Oslo manual-based innovation survey data. In their merged dataset, which spans 2008-12, 45 percent of manufacturing and 35 percent of service sector firms report organizational innovation (the introduction of new business practices, knowledge management systems, methods of workplace organization, and management of external relations). They find strong complementarities between ICT investment and organization innovation. Their approach enables them to calculate rates of return and they find the highest rate of return to be for firms investing in ICT but also organizational innovation.

Innovation and its attendant implications for organization of activity also may affect the distribution of income. This issue is explored in the paper by **Dominique Guellec, "Digital Innovation and the Distribution of Income."** He suggests that features of the digital economy such as economies of scale might lead to market concentration and rents for "superstar firms," feeding through into high returns for "insiders" in those firms (such as top executives) and for shareholders, and thus income inequality. One countervailing force is that entry might be easier with digital technologies and thus the position of top firms might be easier to challenge. The author finds that the forces of concentration seem to have prevailed. To investigate the implications, he looks at how labor shares of GDP evolved across 27 OECD countries, within 16 manufacturing industries, over the period 1995-2011. The paper finds that labor shares have fallen, controlling for other factors, in those country-industries with growing patenting (their preferred measure of innovation). Combining these results with other evidence suggesting that top executive pay has risen in country-industries where concentration has risen, Guellec argues that the growth of digital economy has had a tendency to lower the labor share and widen labor-income inequality.

Baruch Lev's lunchtime talk focused on how on-going innovation (especially the rising importance of intangible capital) has affected financial accounting. Because these assets are both central to firm value but only captured in limited ways on firm financial reports, Lev made the case that that financial reports have become increasingly less useful indicators of company performance and that share price informativeness also has been falling. His comments highlighted the important role that could be played by business accounting in tracking innovative activity and how making progress on economic measurement will require collaboration among many different groups of stakeholders.

A final topic addressed by the papers is how best to improve innovation-related measures of economic activity within the current conceptual frameworks for measurement. **Wen Chen, Bart Los, and Marcel Timmer in "Measuring the Returns to Intangibles: A Global Value Chain**

Approach extend the usual approach to modelling production, arguing that studies need to look at cross-border production to complement country studies. They set out a global value chain (GVC) production function that tracks the value added in each stage of production in any country-industry and define a new residual as the difference between the value of the final good and the payments to all tangibles (capital and labor) in any stage. They focus on GVCs of manufactured goods and find the residual, which they interpret as income accruing to intangibles that are (mostly) not covered in current national accounts statistics. They find this residual—the return to intangibles in their system—to be rather large; they also document decreasing labor and increasing capital income shares over the period 2000-14 as mainly due to increasing income for intangible assets, in particular in GVCs of durable goods. They further suggest that this period should be seen as an exceptional period in the global economy during which multinational firms benefitted from reduced labor costs through offshoring, while capitalizing on existing firm-specific intangibles, such as brand names, at little marginal cost.

Accurate measures of quality-adjusted prices can be challenging to obtain for products undergoing rapid technical advance, such as semiconductors. Getting these prices right is critical given the role that semiconductors play as one of the general-purpose technologies underlying the digital revolution. In **"Measuring Moore's Law: Evidence from Price, Cost, and Quality Indexes," Kenneth Flamm** provides a comprehensive history of the evolution of semiconductor technology in recent decades and how these developments generated the rapid price declines often summarized in Moore's Law. Flamm provides evidence that since around 2000 both the pace of technical advance and the rate of price declines have slowed for high-volume semiconductors—including memory chips, microprocessors, and custom-chip designs outsourced to contract manufacturers. (This general pattern also is evident in official measures of semiconductor prices.) If Flamm's assessment is right, this slowdown bodes ill for future gains in productivity with a critical element of the digital revolution is developing more slowly. However, Flamm's results (and those implicit in official price indexes) are not without controversy, and his discussant, Stephen Oliner raised a variety of questions and pointed to other work that reaches a different conclusion.[6]

In **"Accounting for Innovation in Consumer Digital Services: IT still matters," David Byrne and Carol Corrado** present a framework for measuring the GDP impacts of innovations in consumer content delivery, which have been especially rapid since the advent of the 21st century, or "mobile information age." They argue that the flow of services from consumers' connected IT capital capture what Brynjolfsson and Saunders (2009) call "free goods" and that this service flow should augment the existing measure of personal consumption in GDP. They develop a quality-adjusted price index for these services as well as the paid-for access services (already included in GDP) that are needed for content delivery via consumer-owned IT devices. Their estimates imply that accounting for these innovations in consumer content delivery matters: The innovations boost the consumer surplus of connected users by about $30,000 (2017 dollars) from 2004 to 2017 and contribute more than 1/2 percentage point per year to U.S. real GDP growth during the last ten years. Their accounting of innovations in consumer content delivery is (conservatively) estimated to have moderated the post-2007 GDP growth slowdown by nearly 0.3 percentage points per year. The price index for paid-for content delivery services (i.e., cellular, cable TV, and multi-device streaming services) that they develop in this paper has a similar impact on consumer price inflation, i.e., relative to official consumer prices calculated by the Bureau of Economic Analysis, Byrne and Corrado argue elsewhere that prices for consumer

[6] See Byrne, Oliner, and Sichel (2018)

digital access services (alone) have had an increasing deflationary impact since 1987 (Byrne and Corrado (2020)).

Cloud computing is one area where developments have leapt ahead of measurement. In **"The Rise of Cloud Computing: Minding Your P's, Q's, and K's," David Byrne, Carol Corrado, and Daniel Sichel** document the explosive growth of cloud computing, develop new quarterly hedonic price indexes for cloud computing services, and investigate the puzzle of why investment in IT equipment in the NIPAs has been so weak while capital expenditures for IT equipment associated with cloud infrastructure has exploded. On prices, the paper focuses on those at Amazon Web Services and estimates that from 2009 to 2016 cloud computing prices fell rapidly, with quickening and double-digit declines after 2014. On the IT equipment puzzle, the paper argues that cloud service providers are undertaking large amounts of own-account investment in IT equipment and that some of this investment may have been missed in the GDP accounts. (In the 2018 Comprehensive Revision of the NIPA, the Bureau of Economic Analysis took steps to better capture this own-account investment.)

The final paper is by **Erich Strassner and David Wasshausen** of the Bureau of Economic Analysis (BEA), **"BEA Deflators for Information and Communications Technology Goods and Services: Historical Analyses and Future Plans."** With an aim toward facilitating and encouraging further price research, the paper first provides a historical perspective and analysis of BEA's information and communications technology (ICT) prices, including an overview of the sources and methods used to construct their quality-adjusted prices. The authors then discuss current-work and future plans for continuing to ensure the accuracy of BEA's price indexes and corresponding inflation-adjusted measures and provide an update that assesses recent progress as reflected in BEA's 15th comprehensive update of the national accounts, released in 2018.

CONCLUSION

As in past NBER and CRIW conferences, this one stimulated a rich discussion by experts in the areas covered by the volume. Discussants comments on the papers provided extremely valuable insights and stimulated further conversation. For these contributions, we thank discussants **Barry Bosworth, Bronwyn Hall, Shane Greenstein, Jonathan Haskel, Stephen Oliner, Mark Roberts,** and **Scott Stern**. As noted above, we also were fortunate to have three dynamic speakers during meals provide insightful comments that dovetailed tightly with the themes of the conference. For these comments, we thank **Diane Coyle, Baruch Lev,** and **Eric von Hippel** for their important contributions to the conference.

In addition, we were fortunate to conclude the conference with a terrific panel discussion on next steps. That panel, chaired by **Ernst Berndt, included Dennis Fixler, Erica Groshen, Ron Jarmin,** and **Scott Stern**. Berndt focused on the relationship between the academic/research community and the statistical agencies. While in the past, academics have offered suggestions for how statistical agencies can improve statistics, Berndt suggested that the statistical agencies offer suggestions on research topics to academics as well as suggestions for organizational collaboration. Fixler reviewed progress on measuring innovation made by the Bureau of Economic Analysis in the past decade. He also highlighted some key areas in which further progress is needed, including on-going efforts to improve quality adjustment, how best to incorporate private data, and how best to integrate and share data with other statistical agencies. Groshen picked up on the conference theme of the interaction between innovation and organizational structure, and emphasized that the statistical system needs to be responsive to changes in organizational structures in the econmy. Specifically, all data need to have identifiers so that data can linked, aggregated, and disaggregated

correctly. She also argued that statistical programs should, where possible, be re-engineered to replace survey data with administrative data to engender, at least in part, increased efficiency and nimbleness in our measurement system. Like Berndt, Jarmin focused on the importance of collaboration between statistical agencies and outside researchers. Echoing Fixler, he noted the importance of thinking through how best to link in specialized data from private sources. He also highlighted the potential value of collecting different datasets in a centralized place for researchers to access as easily as possible given data security and resource constraints. Stern focused on the central question of the conference: what is innovation? He noted that economists are good at measuring inputs to innovation with a presumption that these inputs translate into output that is valued. He also highlighted the importance of better understanding innovation that occurs outside firms and for more fully thinking through how we account for the benefits of innovation. As an example, he cited solar energy, which has a modest effect on GDP but is potentially very significant in reducing a negative externality.

As organizers of the conference, we believe that important progress was made on Abramowitz's charge to dig deep to better understand our ignorance about innovation. As noted, understanding the sources and implications of innovation is a vast and complex problem. Given the wide range of approaches and data presented and discussed at the conference, we believe that further progress will depend on greater collaboration among micro and macro economists, between researchers and practitioners, between the business community and statistical agencies and researchers (not least because of the immense amounts of data possessed by the private sector), and between those who directly study innovation and those who work on broader issues of productivity, economic growth, and economic transformation. In our view, the problem is too complex for any individual or single approach to meet the challenge. It is our hope that the conversations and ideas sparked at the conference will be the basis of continued progress and collaboration.

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