Editor's Overview

THIS 25TH ISSUE OF THE *International Productivity Monitor* contains revised versions of papers, as well as discussant comments, presented at a session on productivity organized by the Centre for the Study of Living Standards at the annual meeting of the American Economic Association in San Diego, California January 4-6, 2013. The first two papers focus on the productivity outlook for the United States, the third on the relationship between employment and productivity, and fourth on European productivity performance.

It is now well recognized that the productivity growth resurgence that took place in the United States after 1996 was fuelled by the information technology (IT) revolution. Going forward, the key question is whether this revolution will continue to boost productivity growth dramatically, or have a much more limited impact.

In the lead article, **Martin N. Baily** from the Brookings Institution and the McKinsey Global Institute, **James Manyika** from the McKinsey Global Institute and the Brookings Institution and **Shalabh Gupta** from McKinsey & Company provide an optimistic perspective on future U.S. productivity growth. Drawing on sector case studies done by the McKinsey Global Institute, they identify and document opportunities for productivity advance arising from specific technologies, such as robotics, 3D printing, big data, and the 'internet of things' that will drive future productivity growth in the manufacturing, energy, health care and life sciences, and infrastructure sectors. They forcefully reject the idea that growth opportunities have vanished, noting that necessity can be the mother of invention if pressures on budgets force business and governments to find ways to cut costs and raise efficiency.

In response to Baily, Maniyka and Gupta, **Robert J. Gordon** from Northwestern University presents a less optimistic view of future U.S. productivity growth. While recognizing that productivity growth in manufacturing has been and will likely continue to be rapid, he argues that the remaining 90 per cent of the economy will not see impressive productivity gains, which were fuelled by information technology, enjoyed in the 1996-2004 period. Rather he sees a continuation of the modest productivity gains experienced between 2004 and 2012. Gordon identifies a number of "headwinds" that will reduce future productivity and income growth. Once the negative impact of the demographic, education, inequality and debt headwinds are factored in, together with the likelihood that future inventions will be less important than those of the second Industrial Revolution, disposable income growth for the bottom 99 per cent of the population may be as low as 0.5 per cent per year or even lower.

In the second article, **David M. Byrne** from the Federal Reserve Board, **Stephen D. Oliner** from the American Enterprise Institute and the University of California at Los Angeles and **Daniel E. Sichel** from Wellesley College show through a detailed growth accounting exercise that since 2004 IT has continued to make a significant contribution to U.S. labour productivity growth – 0.73 percentage points per year. While this is down from 1.50 points per year in 1995-2004, it is comparable to the 0.77 points of the 1974-1995 period. They develop a baseline projection of growth in trend labour productivity in the U.S. non-farm business sector of 1.8 per cent per year. While this would represent a period of subpar gains from a long-term historical perspective (though better than recent history), they see a reasonable prospect – particularly given the ongoing advance in semiconductors – that the pace of labour productivity growth could revert to its long-run average of 2¼ per cent. They conclude that the IT revolution is not yet over.

In his comments on Byrne, Oliner and Sichel, **Chad Syverson** from the University of Chicago compares the path of labour productivity growth since the IT revolution began in 1970 with that of labour productivity from 1890, the beginning of the electrification era. He notes in both cases a lag of about 25 years before these two general purpose technologies affected productivity significantly, followed by a period of rapid productivity advance and then a subsequent productivity slowdown (1924-1932 and 2004-2012). The immediate post-1932 period saw a rebound in labour productivity growth. Such a development is possible for the post-2012 period. History shows that productivity growth driven by general purpose technologies can arrive in multiple waves. It need not simply arrive, give what it has and fade away forever thereafter.

In the third article, **Andrea De Michelis** from the Federal Reserve Board, **Marcello Estevão** from the International Monetary Fund and **Beth Anne Wilson** from the Federal Reserve Board provide an innovative, and provocative, analysis of the relationship between productivity and employment growth. Economists have traditionally seen total factor productivity (TFP) growth as exogenous. But the authors make the case that positive labour supply shocks can reduce the efforts of firms to increase efficiency, making TFP endogenous. They present cross-country evidence of a strong negative correlation between TFP growth and labour inputs over the medium to long run among OECD countries. They highlight potential welfare implications of this tradeoff between TPF growth and labour input as policies that increase efficiency at the expense of hours of work and/or employment may result in greater unemployment, income loss, and reduced well-being.

In comments on Michelis, Estevão and Wilson **Barbara Fraumeni** from the University of Southern Maine expresses caution regarding the results and recommends further investigation of the relationship between productivity and employment growth before definitive conclusions are reached. In particular, she recommends that the authors attempt to take account of the age and educational attainment distribution of the workforce within a country in attempting to explain TFP growth.

In the fourth article **Bart van Ark** from the Conference Board and the University of Groningen and **Vivian Chen** and **Kirsten Jäger** from the Conference Board provide a detailed analysis of productivity developments in European countries since 2000 and present productivity forecasts to 2025. They note that the weakness of productivity growth has now moved beyond the services sector to include the goods sector. For the 2013-2025 period they project total factor productivity growth to advance at only a 0.2 per cent average annual rate in both the euro zone countries and at the level of all 27 EU countries.

In comments on Van Ark, Chen and Jäger, **Pascal Petit** from the Université de Paris-Nord provides historical and institutional context for their analysis. He identifies what he calls the "financialization" phenomenon, whereby easy and creative finance led to speculative booms and busts in a number of countries such as Spain. He also notes that labour market reform in Germany, which improved competitiveness, appears to have made that country more recession-proof.

U.S. Productivity Growth: An Optimistic Perspective

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ABSTRACT

Recent literature has expressed considerable pessimism about the prospects for both productivity and overall economic growth in the U.S. economy, based either on the idea that the pace of innovation has slowed or on concern that innovation today is hurting job creation. While recognizing the problems facing the economy, this paper offers a more optimistic view of both innovation and future growth, a potential return to the innovation and employment-led growth of the 1990s. Technological opportunities remain strong in advanced manufacturing and the energy revolution will spur new investment, not only in energy extraction, but also in the transportation sector and in energy-intensive manufacturing. Education, health care, infrastructure (construction) and government are large sectors of the economy that have lagged behind in productivity growth historically. This is not because of a lack of opportunities for innovation and change but because of a lack of incentives for change and institutional rigidity.

RÉSUMÉ

Récemment, la littérature a exprimé un pessimisme considérable en ce qui concerne les perspectives de croissance économique et de croissance de la productivité aux Etats-Unis, soit en soutenant l'idée que le rythme d'innovation a ralenti, soit en soutenant la crainte que, de nos jours, l'innovation nuit à la création d'emplois. Cet article offre une perspective plus optimiste de l'innovation et de la croissance future, en affirmant le retour potentiel de l'innovation et de la croissance tirée par l'emploi des années 1990. Les opportunités au niveau technologique restent fortes dans la fabrication de pointe et la révolution énergétique entrainera de nouveaux investissements, non seulement dans l'extraction des ressources énergétiques, mais également dans le secteur du transport et dans la fabrication à intensité énergétique élevée. L'éducation, les soins de santé, l'infrastructure (construction) et le secteur gouvernemental sont des secteurs vastes de l'économie qui ont historiquement affiché un retard en terme de croissance de la productivité. Ceci n'est pas la conséquence d'un manque d'opportunités pour l'innovation et le changement, mais plutôt la conséquence d'un manque d'incitatifs au changement et de rigidités institutionnelles.

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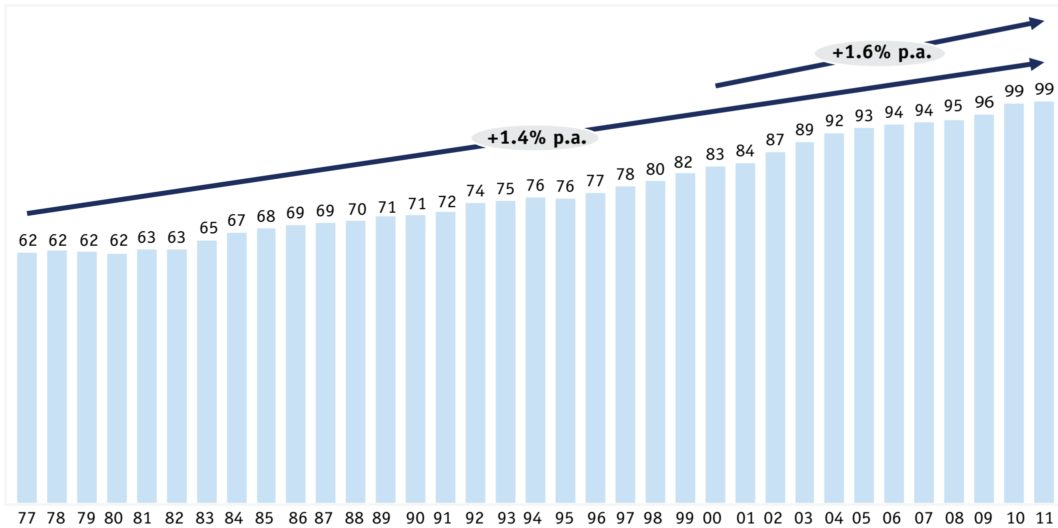
Chart 1
GDP per Worker in the United States, Total Economy, 1977-2011
(thousands of 2005 U.S. dollars)



Sources: U.S. Bureau of Economic Analysis, Moody's Analytics.

The impact of the Great Recession that swept through the advanced economies in 2008 has lingered, with unemployment remaining high and economic growth slow. Forecasters predict that the U.S. economy will not return to full employment until 2017, marking a decade of moderate growth and employment weakness. Parts of Europe face even tougher conditions and little prospect of restoring prosperity for up to ten years into the future.

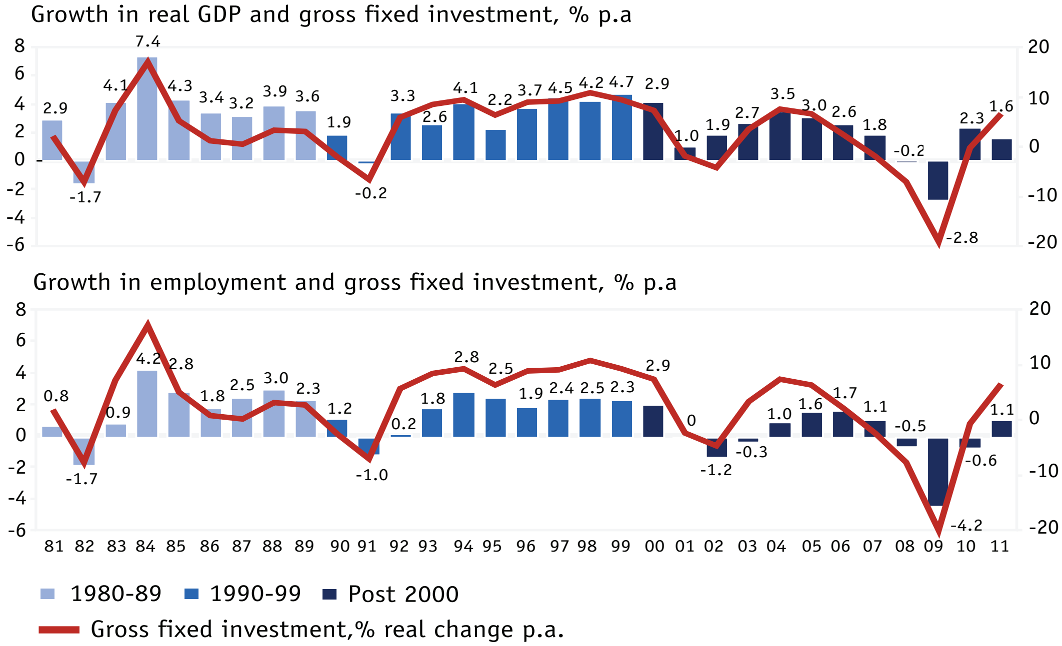
In such a difficult short-run environment, it is not surprising to find pessimistic assessments of the long-run growth path of the economy. Both Robert J. Gordon in his discussion of this article (Gordon, 2013) and in his forthcoming book on U.S. economic growth, and Tyler Cowen (2011) in his recent book, *The Great Stagnation* argue that the golden age of innovation is over. Even technology optimists such as Erik Brynjolfsson and Andrew McAfee (2011), while optimistic about growth and innovation, are pessimistic about future employment prospects, finding that while the digital revolution is accelerating innovation, it is also automating away increasing numbers of jobs. We are, to use their term, in *A Race Against the Machine*.

We do not wish to be Pollyanna, assuring readers that everything will turn out for the best and that rising living standards are guaranteed; indeed, the challenges or headwinds facing the economy are real and important. Even before the onset of the recession in 2008, there was concern over sluggish employment growth, an overvalued housing market and widening income inequality. Global competition has become much more intense and the United States has run trade deficits since the early 1980s.

Where we differ with other authors is that we see tremendous opportunities along with the challenges. We strongly agree with Brynjolfsson and McAfee that digital technology and the digital revolution are proceeding apace, and we also agree that this will eliminate many traditional jobs in manufacturing and elsewhere. But the offset is that innovation-led growth can create new jobs, new lines of business and new profit

Chart 2

Real GDP, Gross Fixed Investment and Employment in the United States, 1987-2011



Sources: U.S. Bureau of Economic Analysis, Moody's Analytics; The Economist Intelligence Unit.

opportunities. Indeed, we saw this in the 1990s when innovation-led growth created new products and services and expanded output and new technologies made productivity gains possible, even though many of these were concentrated in certain sectors (Lewis, 2004). Perhaps even more important, today there are large sectors of the economy that have continued to lag behind in productivity growth, notably health care, education, and construction. Adopting best practices and taking advantage of existing technologies can yield substantial productivity gains for the economy. Another important opportunity lies in energy. New technologies have unlocked reserves of natural gas and oil buried deep below the surface and made it possible to extract these reserves at favorable prices. While we do not ignore the environmental challenges inherent in accessing these reserves, we judge that these can be overcome and that natural gas at low prices and a more stable and secure source of oil are becoming available, a revolution that will have a large impact on U.S. productivity and GDP growth.

In addition to being productivity optimists, we also observe that at the level of the national economy, the history of the last 80 years has shown that productivity growth has largely occurred hand in hand with employment growth. In its February 2011 report *Growth and Renewal in the United States*, the McKinsey Global Institute looked at the past 80 years and found that, while over one-year periods there was some tradeoff between productivity and employment growth, this tradeoff was reduced as the time period was extended and had essentially disappeared over 10-year time spans (Manyika *et al.*, 2011a:6). While demand weakness currently remains a serious issue, in the long-run productivity growth is still the most important way to improve living standards and does not come at the expense of employment (Brynjolfsson and McAfee, 2011).

This article will first review highlights of the performance of U.S. productivity over the past two or three decades. It will then turn to examine a sample of the productivity opportunities available and some of the challenges in seizing these opportunities and generating innovation-led growth in the years ahead.

The Pattern of Recent Economic Growth

A broad measure of overall labour productivity is GDP per person employed. It captures the extent to which technological change, as measured by multifactor productivity growth (MFP) (also known as total factor productivity), increased capital per worker, and changes in human capital have allowed an increase in the amount produced on average by each worker.[2] As Chart 1 shows, the rate of growth of GDP per worker has maintained a fairly steady overall trend since 1977, albeit with periods of faster and slower growth over shorter periods within this time span.

Chart 2 shows the numerator and denominator of the ratio of GDP per worker on an annual basis for the 1981-2011 period, matched to investment data. One finds a significant variability in pattern by business cycle. The expansion of the 1990s was characterized by strong innovation— both technological innovation and innovation in providing new services and devising improved business processes. That expansion incented businesses to invest, create new capacity and increase employment, visible in the high level of investment over this period. Investment was rather weak in the 1980s. From 2000 to 2007 investment was strong in housing but much weaker overall. Investment was hard hit in the Great Recession and since then has not recovered even to its 2007 level. Weak business investment is a problem not only for the cyclical recovery but also for longer term growth.

The pattern of growth just described also shows up in the industry data illustrated in Charts 3 and 4. In the 1990s, the industries that contributed to productivity growth also contributed to both output growth and employment growth.[3] Manufacturing employment held steady. Since 2000, the industries making the biggest contributors to labour productivity growth experienced slow output growth and declining employment. The period since 2000 has been one of extensive restructuring as companies responded both to the dot.com crash and the Great Recession by eliminating employees and lines of business that were not expected to be profitable. Many multinationals saw better investment opportunities in fast-growing emerging markets and labour-intensive manufacturing activities were shutdown in favour of imports.

Opportunities for Productivity Growth

Despite the economic problems encountered in the past decade, we see a range of opportunities for productive economic growth for the U.S. economy going forward. Innovation is still proceeding rapidly and there is tremendous scope to improve productivity in industries such

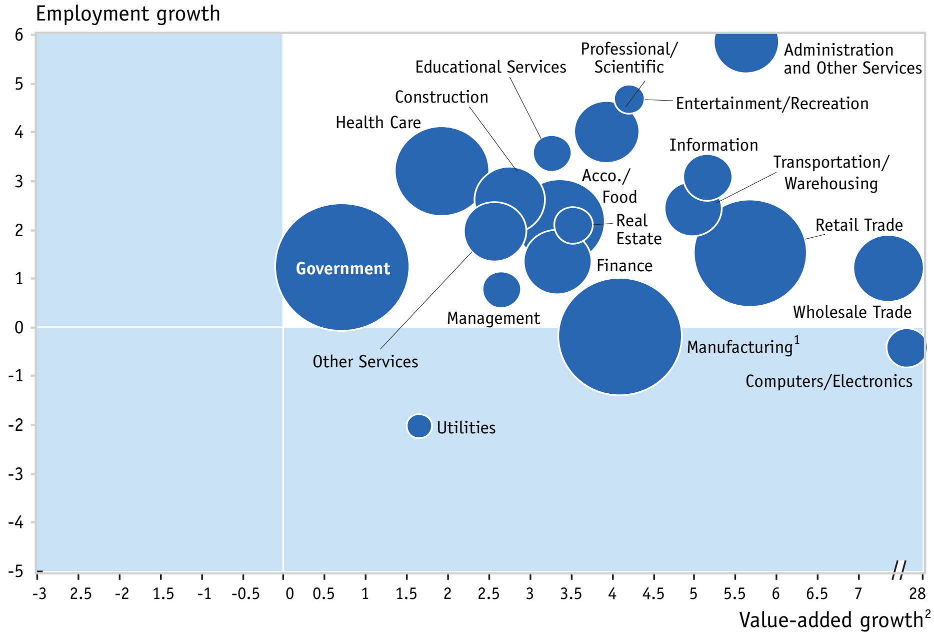
2 Productivity studies often focus on multifactor productivity in the business sector of the economy, or in a specific industry, which is the best way of capturing shifts in the production possibility frontier. GDP per worker is useful as a guide to the amount of economic resources produced by each participant in the economy, whether it comes from multifactor productivity, capital per worker, human capital or the mix of industries.

3 De Avillez (2012) shows that assigning the contribution of labour productivity by industry depends on the approach and formula used. The charts shown here rely on a simplified approach developed by the McKinsey Global Institute, the details of which are available on request. The conclusions of this article are not sensitive to precise estimates of industry contributions shown.

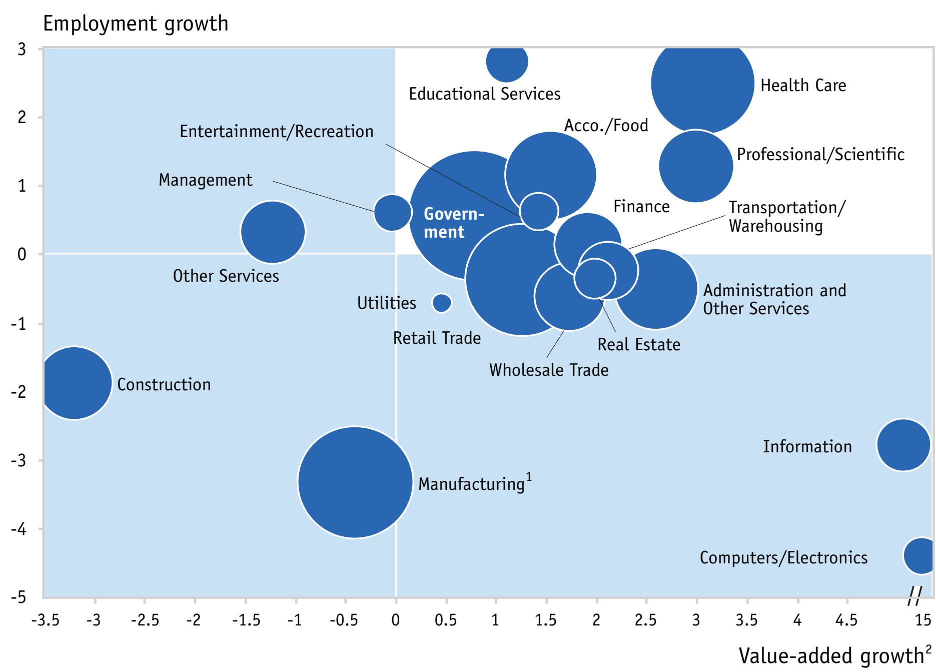
Chart 3

Relationship between Employment and Value-Added Growth by Industry in the United States, average annual rate of change, 1990-2000 and 2000-2011

A) 1990–2000



B) 2000-2011



Notes: 1) Size of bubble represents the share of employment in 1990 in Panel A and in 2000 in Panel B;
2) GDP per worker grew by 1.6 per cent per year in both the 1990–2000 period and the 2000-2011 period;
3) Manufacturing excludes Computers/Electronics.

Sources: U.S. Bureau of Economic Analysis, Moody's Analytics; McKinsey Global Institute Sunrise Productivity Model.

as health care, education and government that have lagged behind historically. In the remainder of this article we will outline some of the opportunities that we see, specifically in manufacturing, energy, health care, and infrastructure. These will be spelled out in more detail in an ongoing McKinsey study of "game changers," opportunities that could move the economy forward substantially.

Manufacturing

Technological innovation is transforming multiple aspects of manufacturing. It is no more a stretch to imagine manufacturing a decade from now barely resembling current processes. We briefly discuss several reasons to be optimistic about productivity growth in manufacturing.

Industrial robotics and automation

The beginning of this decade has seen rapid strides towards adoption of industrial robots for a wide set of tasks that can today only be performed by humans. Many of these tasks require dexterity that robots do not yet possess, while others require minor adjustments and variances which are difficult to program a machine to effectively respond to. While industrial robotics has been a reality and a necessity in industries requiring heavy lifting and repetitive, precise movements – automotive is a classic example – it has been priced well out of range for more regular 'human' tasks. While robotic arms can lift and place heavy car frames on a car manufacturer's assembly line, the robot assembly of mobile phones is not yet viable.

That could soon change with low-cost robots like 'Baxter', which have the potential to fundamentally change manufacturing by increasing precision and productivity without incurring high costs. Baxter is a robot developed by Boston's Rethink Robotics with the capability to work safely alongside humans. Baxter's arms can sense a human in their path and stop movement. It can be 'reprogrammed' for new tasks by a human operator who physically manipulates its arms to move, bend, lift or drop in the desired way. At a sticker price of $20,000, the company claims its costs are equivalent to a human worker earning $4 per hour.

3D printing and additive manufacturing

New technology has provided the ability to create complex objects using a computer-controlled "printer" that deposits successive layers of material to form a metal, plastic or even organic object. The implications for manufacturing are immense. Thus far 3D printing has mostly been used to create prototypes or objects that would be impossible to machine, but in the future the technology could usher in a new ecosystem of smaller value chains and new companies providing printable designs on the web, instead of products on the shelf. With increasing adoption, everyday products will be endlessly customizable – in form, material and dimensions. Small businesses will be able to compete with traditional manufacturers, products will never go out of stock, size of batches will become meaningless, and manufacturing will become truly just-in-time.

Big data

For a number of reasons, the application of big data and advanced analytics is particularly relevant to the manufacturing sector. It is a sector that has already experienced rapid productivity growth in the past decades through IT and automation and therefore owns large, fully digital data sets in several functions along the value chain. Truly global supply chains add significant complexity regarding data security/rights and global real-time data sharing and collaboration. The "extended enterprise" model of most manufacturing companies brings about growing data pools, which span business units and require vertical data integration and coordination across organizational boundaries. As a result, stored data in manufacturing is the biggest among industry sectors globally and is projected to grow further and become more integrated along the supply chain, e.g. through radio-frequency identification (RFID) technologies.

In a report on the economic impact of Big Data (Manyika *et al.*, 2011b), the McKinsey Global Institute identified value levers along the whole manufacturing value chain with the ability to lead the sector to higher productivity levels, indicating huge potential. As an example, application of big data and advanced analytics to R&D and product development was estimated to reduce costs by 20-50 per cent, and a big data-enabled supply chain optimization was estimated as yielding a 2-3 percentage point profit margin improvement.

The '*Internet of Things*'

This refers to the massive connectedness of all manner of inanimate things to networks and to each other, enabled through the proliferation of low-cost sensors. The possibility to connect machines and equipment to each other and to common networks promises to push productivity in several interesting ways.

Connecting machines allows for their remote monitoring. Instructions can be provided to a set of equipment based on the activity of other equipment. We foresee a future where manufacturing facilities can be fully shut down and started up by the owner sitting at home with the help of an internet connection. Extending the applications of connected devices, we could set up closed-loop systems which would automatically make decisions based on optimization algorithms and stimuli from various equipment in the network..

The 'Internet of Things' could also enable greater energy efficiency in manufacturing. A recent report by the International Energy Agency (Waide and Brunner, 2011) investigated energy consumption of electric motor-driven systems (EMDS) and found them to be responsible for over 40 per cent of global energy consumption, leading to over 6,000 megatons of CO2 emissions. Traditionally, motors operate at peak capacity irrespective of load. Smart motors are able to adjust power usage with output, usually through variable speed drives controlled by an intelligent motor controller (IMC). With low-cost sensors allowing improved inter-machine and system communication over wireless networks, it will be possible to make manufacturing systems with thousands of motors smarter, enabling substantial improvements in energy efficiencies.

Taken together, new technologies are transforming manufacturing processes across the value chain. Developments in new materials through breakthroughs in nanotechnology or biologics promise to fundamentally change manufacturing. Product design is witnessing a change with human-centered design driving new research with the help of Big Data on customer preferences collected through social media and the Internet of Things. Production processes are progressing rapidly with advances in modeling and simulation, advanced robotics and additive manufacturing. Traditional business models are being challenged by new ideas like frugal innovation[4] and the circular economy.[5] Entirely new service models are likely to evolve as technologies

4 Frugal innovation is a term coined by the McKinsey Global Institute. It refers to companies in emerging economies that are finding ways to innovate even though they lack the R&D resources of developed country economies. In the fastest-growing markets for manufactured goods — developing economies — company R&D budgets and government research spending tend to be far lower than in advanced economies. For example, India's national R&D budget was around $14 billion in 2010 — a year when Microsoft, Pfizer, and Intel each spent $8 billion to $10 billion on R&D. In this environment, frugal innovation changes the business model by emphasizing shorter launch cycles, innovation through commercialization, and reverse-engineered innovation.

like 3D printing become more widely available, e.g. distributed manufacturing.

Energy

The most important development in the U.S. energy sector is undoubtedly the extraction of natural gas from shale deposits and, increasingly, light tight oil (LTO) – crude oil trapped in shale. Natural gas resources in the United States have nearly doubled since 2003, driven by the development of shale deposits nationwide. The United States has the second largest recoverable shale gas reserves in the world at 24 trillion cubic meters (tcm), after China's reserves of 36 tcm. However, the United States is substantially ahead of the rest of the world in developing these reserves. By 2020, shale gas is expected to add 10-15 billion cubic feet per day over current levels and grow to over 25 per cent of total gas production. This will also lead to a 60 per cent drop in natural gas imports. Substituting energy imports and increasing energy exports could reduce U.S. net energy imports to zero, and cut the goods trade deficit by more than half (ceteris paribus). Along with shale gas, light tight oil production has also developed rapidly. Current LTO production estimates for 2020 are between 5 and 10 million incremental barrels per day, although some see even higher numbers as possible.

The impact of increased domestic energy output is greatest for large energy purchasers, such as manufacturing and transport industries. Within manufacturing, the greatest impact will be on sectors that are highly energy intensive, such as chemicals, metals, paper and pulp, and food manufacturing. Cheaper natural gas is expected to generate an additional investment of $50-$65 billion in domestic petrochemical products and around $15 billion in natural gas-based petrochemical products. While downstream sectors will be advantaged due to cheaper fuel and feedstock, other sectors (e.g. services, construction) could see increased activity to support oil-gas production and manufacturing output.

The new technology of drilling has opened up an opportunity for profitable investment and employment that will increase both GDP and productivity. This will help move the economy back to full employment and generate economic activity that has higher productivity levels than the alternative use of resources.

Health care and life sciences

Productivity growth in health care has traditionally been stymied by poor regulation, institutional inertia and perverse incentives. Cost of treatment, the high cost and risk of malpractice litigation on care-givers and the cost-plus nature of Medicare payments work together to make health care costly and slow to innovate.

In recent years, however, there has been widespread recognition of misaligned incentives, and progress has been made on aligning them through ACOs (accountable care organizations) and other risk-sharing models. Many of these new models have been proposed by the Centers for Medicare and Medicaid Services through the Affordable Care Act, as well as private insurers.

Given regulatory progress and alignment of incentives, several new innovations in life sciences as well as delivery models promise exciting opportunities in health care:

- Data driven decision-making: Technology that allows collection and analysis of massive

5 Circular economy is another term coined by the McKinsey Global Institute. It refers to an alternative to the "take-make-dispose" business model for use of materials in manufacturing. The circular economy maximizes the productivity of materials and energy and minimizes the impact of their extraction and processing. The circular economy is built on four principles: designing products with their entire life cycles in mind; maximizing product life cycles; recycling materials from end-of-life products; and reusing materials across diverse industries and value chains.

datasets is already changing R&D, clinical care, forecasting and marketing. McKinsey Global Institute's 2011 report on Big Data estimated the long term potential of applications across health care to be over $300 billion per year, with more than $200 billion savings on national health care spending. In all, the report estimated Big Data levers could save up to 12 per cent of national health care expenditures in the long term and add nearly 0.7 per cent to average labour productivity growth in the U.S. health care system. Health care providers who have harnessed the power of data driven analysis have often reaped rich dividends.[6]

- Transparency in delivery systems: Ease of connectivity and an expectation of openness between patients and providers is driving pricing transparency. Increased usage of self-diagnosis through online resources and social media is shifting some power towards patients.
- Low-cost channels and solutions: The growth of new low-cost channels and solutions, e.g. "minute clinics", remote care tools and self-service at clinics, promises better care for patients with little or incomplete insurance coverage.

Personalization and the "quantified self": a major trend in health care is the use of big data and advances in obtaining granular information on individuals (e.g. through genome sequencing) to enable the development of highly personalized treatments and medicines. New personal fitness devices like the Fitbit offer the option to track the wearer's activity and sleep cycles. Increasingly, these devices will allow the monitoring of more indicators, like body temperature or pulse rate. These will permit individuals not only to better understand their own unique physiology, but also to be alerted in a timely manner to the need for treatment or exercise.

Infrastructure

This sector has been a laggard in improving productivity – there has been no measured gain in the labour productivity of the construction sector in the last 20 years! The implications of improving productivity are huge. To keep pace with growth, infrastructure investment in the United States will have to rise to 3.6 per cent of GDP, up from the current 2.6 per cent.

McKinsey Global Institute research has shown opportunities in three areas to reduce the need for new investment by obtaining more from the current infrastructure (Dobbs *et al.*, 2011):

- Making better decisions about project selection, e.g. Department of Transportation in Washington state publishes detailed information on plans and progress in a comprehensive performance report to legislators and the public each quarter.
- Streamlining project delivery – More efficient delivery can generate savings of as much as 25 per cent on new projects, or 15 per cent savings on total infrastructure investment. The state of Virginia moved ahead with a controversial plan to widen the I-495 interstate after a private design company came up with a route that eliminated the need to remove hundreds of homes. The plan also reduced the project cost from about $3 billion to around $1 billion.
- Making the most of existing infrastructure –
  a) Intelligent transportation systems (ITS) for roads, rail, airports, and ports can double or triple asset utilization.
  b) Smart grids could help the United States avoid $2 billion to $6 billion a year in

6 In a study conducted in a 20-bed multi-disciplinary PCCU in a major metropolitan area, McKesson's WizOrder system was installed for allergy alerts, drug interaction and dosage and was integrated with EHR data. It was found that the new system helped reduce Adverse Drug Events by 41 per cent through near-elimination of prescription errors, previously responsible for three-fourths of the events.

power infrastructure costs and also help reduce the likelihood of outages that cost the economy tens of billions of dollars per event.

c) Efficient demand management, e.g. California employs a range of demand-management measures to lower per-capita energy use to 40 per cent of the U.S. average.

Conclusion

The growth of GDP per worker has remained fairly solid during the past 30 years and even over the past 10 years, but there are some warning signs. Labour productivity growth was slow from 1973 through 1995 and may now be slowing again. The long period of economic weakness triggered by the financial crisis has been compounded by political gridlock and an unwillingness to resolve policy differences and deal with the long-run deficit problem. The rapid increases in the labour force that occurred with the baby boom generation and the increased entry of women into the workforce are now over.

However, we reject the idea that growth opportunities have vanished. The signs of ongoing innovation abound in Silicon Valley and far beyond. And necessity can be the mother of invention if pressure on budgets forces businesses and government to find ways to cut costs and raise efficiency in health care and infrastructure. Moreover, the energy revolution is a tribute to the innovative power of small and medium-sized businesses in the oil and gas sector that kept looking for ways to drill productively in the United States. Technology support from the Department of Energy also helped. If the environmental challenges are met and overcome, this revolution will open up a wide range of investments, job opportunities and productivity improvements.

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U.S. Productivity Growth: The Slowdown Has Returned After a Temporary Revival

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ABSTRACT

There was never any slowdown in productivity growth in U.S. manufacturing during the postwar period, and indeed there was an unprecedented explosion of manufacturing productivity growth between 1996 and 2004. But the share of the manufacturing sector in the total economy has declined from 30 to 10 per cent since the 1950s. The record for the other 90 per cent, consisting of all the economy outside of manufacturing, is far less encouraging; in non-manufacturing labour productivity growth fell from 2.95 per cent per year in 1948-72 to 1.29 per cent per year in 1972-96. After a brief revival to 2.63 per cent in the brief eight-year period 1996-2004, the growth rate slumped again to 1.47 in the past eight years. This examination of the data provides evidence that the revival of productivity growth associated with the dot.com revolution is over, that multifactor productivity growth in the total economy has returned to the rate achieved in the post-1972 slowdown years.

RÉSUMÉ

Il n'y a jamais eu de ralentissement de la croissance de la productivité dans le secteur de la fabrication aux États-Unis pendant l'après-guerre et il y a effectivement eu une explosion de croissance sans précédent dans les industries manufacturières entre 1996 et 2004. Cependant, la part qu'occupe le secteur de la fabrication dans l'économie totale est passée de 30 à 10 % depuis les années 1950. Les statistiques pour l'autre tranche de 90 %, constituée de tous les secteurs de l'économie autres que la fabrication, sont beaucoup moins encourageantes : dans ces secteurs, la croissance de la productivité du travail a diminué pour passer de 2,95 % par année entre 1948 et 1972 à 1,29 % par année entre 1972 et 1996. Après un bref regain de vie qui l'a de nouveau porté brièvement à 2,63 % entre 1996 et 2004, le taux de croissance a rechuté pour se fixer à 1,47 % au cours des huit dernières années. Cet examen des données prouve que le regain de vie de la croissance de la productivité associé à la révolution du dot.com est terminé, et que la croissance de la productivité multifactorielle dans l'économie totale est revenue au taux où elle se trouvait après le ralentissement de 1972.

THIS COMMENT PROVIDES my perspective on the future of productivity growth in the United States. I concur with the view expressed in Baily, Manyika, and Gupta (2013) that American manufacturing has a bright future of productivity growth, even though its employment prospects are uncertain. But, as I have written elsewhere, "manufacturing is performing a

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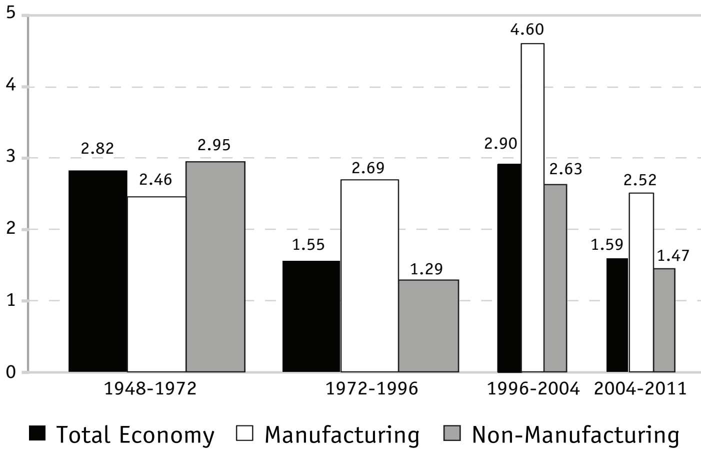
Chart 1
Output per Hour in the United States, Total Economy and Selected Sectors, 1948-2011
(average annual rate of change, per cent)



Source: BLS and BEA

magnificent ballet on a shrinking stage." As we will see, manufacturing represents a steadily declining share of nominal GDP and employment, even though rapid reductions in the relative price of manufactured goods (made possible in large part by rapid productivity gains) have maintained remarkable stability in manufacturing's share of real GDP.

Because the performance of the manufacturing sector is increasingly divorced from the rest of the economy, it is possible to share the authors' optimism about manufacturing while creating a very dismal forecast for the economy as a whole, particularly for future growth of the disposable income of the bottom 99 per cent of the American income distribution (Gordon, 2012). This comment presents several unique charts of historical data that emphasize the growing divergence between productivity growth in manufacturing and in the rest of the economy.

Chart 1 displays annual average growth rates of labour productivity from standard BLS data for the total economy and separately for the manufacturing and non-manufacturing sectors. The growth rates are calculated over four intervals designed to highlight the alternation of growth rates, high-low-high-low. These growth rate cycles are particularly evident when the postwar 1948-2011 period is divided at 1972, 1996, and 2004. Note that the width of the bars on the charts are proportional to the number of years in each interval.[2]

For the total economy, labour productivity displays the well-known rapid growth of 2.82 per cent per year for 1948-72, slow growth of 1.55 per cent for 1972-96, then a shorter eight-year interval of rapid growth for 1996-2004, and finally a second slowdown that has been little noticed heretofore, a growth rate of 1.59 per cent for 2004-12, virtually identical to what we have come to call the "dismal years" after 1972. But productivity growth in manufacturing shows a much happier picture of growth in these four intervals respectively of 2.46 per cent, 2.69 per cent, 4.60 per cent, and 2.52 per cent respectively. In manufacturing, there has been no slowdown at all, with the 2004-12 period matching the growth rate of 2.46 per cent achieved in the "golden years" of 1948-72 and the dot.com years of 1996-2004 exceeding any precedent in U.S. history.

Arithmetic dictates that the non-manufacturing sector mimicks the alternation of fast-slow-fast-slow evident in the total economy. The growth rates for the four intervals in non-manufacturing alternate between fast (2.95 per cent in 1948-72), then slow (1.29 per cent in 1972-96), then fast again (2.63 per cent in 1996-2004), and then a return to slow (1.47 per cent in 2004-

2 The BLS publishes data only for the private business sector (with and without the farm sector). All aggregate data in this comment refer to the total economy. Coverage is extended from the private business sector to the total economy by using BEA data on output and hours for the non-private sector, i.e., government, households, and institutions. The BLS does not publish productivity measures for non-manufacturing; these are backed out from the underlying data by using BEA shares of nominal value added in each sector.

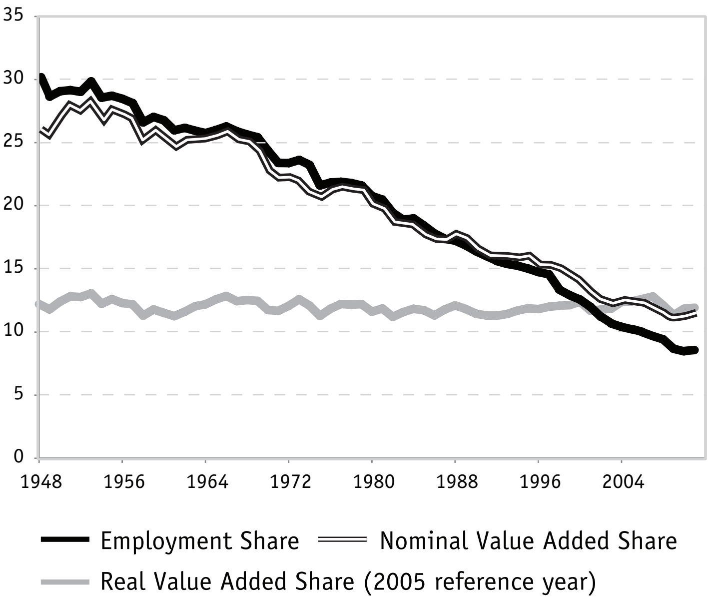
2011). The emerging data for 2012 confirm that productivity growth has returned to a slow path. Total economy labour productivity growth averaged only 0.3 per cent per year in the 12 quarters ending in 2012:Q4.

This initial examination of the data confirms the conclusion of Baily *et al.* (2013) – the United States has many problems, but productivity growth in the manufacturing sector is not one of them. The problem is that manufacturing is shrinking as a share of the total economy and as a result, its outstanding performance has an ever-smaller weight in the determination of productivity growth for the total economy. Chart 2 shows that between 1953 and 2011 the share of overall employment in the manufacturing sector dropped from 30 per cent to 8 per cent. Almost as dramatic was the decline in manufacturing's share of nominal GDP from 28 per cent to 12 per cent. Only the real GDP share remained relatively stable, starting and ending the postwar years at roughly 12 per cent. But the elementary theory of chain-weighted index numbers requires that the share of manufacturing in the national total be based on its share in nominal GDP, not real GDP.

At the total economy level, the U.S. productivity performance cannot be saved by manufacturing alone because the share of that sector is shrinking. In my view, productivity growth is faltering in the total economy because of a reality that is becoming ever more evident as the years march on. The second Industrial Revolution of the late 19th century, with all its inventions and spin-offs, was fundamentally more important than the third Industrial Revolution associated with the computer and its spin-offs.

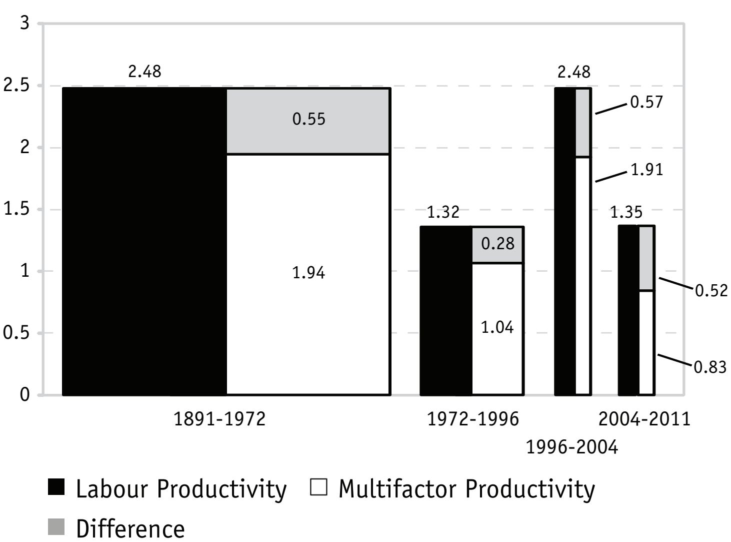
Chart 3 is a novel way to appreciate the role of the two industrial revolutions. Shown are the growth rate of labour productivity, multifactor productivity (MFP) and the difference between them, with the same postwar years separating

Chart 2
Importance of Manufacturing in the U.S. Total Economy, 1948-2011
(per cent)



Source: BLS and BEA.

Chart 3
Output per Hour and Multifactor Productivity in the United States, Total Economy, 1891-2011
(average annual rate of change, per cent)



Source: BLS, BEA, and Kendrick (1961).

the intervals but now with the first period extending back to 1891 rather than 1948.[3] By making the width of the bars proportional to the length of each interval, Chart 3 provides a convincing story of diminishing returns that was interrupted only briefly during 1996-2004.

The U.S. economy achieved a growth rate of labour productivity of 2.48 per cent per year for 81 years, followed by 24 years of 1.32 per cent, then a temporary recovery back to 2.48 per cent per cent, and a final slowdown to 1.35 per cent. The similarity of the growth rates in 1891-1972 with 1996-2004, and of 1972-96 with 1996-2011 is quite remarkable. The MFP series shown here includes the effects of shorter-lived capital ("capital quality") and higher educational attainment ("labour quality") as part of MFP rather than as separate contributions, a choice made due to data limitations rather than any disagreement with the Jorgenson-like MFP concept adopted by the BLS in its published MFP measures for the postwar years.

A remarkable aspect of Table 3 is the lack of importance of capital deepening (the difference between the growth rates of labour productivity and MFP) in explaining the ups and downs of U.S. economic growth over the past 120 years. As a result, the MFP growth rates exhibit the same ups and downs of the labour productivity growth measures. In the four intervals average annual MFP growth was 1.94 per cent for 1891-1972, 1.04 per cent in 1972-96, back up to 1.91 per cent in 1996-2004, and a mere 0.83 per cent for 2004-11.

Part of the reason for slowing productivity growth is the declining importance of inventions. I have often posed the following set of choices. Option A is to keep everything invented up until ten years ago, including laptops, Google, Amazon, and Wikipedia, while also keeping running water and indoor toilets. Option B is to keep everything invented up until yesterday, including Facebook, iphones, and ipads, but give up running water and indoor toilets; one must go outside to take care of one's needs; one must carry all the water for cooking, cleaning, and bathing in buckets and pails. Often audiences laugh when confronted with the choice between A and B, because the answer seems so obvious.

But running water and indoor toilets were not the only inventions between 1870 and 1970 that made it possible for U.S. labour productivity to grow at the 2.48 per cent rate displayed in Chart 3. The list is endless – electric light, elevators that made possible the vertical city, electric machine tools and hand tools, central heating, air conditioning, the internal combustion engine that replaced the horse, commercial aviation, phonographs, motion pictures, radio, TV, and many others including fundamental medical inventions ranging from aspirin to penicillin. By comparison the computer revolution kick-started productivity growth between 1996 and 2004 for only eight years, compared to the 81 years propelled by the second Industrial Revolution of the late nineteenth century.

While the diminishing importance of inventions may be controversial and difficult to quantify, the dire situation of education in the United States is easier to measure and interpret. The United States reached an educational plateau

3 Labour productivity growth estimates differ slightly between charts because they were constructed using a different mix of BLS and BEA sources, as needed for the bar charts to refer to the total economy. In Chart 1, the manufacturing sector data are as published by the BLS. For the total economy, the BLS data on the private business sector are supplemented by BEA data on output and hours in the non-private sector (government, households, institutions). The non-manufacturing growth rates are "backed out" from the total and manufacturing data by using BEA nominal shares of manufacturing and non-manufacturing in the total economy. For Charts 3 and 4, we use a different set of sources: output comes from Kendrick (1961) for 1891-1929 and from the BEA for 1929-2011 or 2012; hours come from Kendrick for 1891-1948 and from an unpublished BLS series on total economy hours for 1948-2011 or 2012. The capital stock estimates used to calculate to contribution of capital deepening to labour productivity growth come from Kendrick for 1891 to 1929 and from the BEA Fixed Assets Tables for 1929-2011.

more than 20 years ago. It is the only developed nation in which the 55-64 age group is as well-educated as the 25-34 age group. The United States has steadily slipped down the league table of post-secondary education completion and currently registers 15 percentage points lower than Canada. College cost inflation is even worse than inflation in the price of medical care, and college debt has now reached $1 trillion. The U.S. high school dropout rate scrapes the bottom of the OECD league tables. Dale Jorgenson has suggested that the transition from rising educational attainment to the current plateau will subtract 0.3 per cent per year from future growth.

The American economy is in deep trouble not only because of the inevitable slowing of productivity growth that is already evident in the data displayed in Chart 3. Growth in our standard of living is conventionally measured by output per capita, whereas labour productivity is output per hour worked. The standard of living can grow faster than labour productivity when there is an increase in hours per capita, and this happened between 1965 and 1990 as females entered the labour force.

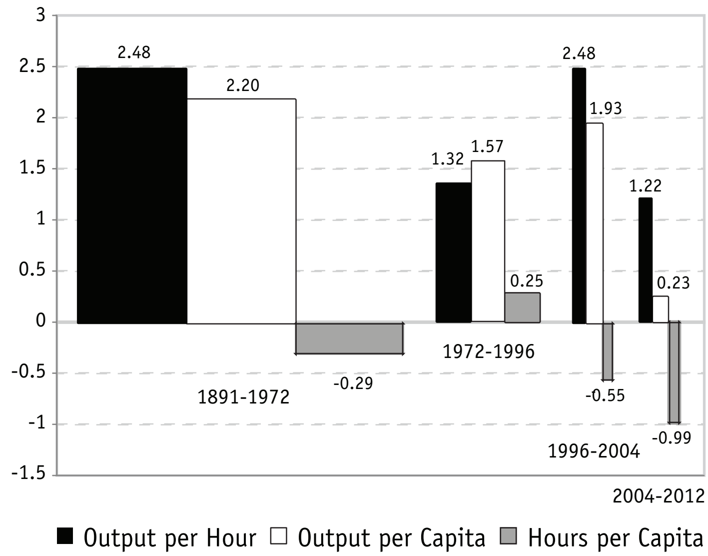
The relationship between growth in labour productivity and in the standard living is shown in Chart 4, where again the width of the bars reflect the length of the periods shown. In the golden age of 1891-1972, the standard of living almost kept up with productivity, falling short by 0.29 percentage points annual decline in hours per capita as working conditions improved and the average work week declined from roughly 60 to 40 hours. Then in 1972-96 the standard of living grew 0.25 percentage per year faster than labour productivity, as the entry of females into the labour force boosted hours per capita.

But after 1996 the bottom fell out of hours per capita, with a negative growth rate of 0.55 per cent per year during 1996-2004 and a catastrophic fall of 0.99 per cent per year between 2004 and 2011.

Chart 4

Output per Hour, Output per Capita, and Hours per Capita in the United States, 1891-2012

(average annual rate of change, per cent)

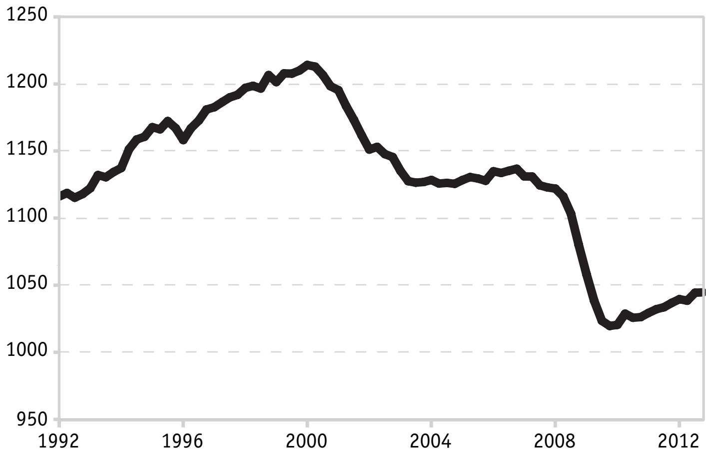


Source: BLS, BEA, and Kendrick (1961).

As a result, per capita income grew much more slowly than labour productivity in 1996-2004 and hardly grew at all between 2004 and 2011. Why did hours per capita fall so fast? Since the earliest cohort of the baby boomers was born in 1947, even those early retirees at age 62 would not have influenced the statistics until 2009, and yet the decline in hours began before that.

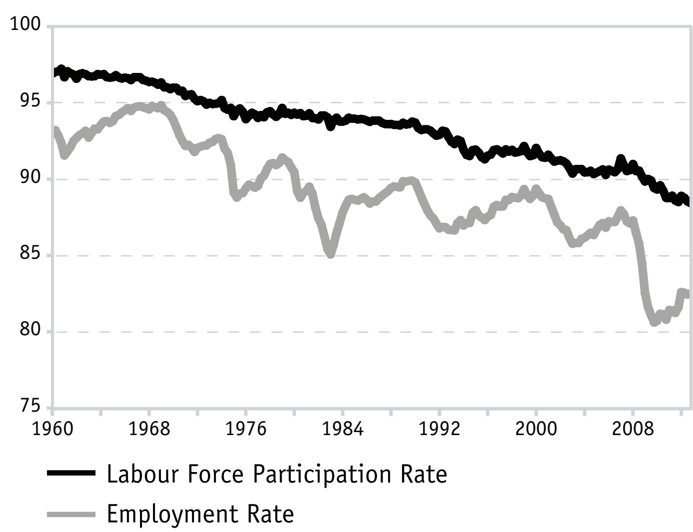
The data on hours per capita are plotted in Chart 5 and show a two-stage reduction in 2000-03 and then again after 2007. This chart supports the view of several analysts that the 2001-07 economic expansion was ephemeral, financed by an explosion of consumer and mortgage debt that disguised a fundamental underlying deterioration of the labour market. The further decline in hours per capita since 2007 may be due to the recession and sluggish recovery but cannot be swept aside in the absence of any evidence that the pace of the recovery is picking up steam.

Chart 5
Hours per Capita in the United States, 1992:Q1-2012:Q4
(Hours/Person)



Source: BLS.

Chart 6
Employment Rate and Labour Force Participation Rate in the United States, Males Ages 25-54, 1960:Q1-2012:Q4
(per cent)



Source: BLS.

Underlying the discouraging data on hours per capita is the phenomenon of labour force drop-out experienced by prime-age males (25-54). Chart 6 shows that the labour force participation rate of prime-age males declined between 1960 and 2012 from 96.9 per cent to 88.5 per cent. The employment-population ratio (or employment rate) declined even more, from 93.2 per cent to 82.6 per cent. This collapse in the employment-population ratio helps explain much of the reduction of hours per capita displayed in Chart 5, and most of the rest can be explained by the increase of involuntary part-time employment in the recent recession and sluggish recovery.

The headwinds buffeting the U.S. economy are formidable. The education headwind reduces future productivity growth. Other headwinds decrease growth in the standard of living relative to productivity growth, starting with the demographic headwind discussed above. Inequality is currently reducing the per capita income growth of the bottom 99 per cent of the income distribution a full 0.55 percentage points below the growth of the economy-wide averages shown in our charts. A further subtraction from future growth must be made when we compare growth of disposable income for the bottom 99 per cent compared to total income, because any significant attempt to stop the growth in the federal government's ratio of debt to GDP must involve slowing the growth of transfer payments and/or increasing the growth rate of tax payments, both of which reduce growth in disposable income compared to total income.

While I share the optimism of Baily *et al.* (2013) about the future of manufacturing productivity, I cannot find any escape from the inexorable arithmetic of the "exercise in subtraction" that I have discussed. The best current estimates of growth of per capita GDP for the UK in the four centuries between 1300 and 1700 register a mere 0.2 per cent annual rate, implying an interminable 350 years for the standard living to double, compared to the mere 35 years to which Americans became accustomed between 1891 and 2007. Once we subtract from the historical record the demographic, education, inequality, and debt headwinds, together with the likelihood that future inventions will not be as important as those of the second Industrial Revolution, we face a significant possibility that the disposable income growth for the bottom 99 per cent of the income distribution could be as low as 0.5 per cent per year, or perhaps even 0.2 per cent.

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Is the Information Technology Revolution Over?

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Abstract

Given the slowdown in labour productivity growth in the mid-2000s, some have argued that the boost to labour productivity from IT may have run its course. This article contributes three types of evidence to this debate. First, we show that since 2004 IT has continued to make a significant contribution to U.S. labour productivity growth, though it is no longer providing the boost that it did during the productivity resurgence from 1995 to 2004. Second, we present evidence that semiconductor technology, a key ingredient of the IT revolution, has continued to advance at a rapid pace. Finally, we develop projections of growth in trend labour productivity in the U.S. non-farm business sector. The baseline projection of about 1¾ per cent a year is better than recent history but is still below the long-run average of 2¼ per cent. However, we see a reasonable prospect — particularly given the ongoing advance in semiconductors — that the pace of labour productivity growth could rise back up to the long-run average. While the evidence is far from conclusive, we judge that "No, the IT revolution is not over."

Résumé

Compte tenu du ralentissement de la croissance de la productivité du travail au milieu des années 2000, certains prétendent que la hausse fulgurante de la productivité du travail grâce à la TI a fini par s'estomper. D'une part, nous constatons que, depuis 2004, la TI contribue toujours de façon significative à la croissance de la productivité du travail aux États-Unis. Par ailleurs, nous présentons des preuves selon lesquelles la technologie des semi-conducteurs, un ingrédient clé de la révolution de la TI, a continué de progresser à un rythme rapide. Enfin, nous élaborons une projection de la croissance de base de la tendance de la productivité du travail dans le secteur des entreprises non agricoles aux États-Unis de 1,75 % par année. Bien que cette statistique laisse entrevoir des gains inférieurs à la normale (mais meilleurs que dans l'histoire récente), nous croyons raisonnablement — surtout compte tenu de la progression continue des semi-conducteurs — que le rythme de croissance de la productivité du travail pourrait revenir à sa moyenne à long terme de 2,25 %. Bien que ces preuves soient loin d'être concluantes, nous croyons que “non, la révolution de la TI n'est pas terminée”.

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THE RATE OF INCREASE IN labour productivity in the United States — an essential element determining improvements in living standards — slowed in the mid-2000s, as highlighted by Fernald (2012), Gordon (2012), Jorgenson (2012), and Kahn and Rich (2013), among others. If this development persists, the long-run outlook for economic growth, and for improvements in living standards, will have darkened. Accordingly, it is important to identify the source of the slowdown and assess the implications for future growth.

One possible explanation of the slower pace of productivity growth is that the economy has taken a long time to recover from the financial crisis and Great Recession, as the repair of balance sheets has proceeded slowly and as uncertainty about the strength of the recovery has held back investment.[2] Although the slowdown in labour productivity growth started before the onset of the financial crisis, those developments could, nonetheless, be contributing to the continued tepid advance. Another possibility — advocated most prominently by Cowen (2011) — is that the U.S. economy has entered a long period of stagnation as the easy innovations largely have been exploited already. Gordon (2012 and 2013) has offered a third take on the slowdown, related to Cowen's. Namely, Gordon argues that the information technology revolution has mostly run its course and that the boost to productivity growth in the mid-1990s from those developments lasted only about a decade.[3] Brynjolfsson and McAfee (2011) and others have made the opposite argument, that the information technology (IT) revolution still has a long way to run and will continue to dramatically transform the U.S. economy.[4] Taking a middle ground, Baily, Manyika, and Gupta (2013) argue that technology (in IT or other fields) is not stagnating but that the future path of productivity is very uncertain. The question raised by this debate is the central focus of this article: is the IT revolution in the United States over?[5]

Obviously, this question is difficult to answer. The structural transformations and economic benefits spawned by continuing advances in IT are challenging to track and quantify. For example, what will be the economic consequences of massively greater connectivity with handheld and other devices and ready access to huge amounts of information, of 3-D printing and other dramatic changes in manufacturing processes, and of the changes brought on by companies like Google, Apple, Facebook, and Amazon that have rapidly come to dominate market segments that were not even imagined some years ago? One way to cut through this complexity is to concentrate on a central theme in these developments — the ability to harness ever-greater

2 Reinhart and Rogoff (2009) documented the typical pattern of slow recovery from financial crises. See Fernald (2012) for a discussion of the performance of productivity before, during, and after the Great Recession.

3 A large literature has examined these issues in the past. For our contribution to this literature and for citations to the earlier literature, see Oliner and Sichel (2000, 2002) and Oliner, Sichel, and Stiroh (2007). An interesting recent paper is Feenstra, Mandel, Reinsdorf, and Slaughter (2013), which presents evidence that about one-eighth of the pickup in labour productivity growth in the United States (and one-fifth of the pickup in multifactor productivity growth) after 1995 reflected mismeasurement in the terms of trade.

4 We use the term IT to refer to the collection of technologies related to computer hardware, software, and communication equipment. Other authors have used the term ICT (referring to information and communication technologies). We regard the two terms as synonymous. Although the IT capital considered in this article encompasses a wide range of assets, it excludes intangible capital other than software. For research that takes intangible capital into account, see Corrado, Hulten, and Sichel (2009), Corrado and Hulten (2012), Corrado, Haskel, Jona-Lasinio, and Iommi (2012), and Oliner, Sichel, and Stiroh (2007).

5 For more on Brynjolfsson's and Gordon's perspectives, see their debate on TED (Technology, Entertainment, Design) on February 26, 2013. Available at http://conferences.ted.com/TED2013/program/guide.php.

computing power that comes in progressively smaller and less expensive packages. That focus on the capital that lies behind the IT revolution drives the analysis in this article. Our analysis is by no means definitive, but we believe it provides a useful contribution to the debate over whether the IT revolution is over.

Our evidence comes in three parts. First, we use the growth accounting framework developed by Oliner and Sichel (2002) and Oliner, Sichel, and Stiroh (2007) to assess the contribution of IT to growth in labour productivity. This methodology is well suited to the task because it focuses on the contribution of IT to labour productivity growth from both the *use* of IT and from efficiency gains in the *production* of IT and because it can be updated with the most recent data to provide estimates through 2012. Our growth accounting evidence indicates that the contribution of IT to labour productivity growth in the United States from 2004 to 2012 stepped down to roughly its contribution from the mid-1970s to 1995. This evidence supports the view that the contribution from IT is no longer providing the boost to growth in labour productivity that it did during the years of the productivity resurgence from 1995 to 2004. Nonetheless, the IT contribution remains substantial, accounting for more than a third of labour productivity growth since 2004.

Those results indicate where the economy has been. For the second part of our answer, we use the steady state of our multi-sector growth model to assess the outlook for growth in labour productivity. This part of the article allows us to translate alternative assumptions about the pace of technological progress in the IT sector and the rest of the economy into an overall growth rate of labour productivity. We find that a plausible assessment of these underlying trends points to labour productivity growth for the non-farm business sector of 1.8 per cent annually. This projection is about the same as the average forecast of other productivity analysts.

Our baseline projection represents a modest pickup from the sluggish pace of labour productivity growth experienced since 2004. The pickup reflects ongoing advances in IT and an assumption that those gains and innovations in other sectors spur some improvement in multifactor productivity (MFP) growth outside of the IT sector relative to its tepid pace from 2004 to 2012.[6] These developments feed through the economy to provide a modest boost to labour productivity growth. That said, our projection of growth in labour productivity falls short of the long-run average rate of 2¼ per cent that has prevailed since 1889 and suggests neither a return to rapid growth nor economic stagnation but rather a period of moderate gains.[7]

Given the ongoing advance in semiconductor technology described below, along with the uneven pattern of productivity growth during earlier epochs of innovation, we also consider an alternative scenario in which a somewhat faster pace of improvement in IT spurs more rapid innovation throughout the economy.[8] With plausible assumptions, this alternative scenario generates labour produc-

6 See Baily, Manyika, and Gupta (2013) for a discussion of ongoing innovation in different sectors of the economy.

7 To calculate this long historical average, we used data on output and hours from Kendrick (1961) for 1889-1929 and from the Bureau of Economic Analysis (output) and Kendrick (hours) for 1929-47. Gordon (2010: 25) provides details about the sources of these data series. For 1947-2012, we used data from the Bureau of Labor Statistics on output per hour in the non-farm business sector. The growth rate over each period is calculated as the average log difference between the initial and final year of the period.

8 As Chad Syverson points out in his comments on this article (Syverson, 2013), electrification generated, after a long lag, a period of elevated growth in labour productivity that lasted for about a decade. That pickup was followed by a slowdown, but, subsequently, productivity growth rates picked up again.

tivity growth of about 2½ per cent, above the long-run historical average.

Finally, we reassess the pace of advance of semiconductor technology.[9] We believe that these developments are an essential consideration, because exceptionally rapid improvements in semiconductor technology — making computing power faster, smaller, and cheaper — have been a key ingredient of the IT revolution. On this front, the official price indexes for semiconductors developed by the Bureau of Labor Statistics (BLS) show that quality-adjusted semiconductor prices are not falling nearly as rapidly as they did prior to the mid-2000s. This development implies, all else equal, that the pace of technical progress in the semiconductor industry has slowed, a narrative that would comport well with Gordon's view that the IT revolution in the United States largely is over. However, our reassessment indicates that technical progress in the semiconductor industry has continued to proceed at a rapid pace. We also provide preliminary results from a separate research project that suggest the BLS price series may have substantially understated the decline in semiconductor prices in recent years.

Our three types of analysis, taken together, provide some useful insights into the question of whether the IT revolution is over. While the growth accounting evidence through 2012 confirms Gordon's view that the contribution from IT has fallen since 2004, the results from our steady-state analysis and our evidence on semiconductor prices point in a more optimistic direction. To answer the question posed in the title of the paper: "No, we do not believe the IT revolution is over." While our baseline projection anticipates a period of slightly sub-par gains for labour productivity, we see a reasonable prospect that the pace of labour productivity growth could rise back up to its long-run average of 2¼ per cent or even move higher.

Growth Accounting: Analytical Framework, Data, and Results

This section assesses the contributions to the increase in labour productivity from 1974 to 2012 through the lens of a growth accounting model designed to focus on the use and production of IT capital.

Analytical Framework

Here we provide a brief overview of the growth accounting framework. Additional detail can be found in Oliner, Sichel, and Stiroh (2007), henceforth OSS, and the appendix to that article.

The model that underlies our analysis differs from that in OSS only with regard to the treatment of intangible capital. Here, we use the measure of non-farm business output in the National Income and Product Accounts (NIPAs), which excludes most types of intangible capital other than software. In contrast, OSS incorporated a broader set of intangible assets to explore the role of intangibles in driving productivity growth. Although that analysis yielded useful insights about the sources of growth, the standard output measure used here lines up with the official data for the United States.

The growth accounting model divides non-farm business into four sectors that produce final output: computer hardware, software, communication equipment, and a large non-IT-producing sector. We also include a sector that produces semiconductors, which are either consumed as intermediate input by the domestic final-output sectors or exported. Every sector is

9 For a discussion of the linkages between the pace of innovation in semiconductor manufacturing and semiconductor prices, see Aizcorbe, Oliner, and Sichel (2008) and Flamm (2007).

assumed to have constant returns to scale, and we assume the economy is perfectly competitive. In addition, as discussed in OSS, we allow for cyclical variation in the utilization of capital and labour and for adjustment costs that reduce market output when firms install new capital. The treatment of both adjustment costs and cyclical utilization follows that in Basu, Fernald, and Shapiro (2001).

The appendix to OSS shows that this model generates a standard decomposition of growth in output per hour:

$$(1)\quad \dot{Y} - \dot{H} = \sum_j \alpha_j^K(\dot{K}_j - \dot{H}) + \alpha^L \dot{q} + \dot{MFP},$$

where the dots signify growth rates; Y is non-farm business output; H is aggregate hours worked; K_j is capital input of type j (where j = computer hardware, software, communication equipment, and an aggregate of all other tangible capital); α^L and α_j^K are, respectively, the income shares for labour and each type of capital; q measures labour composition effects that create a wedge between aggregate labour input and hours worked; and MFP denotes multifactor productivity. Equation 1 expresses the growth in labour productivity as the sum of the contributions from capital deepening, compositional changes in labour input, and multifactor productivity.[10]

The other key result from the model is an expression for the decomposition of aggregate MFP growth into sectoral contributions:

$$(2)\quad \dot{MFP} = \sum_i \mu_i \dot{MFP}_i + \mu_S \dot{MFP}_S,$$

where i indexes the final-output sectors (computer hardware, software, communication equipment, and all other non-farm business); S denotes the semiconductor sector; and each μ represents gross output in that sector divided by aggregate value added, both in current dollars. Thus, aggregate MFP growth equals a share-weighted sum of the sectoral MFP growth rates.

We estimate these sectoral growth rates with the "dual" method that employs data on prices of output and inputs, rather than data on quantities. Because the necessary price data are available much sooner than the corresponding quantity data, the dual method allows us to calculate more timely estimates of sectoral MFP growth.

Data

For the most part, the data sources track those used in OSS and Oliner and Sichel (2000, 2002), which relied heavily on data from the BLS and the NIPAs. That said, we have made some changes to our data sources. We highlight briefly a few key changes here, with details on our data sources provided in an appendix available online.[11]

For our capital deepening estimates, we are now working from a higher level of aggregation than in our earlier research. Previously, we built up estimates of capital deepening from data on 63 different types of assets, including detail on different types of hardware and software. Now, for the period from 1987 to 2010 for which the BLS provides extensive data, we are starting directly with BLS estimates for hardware, software, and communication equipment; that is, we are using the BLS aggregation within these categories rather than doing our own aggregation. Similarly,

10 Equation 1 simplifies one aspect of the expression derived in OSS. Technically, the weight on the capital deepening term for type j capital equals its income share minus the elasticity of adjustment costs with respect to that type of capital. We have suppressed the adjustment cost elasticity in equation 1. Because empirical estimates of asset-specific adjustment cost elasticities are not available, OSS approximated the theoretically correct weights with standard income shares. We do the same here and simply start from that point in equation 1. The approximation does not affect the total weight summed across the capital terms, as the theoretically correct weights and the standard capital income shares both sum to one minus the labour share. But the approximation could result in some misallocation of the weights across types of capital.

11 The Data Appendix can be found at http://www.csls.ca/ipm/25/appendix-byrne-oliner-sichel.pdf.

Table 1

Contributions to Growth of Labour Productivity in the U.S. Non-Farm Business Sector[a]

	1974-1995 (1)	1995-2004 (2)	2004-2012 (3)	Change between 1974-1995 and 1995-2004 (2) – (1)	Change between 1995-2004 and 2004-2012 (3) – (2)
1. Growth of labour productivity[b]	1.56	3.06	1.56	1.50	-1.50
Contributions (percentage points per year):					
2. Capital deepening	0.74	1.22	0.74	0.48	-0.48
3. IT capital	0.41	0.78	0.36	0.37	-0.42
4. Computer hardware	0.18	0.38	0.12	0.20	-0.26
5. Software	0.16	0.27	0.16	0.11	-0.11
6. Communication equipment	0.07	0.13	0.08	0.06	-0.05
7. Other capital	0.33	0.44	0.38	0.11	-0.06
8. Labour composition	0.26	0.22	0.34	-0.04	0.12
9. Multifactor productivity (MFP)	0.56	1.62	0.48	1.06	-1.14
10. Effect of adjustment costs	0.07	0.07	-0.02	0.00	-0.09
11. Effect of utilization	-0.01	-0.06	0.16	-0.05	0.22
12. MFP after adjustments	0.50	1.61	0.34	1.11	-1.27
13. IT-producing sectors	0.36	0.72	0.28	0.36	-0.44
14. Semiconductors	0.09	0.37	0.14	0.28	-0.23
15. Computer hardware	0.17	0.17	0.04	0.00	-0.13
16. Software	0.06	0.10	0.08	0.04	-0.02
17. Communication equipment	0.05	0.07	0.02	0.02	-0.05
18. Other non-farm business	0.13	0.90	0.06	0.77	-0.84
Memo:					
19. Total IT contribution[c]	0.77	1.50	0.64	0.73	-0.86

Source: Authors' calculations.

a. Detail may not sum to totals due to rounding.

b. Measured as 100 times average annual log difference for the indicated years.

c. Sum of lines 3 and 13.

we are relying directly on BLS data for estimates of overall capital deepening. For 2011 and 2012 we extend the BLS data using NIPA data at this higher level of aggregation. Before 1987, the BLS does not provide the necessary detail for IT capital on its website, and we splice in estimates from the data constructed in OSS.

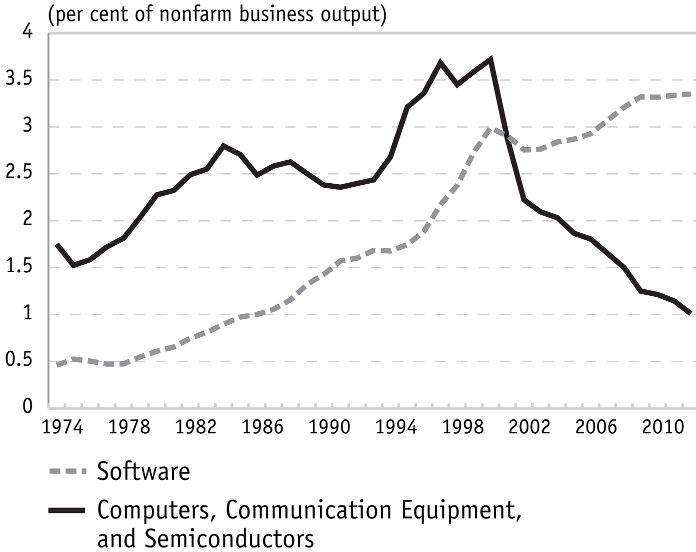
For the decomposition of MFP growth into sectoral contributions, we now use different price indexes for the output of the communications sector and the semiconductor sector. For the communications sector, we use the price index developed by Byrne and Corrado (2007), which falls more rapidly than does the NIPA price index for communication equipment. For semiconductor prices, we use the new index developed for the Federal Reserve's Industrial Production data.[12] The Fed's series incorporates a new hedonic index for microprocessors (MPUs) since 2006 that falls more rapidly than the current BLS price index.

Results

Table 1 summarizes our growth accounting results, both for the decomposition of labour productivity growth into capital deepening and aggregate MFP (to highlight IT use) and for the decomposition of MFP growth by sec-

12 This index was incorporated into the Industrial Production data in March 2013.

Chart 1
Current-dollar Output Shares for IT Industries



Source: Authors' calculations.

tor (to highlight efficiency gains in IT production).

As can be seen from the first three columns, labour productivity growth from 2004 to 2012 ran at just above an annual rate of 1½ per cent, down considerably from the elevated pace of the 1995-2004 period and in line with the disappointing average rate that prevailed over the prior two decades. The sources of labour productivity growth follow a similar pattern, with both the contribution of overall capital deepening and MFP growth falling off over 2004-2012 to about the pace observed from 1974 to 1995.

The memo item in the table shows the combined contribution to labour productivity growth from the *use* and *production* of IT. That contribution was 0.64 percentage point from 2004 to 2012, down significantly from its value from 1995 to 2004 and even a little below its contribution from 1974 to 1995. Nonetheless, the contribution of IT to labour productivity growth remains sizable, accounting for more than one-third of the growth in labour productivity from 2004 to 2012. The substantial contribution of IT is notable given that the share of total income accruing to IT capital remains small and that the IT-producing sector has never accounted for as much as 7 per cent of current-dollar output in non-farm business (Chart 1).

As for the separate contributions from the use of IT (capital deepening) and from efficiency gains in the production of IT, the patterns are similar, with the contributions over 2004-2012 well off from the rapid pace during 1995-2004 and just a little below the contribution from 1974 to 1995. The slowdown in the contribution from the production of IT reflects both a slower pace of advance of MFP in each IT sector and a sizable step-down in the current-dollar output share of the industries producing computer hardware, communication equipment, and semiconductors. This drop reflects substantial movement of IT manufacturing from the United States to foreign locations. Indeed, as shown in Chart 1, the share of current-dollar non-farm business output represented by the production of computer hardware, communication equipment, and semiconductors has fallen more than 70 per cent from its peak in 2000.[13] In contrast, the output share of the software industry was higher from 2004 to 2012 than in either of the earlier periods.

These estimates reinforce Gordon's story that the contribution of the IT revolution has been disappointing since the mid-2000s. That said, sorting out the implications of these results for the future role of IT in the U.S. economy is difficult. One possibility is that the IT revolution largely has run its course and will provide much less of a lasting imprint on living standards than did the earlier epochs

13 As discussed later in the article, these shares likely are understated because the domestic activity of these firms is mismeasured to some extent. However, correcting any such mismeasurement would leave the trends in Chart 1 intact.

of innovation. Another possibility is that the boost to labour productivity growth is taking a pause during the transition from the personal computer (PC) era to the post-PC era. Just as a long lag transpired from the development of the PC in the early 1980s to the subsequent pickup in labour productivity growth, there could be a lagged payoff from the development and diffusion of extensive connectivity, handheld devices, and ever-greater and cheaper computing power.

In 1987, Robert Solow (Solow, 1987:36) famously said "You see the computer revolution everywhere except in the productivity data." As highlighted by Oliner and Sichel (1994), computers comprised too small a share of the capital stock in 1987 to have made a large contribution to overall productivity growth. But, several years later, the imprint of the revolution became very evident. In a parallel vein, one could now say: "You see massive connectivity and ever-cheaper computing power everywhere but in the productivity data." Subsequently, those contributions could become evident in aggregate data. That, of course, is just speculation about the future. The next part of our analysis looks ahead to highlight plausible paths for labour productivity growth in the years ahead.

Outlook for Productivity Growth

We now turn to the outlook for labour productivity in the United States. The first part of this section uses the steady state of our growth accounting model to develop estimates of future growth of labour productivity. We then compare the steady-state results to the projections from a variety of other sources.

Steady-state Analysis

We update the steady-state analysis in Oliner and Sichel (2002) and OSS to incorporate the latest available data. As in that earlier work, we impose a set of conditions on the growth accounting model to derive an expression for the growth of labour productivity in the steady state. These conditions include that (i) real output in each sector grows at a constant rate (which differs across sectors); (ii) real investment in each type of capital grows at the same constant rate as the real stock of that capital; (iii) labour hours grow at the same constant rate in every sector; (iv) the work week is constant; and (v) the growth contribution from the change in labour composition is constant.

Under these conditions, the appendix to OSS shows that the steady-state growth of aggregate labour productivity can be expressed as:

$$(3)\ \dot{Y} - \dot{H} = \sum_i [(\alpha_i^K / \alpha^L)(\dot{MFP}_i - \beta_i^S \dot{MFP}_S)] + \dot{q} + \dot{MFP}$$

with

$$(4)\ \dot{MFP} = \sum_i \mu_i \dot{MFP}_i + \mu_S \dot{MFP}_S$$

As before, the α_i^K's denote income shares for each type of capital, β_i^S is the semiconductor share of total costs in final-output sector i, $\dot{q}$ is the change in labour composition, and the μ's denote current-dollar output shares in each sector. The expression for aggregate MFP growth in equation 4 is unchanged from equation 2, the expression that holds outside the steady state. Although no explicit terms for capital deepening appear in equation 3, capital deepening is determined endogenously from the improvement in technology. The terms in brackets capture the growth contribution from this induced capital deepening. Accordingly, equation 3 shows that steady-state growth in output per hour equals the sum of growth in MFP, the change in labour composition, and the contribution from the capital deepening induced by MFP growth.[14]

14 In the steady state, cyclical factors and adjustment costs have no effect on MFP growth. These effects disappear as a consequence of assuming that the work week is constant and that investment and capital stock grow at the same rate for each type of capital.

Table 2
Steady-State Growth of Labour Productivity in the U.S. Non-Farm Business Sector[a]

Source	History	Steady State	
	2004-12	Baseline[b]	Alternative[c]
Growth of labour productivity (per cent per year)	1.56	1.80	2.47
Contributions (percentage points per year):			
Capital deepening	0.74	1.03	1.34
Change in labour composition	0.34	0.07	0.07
MFP	0.48	0.70	1.06
IT-producing sectors[d]	0.29	0.38	0.46
Other non-farm business[d,e]	0.05	0.33	0.60
Adjustments[f]	0.14	0.00	0.00
Memo:			
MFP growth in other non-farm business	0.05	0.34	0.62

Source: Authors' estimates.

a. Detail may not sum to totals due to rounding.

b. Uses midpoint values for all parameters.

c. Uses upper-bound values for decline in IT-sector prices and upper-bound value for MFP growth in other non-farm business. All other parameters set to midpoint values.

d. After excluding the effects of adjustment costs and cyclical utilization.

e. Equals the product of MFP growth in this sector (shown in the memo line) and the sector's share of non-farm business output (which is close to one).

f. For effects of adjustment costs and cyclical utilization.

Steady-state growth in labour productivity depends on a large number of parameters — about 30 in all after accounting for those that lie behind the income shares and sectoral MFP growth rates shown in equations 3 and 4. We consider a range of values for these parameters. The complete list can be found in Appendix Table A1. Individually, most of these parameters do not have large effects on the steady-state growth rate. However, two parameters in equations 3 and 4 are important: the rate of improvement in labour composition and MFP growth for non-farm business outside the IT-producing sector ("other non-farm business"). For labour composition effects, we rely on the latest projection based on the methodology in Jorgenson, Ho, and Stiroh (2005).[15] In this projection, changes in labour composition boost labour productivity growth only 0.07 percentage point per year on average between 2012 and 2022, as educational attainment is anticipated to reach a plateau. To allow for uncertainty around this projection, we specify a range that runs from 0 to 0.14 percentage point. For MFP growth in other non-farm business, we use values that range from 0.06 to 0.62 per cent per year. The lower bound equals the average growth rate from 2004 to 2012, while the upper bound equals two-thirds of the much faster pace registered from 1996 to 2004, which would be a notable improvement over the recent performance.[16]

Using equations 3 and 4, we find that steady-state growth in labour productivity ranges from an annual rate of 0.88 per cent (when each parameter is set to its lower-bound value) to 2.82 per cent (using the upper-bound values). The wide range reflects the uncertainty about the future values of the underlying parameters. To obtain a baseline steady-state estimate, we set each parameter to the midpoint of its range. The resulting estimate of 1.80 per cent, shown in Table 2, is about 1/4 percentage point above the relatively small gains recorded on average since 2004. The contributions from capital deepening and MFP move up notably from the 2004-2012 pace, but these larger contributions are offset in part by the reduced contribution from labour composition.[17]

Table 2 also presents an alternative scenario that embeds a somewhat more optimistic view about the outlook for information technology.

15 We received this projection from Dale Jorgenson by email on December 19, 2012.

16 Although the steady-state projection does not apply to a specific time period, we think of it as pertaining to the outlook five to ten years ahead.

17 This contribution declines not only because of the projection that educational attainment will plateau, but also because the job losses during the Great Recession were skewed toward less educated workers, which shifted the mix of employment over 2004-12 toward more skilled workers, boosting the labour composition effect over that period.

In this alternative scenario, we allow for faster MFP growth in the IT-producing sectors by setting the rate of decline in output prices in each component industry to its upper-bound value. With this change, semiconductor prices fall 6 percentage points (at an annual rate) more quickly than in the baseline, while the speedup in the other IT sectors ranges from about 1 percentage point (software) to 3¾ percentage points (computer hardware). These price changes are not especially large in the context of the observed variation since 1974 (see Appendix Table A1). We assume that the resulting faster diffusion of new technology boosts MFP growth in the rest of non-farm business from the baseline value of 0.34 per cent annually to the upper-bound value of 0.62 per cent. All other parameters remain at their baseline values.

With these changes, steady-state growth of labour productivity rises to 2.47 per cent at an annual rate, almost ¾ percentage point above the baseline estimate. The faster assumed MFP growth directly augments the rate of increase in labour productivity. It also has a multiplier effect by inducing additional capital deepening. This scenario illustrates that it would not take a very large increase in the impetus from IT to raise labour productivity growth back to the neighborhood of its long-term historical average of 2¼ per cent or above.

Other Estimates

Table 3 compares our steady-state results to the projections of future growth in labour productivity from other analysts. The table displays the most recent projections from each source, along with the earlier projections that were presented in OSS.[18] As shown, the earlier projections ranged from 2.0 per cent to 2.5 per cent at an annual rate, with an average of 2.3 per cent — the same as the midpoint of the steady-state range in OSS. These earlier projections all have been revised down, some quite substantially. The average markdown from 2.3 per cent to 1.9 per cent virtually matches the downward revision in our steady-state estimate. Thus, compared with projections from six years ago, the average projected growth of labour productivity has moved down from about the long-run historical average to a pace somewhat below that average.

Table 3
Alternative Projections of U.S. Labour Productivity Growth
(per cent per year)

Source	As of 2007	As of 2012-13
1. Baseline steady-state estimate	2.3	1.8
2. Congressional Budget Office	2.3	2.1
3. John Fernald	n.a.	1.9
4. Robert Gordon	2.0	1.75
5. James Kahn and Robert Rich	2.5	1.8
6. Survey of Professional Forecasters[a]	2.2	1.8
Average of lines 2 through 6	2.3	1.9

Sources: 2007 estimates from Oliner, Sichel, and Stiroh (2007:Table 12) and 2012-13 estimates from Congressional Budget Office (2013:Table 2-2); Fernald (2012) "Benchmark Scenario" in Table 2; Gordon (2010), with adjustment provided in private correspondence; Kahn-Rich Productivity Model Update (February 2013) posted at http://www.newyorkfed.org/research/national_economy/richkahn_prodmod.pdf; Federal Reserve Bank of Philadelphia, *Survey of Professional Forecasters*, February 15, 2013, Table 7.

a. Median forecast in the survey.

We would stress that the similarity among these projections belies the high degree of uncertainty about future productivity growth. The range of estimates from our steady-state framework hints at this uncertainty. The low end of the range (less than 1 per cent) represents a dismal rate of productivity growth from a historical perspective, while the top end (about 2.8 per cent) is well above the historical average. The only projection in the table with a statistically-based confidence range is that from Kahn and Rich (2013).

18 With only a few exceptions, these projections refer to the non-farm business sector as defined by BLS over horizons of ten years or more. Among the exceptions, Kahn and Rich (2013) employ a five-year horizon, while there is no explicit projection period in Fernald (2012). In addition, Fernald's projection refers to the private business sector, which includes the farm sector.

Table 4
Year of Introduction for New Semiconductor Technology

Process (nanometers)	Industry Frontier	Intel MPU Chips
10,000	1969	1971
8,000	1972	n.a.
6,000	n.a.	1974
5,000	1974	n.a.
4,000	1976	n.a.
3,000	1979	1979[a]
2,000	1982	n.a.
1,500	1984	1982
1,250	1986	n.a.
1,000	1988	1989
800	1990	1991
600	1993	1994
350	1995	1995
250	1997	1997
180	1999	1999
130	2001	2001
90	2003	2004
65	2005	2005
45	2007	2007
32	2010	2010
22	2012	2012

Sources: Industry frontier: VLSI Research Inc. (2006) for the 65 nanometer and earlier processes and private correspondence with Dan Hutcheson (November 10, 2012) for the more recent processes. Intel MPU chips: http://www.intel.com/pressroom/kits/quickref-fam.htm.

a. Intel began making MPU chips with this process in 1979. We omitted Intel's earlier use of the 3000 nanometer process (starting in 1976) to produce less complex devices, such as scales.

n.a.: Not available

In their regime-switching model, the 75 per cent confidence band for productivity growth five years ahead runs from slightly below zero to about 4 per cent. Suffice it to say, productivity growth is extremely hard to predict. Almost all analysts have failed to anticipate the major shifts in growth over the past several decades, and we should not expect better going forward.

Trends in Semiconductor Technology

The contribution of information technology to economic growth depends importantly on the improvements in the semiconductor chips embedded in IT capital goods and on prices of those chips. This section presents the latest available information on technological progress in the semiconductor industry and on chip prices.

Technology Cycles

As discussed in Aizcorbe, Oliner, and Sichel (2008), there is a broad consensus that the pace of technical advance in the semiconductor industry sped up in the mid-1990s, a development first brought to the attention of economists by Jorgenson (2001). The standard definition of a semiconductor technology cycle is the amount of time required to achieve a 30 per cent reduction in the width of the smallest feature on a chip. Because chips are rectangular, a 30 per cent reduction in both the horizontal and vertical directions implies about a 50 per cent reduction (0.7*0.7) in the area required for the smallest chip component.

Table 4 presents the history of these scaling reductions for the semiconductor industry as a whole and microprocessor (MPU) chips produced by Intel, updating a similar table in Aizcorbe, Oliner, and Sichel (2008). As shown, the industry has achieved massive reductions in scaling over time, leaving the width of a chip component in 2012 about 450 times smaller (10,000/22) than in 1969. Throughout this period, Intel always has been at the industry frontier or within a year of the frontier.[19]

Given these introduction dates, Table 5 reports the average length of the technology

19 For the 1,500 nanometer process introduced in the early 1980s, the data indicate that Intel sold chips based on this technology two years before the process was used anywhere in the industry, an obvious inconsistency. Fortunately, this problem has no effect on the average length of the technology cycles that we present below because the average length depends only on the frontier technology at the beginning and end of the period under consideration, and there are no inconsistencies in these endpoint values.

cycle (as defined above) for various periods. For the industry as a whole, the technology cycle averaged three years until 1993 and then dropped to about two years from 1993 to 2012. Within the later period, the scaling advances were especially rapid from 1993 to 2003 and a bit slower after 2003. Even so, the average cycle since 2003 has remained substantially shorter than the three-year cycle in effect before the 1990s. For Intel's MPU chips, there has been no pullback at all from the two-year cycle. The upshot is that the cycles in semiconductor technology — a key driver of quality improvement in IT products — have remained rapid.

While the pace of miniaturization has been sustained, semiconductor producers have changed the approach used to translate these engineering gains into faster performance. Historically, each new generation of technology in semiconductors has allowed for an increase in the number of basic calculations performed per second for a given chip design. However, as speed continued to increase, dissipating the generated heat became problematic. In response, Intel shifted in 2006 toward raising "clock-speed" more slowly and boosted performance instead by placing multiple copies of the core architecture on each chip — a change enabled by smaller feature size — and by improving the design of those cores (Shenoy and Daniel, 2006).

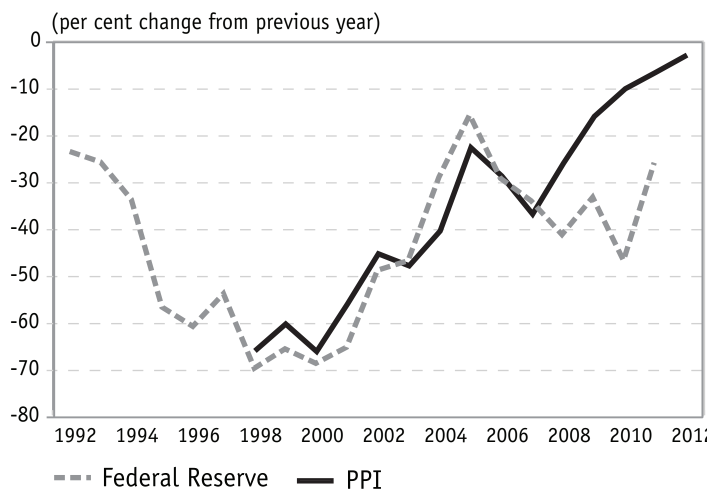
The effect of this strategy on the rate of increase in performance for end users has been a matter of some debate. Pillai (2013) examines the record and presents evidence that scores for Intel MPUs on benchmark performance tests — based on standard tasks designed to reflect the needs of computer users — rose more slowly from 2001 to 2008 than in the 1990s. Our own examination of more recent data suggests the slower rate of performance improvement has persisted through 2012. Nonetheless, even on this slower trend, our results show that the end-user performance of Intel's MPU chips improved roughly 30 per cent per year on average from 2001 to 2012. End users have continued to see substantial gains in performance, just not the extraordinary rate of increase recorded in the 1990s.

Table 5
Semiconductor Technology Cycles
(Years needed for 30 per cent reduction in linear scaling)

Industry Frontier		Intel MPU Chips	
Period	**Years**	**Period**	**Years**
1969-1993	3.0	1971-1994	2.9
1993-2012	2.1	1994-2012	1.9
1993-2003	1.9	1994-2004	1.9
2003-2012	2.3	2004-2012	2.0

Source: Authors' calculations from data in table 4.

Chart 2
Price Indexes for Microprocessors (MPUs)



Sources: BLS and Federal Reserve Board.

Prices for MPUs

Advances in semiconductor technology have driven down the constant-quality prices of MPUs and other chips at a rapid rate over the past several decades.[20] These declines, in turn, have lowered the prices of computer hardware, communication equipment, and other goods in which the chips are embedded, spurring the diffusion of IT capital goods throughout the economy. Thus, semiconductor prices play a central role in our assessment of whether the IT revolution still has legs.

On this score, the recent data on MPU prices, as measured by the producer price index (PPI), are not encouraging. As shown by the solid line in Chart 2, from the late 1990s — when the BLS adopted the current PPI methodology — to 2007, MPU prices fell at an average annual rate of about 50 per cent. But the rate of decline slowed in each year after 2007, so much so that the price index barely fell at all in 2012. The PPI data, if correct, would indicate that a fundamentally adverse shift in semiconductor price trends has taken place over the past several years.

In a separate in-progress paper, we are developing a new hedonic price index for MPUs, and some key results from that article are reported here. We compiled wholesale price lists for Intel MPUs and matched these prices to benchmark performance scores and other chip characteristics.[21] We then estimated a hedonic regression back to 2006 using only the list price at the time of introduction. We omitted the list prices for subsequent periods because in many cases those prices were not adjusted down when a more powerful, closely-related chip entered the market, contrary to the pattern in earlier years. The absence of price adjustment raises concern that existing chips are being sold at a discount relative to the constant list price that widens when new models are introduced. Thus, to the extent that significant chip sales are taking place at transaction prices that fall ever further below the list prices, a standard procedure that relied on those list prices or other similar prices reported by manufacturers would be biased. Our hedonic index, which only uses prices at the time of each new chip's introduction, provides a very rough way of avoiding this potential bias. This new hedonic index was incorporated into the Federal Reserve's March 2013 annual revision of its industrial production indexes.[22]

The key result from this new price index is that MPU prices have remained on a fairly steep downtrend, in sharp contrast to the picture painted by the PPI. The dashed line in Chart 2 presents the MPU price index constructed by Federal Reserve staff from its inception in 1992 through 2011, the final year that incorporates the new hedonic results. The Fed index of MPU prices fell at an average annual rate of 36 per cent from 2006 to 2011, somewhat less than that observed during the period of extraordinary productivity gains in the late 1990s, but substantially greater than the drop in the PPI in recent years. Moreover, unlike the PPI, the Fed's index provides no sign of a trend toward slower price declines over the past several years. All in all, the Fed's MPU price index lines up reasonably well with the MPU performance data described above — both series have reverted to historically normal rates of change after a period of unusually rapid performance gains and price declines.

Other IT-Related Measurement Issues

Beginning in the 1970s, many studies of semiconductors, computers, communication equipment, and software have concluded that quality-adjusted IT prices have fallen at remarkable

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20 Chips other than MPUs and memory (including those used in smartphones) are often produced using a technology behind the frontier. These chips adopt new technology, albeit with a lag. This process transmits the price declines at the frontier to a wide range of different chips.

21 Although we do not have access to BLS' source data, comments by BLS staff indicate that published wholesale price lists for MPUs have been used to supplement the data collected by the PPI survey (Holdway, 2001). We focus on Intel because of its large share of domestic MPU production.

22 For additional information, see the discussion of the revision at http://www.federalreserve.gov/releases/g17/revisions/Current/DefaultRev.htm. The price index is available at http://www.federalreserve.gov/releases/g17/download.htm.

rates, and indexes capturing these price declines have been incorporated into the NIPAs in many cases (Wasshausen and Moulton, 2006). However, despite this considerable progress on measuring IT prices, some important measurement challenges remain to be addressed. Here, we list three rather different areas that, in our view, would benefit from additional research.

First, investment in software is the largest component of IT investment, and quality adjustment has proven difficult for this category. While the BEA has closely studied software prices, this area has proved a tough nut to crack, and the agency is still using proxies for the prices of a significant fraction of software. With these proxies, the BEA's prices for own-account and custom software have increased in recent years. For prepackaged software, Copeland (2013) finds sizable declines in quality adjusted prices using scanner data.[23] Those declines are faster than those in the PPI for prepackaged software and contrast sharply with the price increases for custom and own-account software, suggesting that further work on software prices would be valuable.

Second, even if well-constructed price indexes for all IT equipment and software were available, the impact of the IT revolution may be understated for a very different reason. It has become common for U.S. manufacturing firms to outsource fabrication of electronics, frequently to offshore locations, but to retain the design and management tasks within the company, often in domestic locations. Because these so-called "factoryless manufacturers" may create the intellectual property and bear the entrepreneurial risk for products with rapidly increasing quality, the real value-added of these establishments arguably should reflect the innovation embodied in the product. Because in practice this activity is often classified within wholesale trade, the resulting output is not counted as part of the IT sector of the economy. Early studies of companies using the factoryless business model indicate this may be an appreciable share of economic activity (Bayard, Byrne, and Smith, 2013, and Doherty, 2013).

Finally, IT as defined in this article does not encompass all products with significant electronic content. We expect the prices for a broad array of electronic equipment would reflect the price declines for their semiconductor inputs, including navigation equipment, electromedical equipment, and a variety of types of industrial process equipment.[24] In fact, the PPIs for the output of these industries increase in most cases, again raising an important question for price analysts to investigate.[25]

These three rather different concerns all point to the possibility that the full impact of the IT revolution has not yet been recorded.

Conclusion

Is the information technology revolution over? In light of the slower pace of productivity gains since the mid-2000s, Robert Gordon has argued that the boost to productivity growth from adoption of IT largely had run its course by that point. Erik Brynjolfsson and others make the opposite case, arguing that dramatic transformations related to IT continue and will leave a significant imprint on economic activity. We bring three types of evidence to this debate, focusing on the IT capital that underlies IT-related innovations in the economy.

23 Also, see Prud'homme, Sanga, and Yu (2005) for similar evidence using Canadian scanner data.

24 Even products within the IT category may benefit from a closer look. For example, Chwelos, Berndt, and Cockburn (2008) develop hedonic price indexes for personal digital assistants from 1999 to 2004 and find average price declines ranging from 19 to 26 per cent per year.

25 A BLS paper by Holdway (2011) on the use of hedonics indicates that resource constraints have limited the expansion of the use of hedonic techniques.

What does this evidence show? Our analysis indicates that the contributions of IT to labour productivity growth from 2004 to 2012 look much as they did before 1995, supporting Gordon's side of the argument. Our baseline projection of the trend in labour productivity points to moderate growth, better than the average pace from 2004 to 2012, but still noticeably below the very long-run average rate of labour productivity growth. On the more optimistic side, we present evidence that innovation for semiconductors is continuing at a rapid pace, raising the possibility of a second wave in the IT revolution, and we see a reasonable prospect that the pace of labour productivity growth could rise to its long-run average of 2¼ per cent or even above. Accordingly, with all the humility that must attend any projection of labour productivity, our answer to the title question of the paper is: No, the information technology revolution is not over.

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Appendix Table A1. Parameter Values for Steady-State Calculations

	Historical Averages			Steady-State		Method for Setting Bounds
	1974-1995	1996-2004	2005-2012	Lower Bound	Upper Bound	
Output shares[1] (μ)						
1. Computer hardware	1.11	1.12	0.44	0.15	0.50	A
2. Software	1.02	2.60	3.17	3.00	3.50	A
3. Communication equipment	0.85	1.08	0.47	0.25	0.60	A
4. Other final-output sectors	97.05	95.20	95.84	96.52	95.32	B
5. Net exports of semiconductors	-0.04	-0.01	0.08	0.08	0.08	C
6. Total semiconductor output	0.39	0.80	0.52	0.40	0.65	A
Semiconductor cost shares[1] (β)						
7. Computer hardware	14.79	22.23	22.31	15.00	20.00	A
8. Software	0.00	0.00	0.00	0.00	0.00	C
9. Communication equipment	6.00	17.29	18.88	14.00	20.00	A
10. Other final-output sectors	0.21	0.38	0.26	0.29	0.34	B
Relative inflation rates[2] (π)						
11. Semiconductors	-26.25	-43.29	-26.28	-24.23	-36.35	D
12. Computer hardware	-19.11	-22.58	-14.72	-15.21	-22.81	D
13. Software	-5.57	-2.81	-2.43	-3.40	-5.11	D
14. Communication equipment	-6.89	-13.31	-8.55	-7.01	-10.51	D
Depreciation rates[3] (δ)						
15. Computer hardware	23.95	28.80	31.38	31.38	31.38	C
16. Software	31.58	34.44	37.75	37.75	37.75	C
17. Communication equipment	11.76	11.20	11.79	11.79	11.79	C
18. Other business fixed capital	5.69	5.76	5.38	5.38	5.38	C
Expected capital gains/losses[4] (Π)						
19. Computer hardware	-15.69	-15.74	-9.61	-10.28	-15.42	E
20. Software	0.35	-0.41	-0.26	-0.27	-0.40	E
21. Communication equipment	2.45	-3.44	-3.73	-2.86	-4.29	E
22. Other business fixed capital	5.74	3.10	2.69	2.33	3.49	E
Capital-output ratios ($Tp_K K/pY$)						
23. Computer hardware	0.020	0.030	0.024	0.020	0.029	A
24. Software	0.026	0.068	0.084	0.082	0.092	A
25. Communication equipment	0.072	0.081	0.070	0.060	0.075	A
26. Other business fixed capital	2.32	1.91	2.09	1.90	2.30	A
Income shares[1] (α)						
27. Computer hardware	0.98	1.50	1.13	.96	1.55	B
28. Software	1.04	2.76	3.75	3.66	4.12	B
29. Communication equipment	1.29	1.67	1.54	1.27	1.70	B
30. Other business fixed capital	19.91	16.53	19.38	18.29	19.47	B
31. Other capital[5]	8.85	7.53	8.11	8.11	8.11	C
32. labour	67.93	70.01	66.09	67.11	65.07	B
Other parameters						
33. Growth of "other" sector MFP[3]	0.14	0.94	0.06	0.06	0.62	F
34. Change in labour composition[3] (*q*)	0.26	0.22	0.34	0.00	0.14	G
35. Nominal return on capital[3] (*R*)	8.62	5.99	6.58	6.58	6.58	C
36. Ratio of domestic semiconductor output to domestic use (1+θ)	0.93	1.01	1.20	1.20	1.20	C

1. Current-dollar shares, in per cent.
2. Output price inflation in each sector minus that in the "other final-output" sector, in percentage points.
3. In per cent.
4. Three-year moving average of price inflation for each asset, in per cent.
5. Includes land, inventories, and tenant-occupied housing.

Key: Methods for setting steady-state bounds.

A. Range around recent values.
B. Implied by other series.
C. Average value over 2005-2012.
D. The lower and upper bounds equal, respectively, 0.8 and 1.2 times the average rate of change over 1974-2012.
E. The lower and upper bounds equal, respectively, 0.8 and 1.2 times the average rate of change over 1996-2012.
F. The lower bound equals the average rate of MFP growth in this sector over 2005-12; the upper bound equals 2/3 times the average rate over 1996-2004.
G. Based on a forecast obtained from Dale Jorgenson for 2012-22 (private correspondence, December 19, 2012). Jorgenson's forecast is a point estimate of 0.07 per cent annually. We set symmetric bounds around this point forecast.

DATA APPENDIX

This appendix describes the data series used in the article. All data are annual and cover the period from 1974 to 2012 inclusive.

Real Output per Hour in the Non-Farm Business Sector (*Y/H*)

Data from 1974 through 2008 are from the tables the BLS makes available with its multifactor productivity (MFP) release. We used the version of the MFP data released on March 21, 2012.[1] For 2009-2012, we extended the BLS series using the annual growth rate of BLS' series for output per hour in the non-farm business sector from its quarterly Productivity and Cost (P&C) Release.[2] We used data from the P&C release starting in 2009 so as to incorporate revisions to real output in the non-farm business sector in the BEA's 2012 annual revision of the National Income and Product Accounts (NIPAs).

Real Output (*Y*), Current-dollar Output (*pY*), and Price Index (*p*) for the Non-Farm Business Sector

Data for real output and current-dollar output for 1974-2008 are from the MFP dataset. For 2009-2012 we extended the BLS series using annual growth rates for real output and current-dollar output in the non-farm business sector from the NIPAs.[3] We measured p as an implicit price deflator, constructed as the ratio of current-dollar non-farm business output to real non-farm business output from the MFP dataset for the period 1974-2008. For 2009-2012, we extended the series for p using annual growth rates constructed from the NIPA data on real output and current-dollar output in the non-farm business sector.

Labour Hours (*H*)

For 1974 to 2010, labour hours are from the MFP dataset. We extended the data to 2012 using the growth rate in hours of all persons in the non-farm business sector from the P&C release.

Contribution of Capital Deepening in the Non-Farm Business Sector

Overall Capital Deepening

For 1974 to 2010, the contribution of overall capital deepening to growth in labour productivity is calculated as the product of: 1) the log difference of the capital-hours ratio (using real capital input) and 2) capital's income share. Our income shares are time varying and not period averages.[4] The data for the capital-hours ratio and the income shares are from the MFP dataset.

For 2011 and 2012, we extended the series for the overall capital deepening contribution using the following steps. First, we calculated the contributions from 2010 to 2012 for equipment, non-residential structures, inventories, tenant-occupied rental housing, and land (we use these categories because these are the ones for which BLS makes data readily available on their website). For each asset type, the contribution is calculated as the product of the income share and the log difference of the capital-hours ratio. For the numerator of the capital-hours ratio, we constructed productive capital stocks as

1 All other series we use from the MFP data are also from that release. These data are available at http://www.bls.gov/mfp/mprdload.htm. See the spreadsheets titled "Historical Multifactor Productivity Measures (SIC 1948-87 linked to NAICS 1987-2011)" and "Information Capital by Asset Type for Major Sectors."

2 We used data from the release dated February 7, 2013.

3 All of the NIPA data we use are from the release dated January 30, 2013.

4 For each year, the share used is the average of the income share for that year and the income share for the previous year. We use the same procedure for the IT capital shares described below.

described below. For the denominator, we used hours data from BLS as described above. Second, we summed these contributions to obtain a capital deepening contribution for overall capital for 2010 to 2012. Finally, we extrapolated forward from the BLS 2010 contribution with the first-difference in our calculated contributions between 2010 and 2011 and then between 2011 and 2012. We did not use the levels for 2011 and 2012 directly because we are working at a higher level of aggregation than BLS used to calculate the overall capital deepening contribution through 2010, which introduces a wedge between the results in levels for a given year.

IT Capital Deepening

For 1987 to 2010, capital deepening contributions for each type of IT capital are calculated as the product of: 1) the log difference of the capital-hours ratio using real capital input for each type of IT (computer hardware, software, and communication equipment) and 2) the income share for that type of capital. The data for capital input, hours, and the income shares for each type of IT capital are from the MFP dataset.

For 2011 to 2012, we extended the series for the contributions using a procedure exactly parallel to that for the components of overall capital deepening.

For 1974 to 1986, the BLS does not make available the needed IT detail on their website. Accordingly, for each type of IT capital, we construct contributions from data for the income share, capital input, and hours, extrapolating back from the 1987 contributions by splicing in values for these variables from the dataset we constructed for Oliner, Sichel, and Stiroh (2007).

Capital Deepening for Non-IT assets

These contributions are calculated by subtracting the IT capital deepening contributions from the overall capital deepening contribution.

Productive Stocks

To extend the capital deepening contributions to 2011 and 2012 as described above, we used productive capital stocks to measure capital input for each category of capital, in accord with BLS methodology. For the calculations for total capital, we need productive stocks for each of the capital categories we use to sum up to total capital (equipment, non-residential structures, inventories, tenant-occupied rental housing, and land). For the calculations for IT capital, we need productive stocks for each of the IT capital categories (computer hardware, software, and communication equipment).

Depreciable Assets

For depreciable assets (equipment and software, non-residential structures, tenant-occupied rental housing, and the three types of IT capital) we started with productive capital stock data from the MFP dataset through 2010 (the same spreadsheets described above). We extended these BLS productive stock series to 2011 and 2012 using the perpetual inventory method with the following equation:

$K_t = f_t K_{t-1} + (I_t + I_{t-1})/2$,

where (following BLS methodology) K_t is measured as the average of the stocks at the end of years t and $t-1$. For the investment series (I_t), we started with the series for gross investment through 2010 for each category from the BLS datasets. We extended these investment series to 2011 and 2012 using growth rates of real investment for the corresponding series from NIPAs. The term f_t is a translation factor that converts the productive stock from period $t-1$ into the productive stock for period t. We obtain this translation factor (f_t) for each period up through 2010 using the published BLS data and solving for f_t for each year in the equation above. We then use the 2010 value of f_t to generate estimates of the productive stock for 2011 and 2012.

Non-Depreciable Assets (Inventories and Land)

To extend the stock of inventories to 2011, we take the productive stock in 2010 and add the NIPA value for the change in real private inventories for 2011. Then, to extend forward to 2012, we add the 2012 value of the change in inventories to the estimated 2011 stock.

To extend the stock of land to 2011 and 2012, we assume that the real productive stock of land in 2011 and 2012 changed at the average annual rate of change from 2007 to 2010.

Labour Composition (q)

BLS measures the change in labour composition as the difference between the growth rate of labour input and that of labour hours. To calculate labour input, BLS divides the labour force into a number of age-sex-education cells, and then constructs a weighted average of growth in hours worked in each cell, with the weight for each cell equal to its share of total labour compensation. Through 2010, our measure of the change in labour composition is from the MFP dataset. For 2011 and 2012, we assumed that the change in labour composition generated a contribution of 0.25 percentage point to growth in labour productivity.

Income Shares (α_j)

Total Capital

For 1974 to 2010, the income share for total capital is from the MFP dataset. To extend this series to 2011 and 2012, we construct capital income for the five categories of total capital that BLS provides: equipment and software, non-residential structures, inventories, tenant-occupied rental housing, and land. We sum these estimates to generate an estimate of total capital income. The share is then the ratio of this estimate of capital income to total income in the non-farm business sector. Finally, we take this estimate of the capital income share and difference splice it to the 2010 value of the published BLS series for the capital income share to obtain estimates of the income share for 2011 and 2012. With an estimate of the income share for capital in hand, the income share for labour equals unity minus the income share for capital.

IT Capital

For 1987 to 2010, the income shares for each type of IT capital are from the MFP dataset. For 1974 to 1986, we difference splice in the income shares that we constructed for Oliner, Sichel, and Stiroh (2007). To extend the income shares for each IT asset to 2011 and 2012, we use a procedure parallel to the one described for the pieces that add up to total capital.

Capital Income

To estimate capital income for each type of capital for the extension to 2011 and 2012, we use the following equation:

$$\textit{capital income}_j = [(R + \delta_j - \Pi_j)\, p_j K_j]\, T_j.$$

We discuss each component of this equation below. Although we have suppressed the time subscript for expositional convenience, these estimates of capital income vary from year to year. The extension from 2010 to 2011 and 2012 only requires data on the components for those years, but we compile data for each component back to 1974 because the steady-state calculations require the full history.

Depreciation Rate (δ_j)

For equipment and software, non-residential structures, and tenant-occupied rental housing, we use depreciation rates reported in the MFP dataset through 2010. For 2011 and 2012, we use the value reported for 2010. For land and inventories, the depreciation rate is zero. For IT assets, we use a parallel procedure.

Expected Nominal Capital Gain/Loss (Π_j)

For each type of capital, we calculated Πj as a three-year moving average of the per cent change in the price of asset j (p_j). The moving average serves as a proxy for the unobserved expectation of price change. Through 2010, the p_j series for these assets are the investment price indexes from the MFP dataset. Except for land, each p_j series was extended to 2011 and 2012 using the growth rate of the corresponding series for NIPA investment prices.[5] For land, we extended prices to 2011 and 2012 using the average growth rate of land prices in the MFP dataset from 2007 to 2010.

Current-Dollar Productive Capital Stock ($p_j K_j$)

For each asset, this series is simply the product of the real productive stock (K_j) and the asset price index (p_j), both of which are discussed above.

Tax Adjustment (T_j)

For each asset j, this adjustment is $T_j = (1 - c - \tau v)/(1 - \tau)$, where c is the rate of investment tax credit, τ is the corporate tax rate, and v is the present value of $1 of tax depreciation allowances. We include a tax term (T_j) for each asset in the capital income and income share variables we construct. Through 2010, we construct the tax terms (T_j) we need from the MFP dataset.[6] For 2011 and 2012, we use the 2010 value of each tax term.

Nominal Net Return (R)

We calculated R as the ex post net return earned on the productive stock of equipment and non-residential structures. Thus, we obtain R as the solution to the following equation:

$$\sum_{j=1}^{N} [(R + \delta_j - \Pi_j)\, p_j K_j]\, T_j / pY = \sum_{i=1}^{N} \alpha_j$$

where the summations are over computer hardware, software, communication equipment, and other business fixed investment. This procedure yielded an annual series for R from 1990 to 2010. (The BLS data begin in 1987 and we need three lags for the capital gain term so these estimates of R begin in 1990.) For 2011 and 2012, we estimate R as the predicted value from a regression with the following explanatory variables: a constant, two lags of R, the rate of price change for non-farm business output, the acceleration in real non-farm business output, the unemployment rate, and the share of corporate profits in GNP. For the period from 1974 to 1989, we

5 For equipment and software and non-residential structures, we used the price series from NIPA Table 5.3.4. For inventories, we used the implicit price deflator for non-farm inventories from NIPA Table 5.7.9B. For tenant-occupied rental housing, we used the price series for investment in multifamily residential structures from NIPA Table 5.3.4. For each type of IT capital, we used prices from NIPA Table 5.5.4.

6 As part of the MFP dataset, under the heading "Additional Available Measures," BLS provides spreadsheets for 1987-2010 Rental Price Detail Measures by Asset Type for both manufacturing and non-manufacturing industries. To construct income shares for total capital and for IT capital, we need tax terms for computer hardware, software, communication equipment, other business fixed investment, inventories, tenant-occupied rental housing, and land. The tax terms do not vary across industries and do not vary much within asset classes. For computer hardware, we use the common tax term that applies to every type of hardware. For software, we use a weighted average of the tax term for pre-packaged software and custom software and the separate term for own-account software, with a weight of 0.60 on pre-packaged and custom. For communication equipment, inventories, and land, we use the single tax term for each asset type provided by the BLS. To construct the tax term for other business fixed investment (BFI excluding IT), we calculated a weighted average of the tax terms for equipment excluding IT assets and non-residential structures. All types of non-residential structures have a common tax term; for non-IT equipment, we used the tax term that applies to most types of equipment other than motor vehicles, nuclear fuel or IT assets. The weights are year-by-year nominal productive capital shares for equipment excluding IT assets and non-residential structures.

difference splice in estimates of R from Oliner, Sichel, and Stiroh (2007).

Current-Dollar Output Shares (μ_C, μ_{SW}, μ_M, μ_O, μ_S)

The denominator of each output share is current-dollar non-farm business output (pY), the data source for which was described above. Here, we focus on the measurement of current-dollar sectoral output (p_iY_i for i = C, SW, M, O, and S), which is the numerator in each share.

Computer Sector

For 1987 to 2011, we used Census Bureau data from the Annual Survey of Manufacturers (ASM) on product shipments of computer and peripheral equipment (NAICS category 3341). This series includes computer and peripheral equipment shipped by domestic establishments regardless of their industry classification. Before 1987, the ASM data are available only on an industry basis. Industry shipments differ from product shipments by including secondary non-computer products shipped by establishments in the computer and peripheral equipment industry and by excluding computer and peripheral equipment shipped by establishments in other industries. Because of the resulting level difference between the two series, we extrapolate the 1987 level of ASM product shipments back in time using the annual per cent changes in ASM industry shipments. For 2012, we extrapolated the 2011 level of the ASM product shipments forward using a proxy for current-dollar shipments of computer and peripheral equipment. The proxy variable is the product of the annual average level of the Federal Reserve's industrial production index for computer and peripheral equipment and the NIPA price index for all final sales of this equipment (NIPA Table 1.2.4, line 17). We moved the 2011 level of ASM product shipments forward to 2012 by the per cent change in the proxy series.

Software Sector

For 1995 to 2011, we used NIPA data on current-dollar final sales of software, adjusted to exclude own-account software produced by the government. The data are in supplemental NIPA tables posted at http://www.bea.gov/national/info_comm_tech.htm under the headings "GDP and Final Sales of Software" and "Software Investment and Prices, by Type".

We extrapolated the 1995 level back to earlier years and the 2011 level forward to 2012 using the annual per cent changes in the NIPA series for private fixed investment in software (NIPA Table 1.5.5, line 33).

Communication Equipment Sector

We follow the same procedure described above for the computer sector. That is, we use ASM product shipments for communication equipment (NAICS category 3342) for 1987-2011; we then extrapolate back in time with the annual per cent changes in ASM industry shipments and forward to 2012 with the per cent change in a proxy series for current-dollar output of communication equipment. The proxy variable is the product of the annual average level of the Federal Reserve's industrial production index for communication equipment and a price index for domestic output of this equipment constructed using the method described in Byrne and Corrado (2007). Because the Byrne-Corrado index is not yet available for 2012, we assume the 2012 per cent change equaled that for 2011.

Semiconductor Sector

Here too we rely on Census shipments data. For 1987-2011, we use ASM product shipments for integrated circuits (NAICS category 3344131). We then extrapolate back in time with the annual per cent changes in ASM industry shipments for semiconductors and related devices (NAICS code 334413), the closest available industry to integrated circuits. For 2012, we extrapolate the 2011 level of the ASM product shipments forward using the annual per cent change in current-dollar shipments of integrated circuits calculated by Federal Reserve Board staff.

Other Non-Farm Business

We estimate current-dollar output in this sector as a residual after accounting for all other components of non-farm business output:

$p_O Y_O = pY - p_C Y_C - p_{SW} Y_{SW} - p_M Y_M - p_S (S_x - S_m)$,

where the final term is current-dollar net exports of semiconductors. (This is the only part of semiconductor production that shows up in domestic final output.) The data sources for pY, $p_C Y_C$, $p_{SW} Y_{SW}$, and $p_M Y_M$ were described above. We obtain data on current-dollar net exports of semiconductors as follows. For 1989 to 2011, we use series constructed by Federal Reserve Board staff for current-dollar exports and imports of integrated circuits (NAICS code 3344131), which are based on data from the International Trade Commission. We extrapolate the 1989 levels for both series back to 1978 using similarly constructed series for semiconductors and related devices (NAICS code 334413). Before 1978, the detailed trade data are not available, and we extend the export and import series back in time using the annual per cent change in domestic shipments of semiconductors (the series $p_S Y_S$ described above). For 2012, we extrapolate forward the 2011 levels of both exports and imports using the annual per cent change in current-dollar shipments of integrated circuits calculated by Federal Reserve Board staff (the same series used for the 2012 value of semiconductor sector output).

Ratio of Semiconductor Output to Domestic Semiconductor Use (1+θ)

Domestic semiconductor use can be expressed as domestic semiconductor output minus net exports of semiconductors. Thus,

$$1+\theta = Y_S / [Y_S - (S_x - S_m)] = p_S Y_S / [p_S Y_S - (p_S S_x - p_S S_m)],$$

where the second equality converts each series to current dollars. The data sources for $p_S Y_S$ and $p_S S_x - p_S S_m$ were described above.

Rates of Relative Price Change (π_C , π_{SW} , π_M , π_S)

Each π_i series ($i = C$, SW, M, and S) represents the rate of change in the price ratio p_i / p_O, where p_O is the price index for other non-farm business.[7] Here, we describe the data source for each price series that enters these ratios.

Computer Sector

For 1978-2012, we measure p_C with the NIPA price index for final sales of computers and peripheral equipment (NIPA Table 1.2.4, line 17). For earlier years, we extrapolate back the 1978 level with the per cent change in the NIPA price index for private fixed investment in computers and peripheral equipment (NIPA Table 1.5.4, line 32), trend-adjusted to decline one percentage point faster per year. This trend adjustment accounts for the difference in the average annual decline over 1978-95 between the price indexes for private fixed investment in computers and final sales of computers.

Software Sector

For 1995-2011, p_{SW} is an implicit price deflator for final sales of software excluding own-account software produced by the government. Using NIPA data, we calculate this deflator as the ratio of current-dollar final sales excluding

7 We compute the rate of change in each relative price as the per cent change from the prior year's price ratio, not as a log difference. Although growth accounting studies typically use the log difference approximation to calculate rates of change, this approximation is inaccurate for per cent changes as large as those observed for the relative prices of computers and semiconductors.

government own-account software (the series $p_{SW}Y_{SW}$ described above) to a chain aggregate of real software outlays with the same coverage. The data for this calculation come from the supplemental NIPA tables posted at http://www.bea.gov/national/info_comm_tech.htm under the headings "GDP and Final Sales of Software" and "Software Investment and Prices, by Type". We extrapolate the 1995 level of the price deflator back in time and the 2011 level forward to 2012 with the annual per cent change in the NIPA price index for private fixed investment in software (NIPA table 1.5.4, line 33). We did not use a trend adjustment because the price series for software investment fell at a similar rate on average over 1995-2011 as the price deflator for final sales of software.

Communication Equipment Sector

For 1974-2011, we measure p_M with a price index for domestic output of communication equipment constructed using the method described in Byrne and Corrado (2007). Because this index is not yet available for 2012, we assume the per cent change in 2012 was the same as in 2011.

Other Final-Output Sector

p_O is measured as an implicit deflator that equals the ratio of current-dollar output for this sector (the series p_OY_O defined above) to a chain aggregate of the sector's real output (Y_O). We construct Y_O by starting with our series for real non-farm business output (Y) and then "chain stripping-out" all other components of Y (that is, real output of computers, software, and communication equipment, along with real exports and imports of semiconductors). To construct the series for real exports and imports of semiconductors needed for the chain strip-out, we assumed that the price of both exports and imports of semiconductors equals the semiconductor price series described in the next paragraph.

Semiconductor Sector

For 1977-2012, the data source for p_S is the internal Federal Reserve price index for integrated circuits (NAICS product class 3344131 back to 1992, linked to the analogous index for SIC code 36741 for 1977-92). For the years before 1977, we extrapolate back using the price index for memory chips in Grimm (1998). Because Grimm's index covers a narrower set of chips than the Federal Reserve index, we level-adjust the annual per cent changes in Grimm's index by the ratio of the per cent change in the Federal Reserve index to that in Grimm's index between 1977 and 1978, the earliest overlap period.

Semiconductors as a Share of Current-Dollar Input Costs (β_C^S, β_{SW}^S, β_M^S, β_O^S)

Computer sector

For 1997-2011, we estimate β_C^S with proprietary data from iSuppli Corp. on the annual semiconductor cost share of seven different types of computing equipment. We aggregate the product-specific cost shares with domestic shipments weights that vary from year to year. For 2012, we use the share estimated for 2011. For 1990-96, we extrapolate back the 1997 share using the annual per cent changes in the estimated worldwide semiconductor share in computing equipment; we estimate these shares from a variety of proprietary data sources. Finally, for years before 1990, we set the cost share to be a shipment-weighted average of the cost shares for personal computers and all other computing equipment; in this calculation, we use the semiconductor cost shares from 1997, the earliest year for which we have the iSuppli data.

Software Sector

We set β^S_{SW} to zero because semiconductors are not a direct input to software production. (The software industry uses computers and communication equipment that contain semiconductors, but it does not directly use semiconductors.)

Communication Equipment Sector

For 1997-2011, we estimate β^S_M with proprietary data from iSuppli Corp. on the annual semiconductor cost share of 14 different types of communication equipment. We aggregate the product-specific cost shares with domestic shipments weights that vary from year to year. For 2012, we use the share estimated for 2011. For 1990-96, we extrapolate back the 1997 share using the annual per cent changes in the estimated worldwide semiconductor share in communication equipment; we estimate these shares from a variety of proprietary data sources. Finally, for years before 1990, we extrapolate back the 1990 share using the annual per cent changes in the share constructed in Oliner and Sichel (2002) using data from the Semiconductor Industry Association. See the data appendix in Oliner and Sichel (2002) for details.

Other Final-Output Sector

To estimate β^S_O, note that equation A22 in Oliner and Sichel (2002) shows that:

$$\mu_S = \sum_{i=1}^{4} \mu_i \beta^S_i (1+\theta)'$$

which can be written with explicit sectoral notation as

$$\mu_S = [\mu_C\beta^S_C + \mu_{SW}\beta^S_{SW} + \mu_M\beta^S_M + \mu_O\beta^S_O](1+\theta) .$$

Solving this equation for β^S_O yields

$$\beta^S_O = \frac{\mu_S - (1+\theta)[\mu_C\beta^S_C + \mu_{SW}\beta^S_{SW} + \mu_M\beta^S_M]}{\mu_O(1+\theta)} .$$

The data sources for all series on the right-hand side of this expression have been discussed above.

Will History Repeat Itself? Comments on "Is the Information Technology Revolution Over?"

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ABSTRACT

In this article I comment on three aspects of Byrne, Oliner and Sichel's analyses. First, I show that the patterns in labour productivity growth during the IT era echo those observed during electrification. This includes a slowdown of roughly analogous timing to that observed in 2004-2012 — a slowdown that in the electrification era was followed by a productivity growth acceleration. Second, I discuss the implications of continued divergence in mean and median incomes for the analysis of productivity growth in the long run. Third, I explore further the issue of whether technological progress in semiconductor manufacturing is yielding concomitant increases in semiconductor performance.

RÉSUMÉ

Je commenterai trois aspects des analyses de Byrne, Oliner et Sichel. Premièrement, je vais démontrer que les tendances en matière de croissance de la productivité du travail en cette ère de la T.I. reflètent la situation en vigueur au moment de l'électrification. Cela inclut un ralentissement à peu près au même moment que celui qu'on a pu observer entre 2004 et 2012 — un ralentissement qui, lors de l'ère de l'électrification, a été suivi d'une accélération de la croissance de la productivité. Deuxièmement, j'aborderai les répercussions de la divergence continuelle en ce qui a trait aux revenus moyen et médian aux fins de l'analyse de la croissance de la productivité à long terme. Troisièmement, j'examinerai de plus près la question de savoir si les innovations technologiques dans le secteur de la fabrication de semi-conducteurs donnent lieu à des augmentations simultanées du rendement des semi-conducteurs.

THE ARTICLE "Is the Information Technology Revolution Over?" by David M. Byrne, Stephen D. Oliner, and Daniel E. Sichel represents a thought-provoking work which updates and extends the authors' earlier research. It addresses an important question, namely: does the recent slowdown in aggregate productivity growth reflect a petering out of the information technology (IT) revolution?

The article's analysis has three main parts. The first decomposes aggregate labour productivity growth into IT-related factors for three separate periods: 1974-1995, 1995-2004, and 2004-2012, paying particular attention to the

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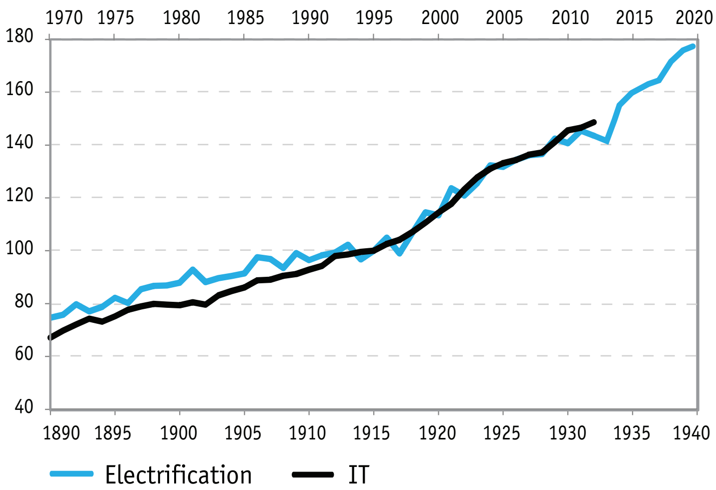
Chart 1
Labour Productivity Growth During the Electrification Era (1890-1940) and the IT Era (1970-2012) in the United States
(1915 = 100 and 1995 = 100)



Source: Kendrick (1961); Byrne, Oliner, and Sichel (2013).

sources of the productivity growth slowdown between the second and third periods. The second computes a projection of average annual labour productivity growth over the foreseeable future. The third assesses the potential for future productivity growth in semiconductor manufacturing, with a focus on the pessimistic case raised by recent patterns in microprocessor price indices. I have one comment on each of these three parts.

Productivity Growth Decomposition

The decomposition starts by pointing out that measured labour productivity growth over 2004-2012 slowed to an average annual rate of 1.6 per cent from the significantly higher 3.1 per cent rate sustained over 1995-2004. This earlier period of accelerated productivity growth followed on the heels of a well-documented period of slow productivity growth extending from the mid-1970s to the mid-1990s. The authors' decomposition indicates that a substantial part of the post-2004 slowdown is accounted for by IT-based sources, but that IT still accounts for a considerable portion — about 40 per cent — of the productivity growth that remains.

While one could quibble with the specific assumptions made by this decomposition, I have no special concerns. Instead, the overall patterns they document raised a question in my mind: are such patterns new? Did labour productivity have similar speed-up and slowdown periods during the diffusion of earlier general purpose technologies? History can offer a guide; electrification was the last general purpose technology to diffuse through the economy prior to IT. Happily, there are data on labour productivity growth during the electrification period that can be compared to the IT experience.

To make this comparison, I use the data originally constructed by Kendrick (1961) for 1890-1947, which the authors themselves use to compute historical average annual labour productivity growth rates in the United States.[2]

It turns out that labour productivity during electrification shared remarkably common patterns with the IT era. This can be seen in Chart 1, which overlays U.S. labour productivity in the IT era from 1970 to 2012 with the Kendrick series for the 1890-1940 period (the IT series years are labeled on the upper horizontal axis, and the series is indexed to a value of 100 in 1995. The electrification series years are on the lower horizontal axis, and the series is indexed to 100 in 1915). During the electrification era, there was an initial period (roughly a quarter century) of relatively slow labour productivity growth, just as was the case in the IT era from 1970-1995. Then both eras saw decade-long accelerations in productivity growth, spanning 1915-1924 during electrification and 1995-2004 in the IT era. Furthermore, analogous to the 2004-2012 slowdown that is the focus of the

2 The data are from Kendrick (1961:Table A-XXII). I use the series "Output per Unit of Labor Input."

article, labour productivity growth slowed in 1924-1932.

The question relevant to this article is whether the 2004-2012 slowdown is likely to persist. We have the benefit in the electrification era data of knowing what happened after the 1924-1932 slowdown. As can be seen in Chart 1, labour productivity growth sped up again, averaging 2.7 per cent per year over 1932-1940.[3]

To be clear, I do not interpret this as predicting that labour productivity growth must again accelerate in 2013. I am not proposing a Jevons-type sunspot theory of labour productivity growth. Rather, I simply make the point that we have been here before: sluggish labour productivity growth at the beginning of the diffusion of a general purpose technology (if one believes, as I do, that the 1890-1915 period for electrification is a reasonable analog to the 1970-1995 period for IT), a decade-long acceleration, and then another multi-year slowdown. In the electrification era, this was followed by another acceleration. Whether this will also occur for IT remains to be seen, but we know it has happened before. History shows that productivity growth driven by general purpose technologies can arrive in multiple waves; it need not simply arrive, give what it has, and fade away forever thereafter.

Predicting Future Productivity Growth

The discussion of potential labour productivity growth after 2012 leads naturally to the second section, a projection of future long-run labour productivity growth.

Forecasting is hard. As with their decomposition exercise, one could argue about some of the specific assumptions they make in their projection. However, everything they do is some form of standard practice in the literature, and I do not find their midpoint estimate of 1.85 per cent per year implausible (this is not far off from the average 2 per cent rate over the prior 120 years, if history is any guide). Furthermore, the authors are admirably candid about the tenuous nature of the exercise.

My comments in this area are on a broader level. Thinking about the future trajectory of productivity growth spurred consideration of what I think is becoming, as it has revealed itself in the data over the past few decades, one of the most consequential features of long-run growth: namely, the divergence between average income (and productivity) growth and median income growth. About 30-40 years ago, the growth of median income started to slow relative to average income growth (and its labour productivity analog), and this divergence has continued since then. While future labour productivity growth is obviously important, I see this divergence as a call to investigate the implications of future labour productivity growth not just for average income, but its distribution as well.

There are normative implications of a continued divergence, of course. Economists will differ in their views of such implications depending on their preferred social welfare functions, and such differences will spur considerable debate. This aside, however, even the non-subjective implications of continued divergence are potentially very far reaching. These range from large shifts in the patterns of human capital investment, to a restructuring of the labour market, and to numerous aspects of political economy, among many others.

I do not suggest that the authors tackle these issues here, as they are far beyond the scope of the work. Instead, I see the divergence of the past few decades as a call to action to all those

3 While the Kendrick data extend to 1947, I stop with the U.S. entry into World War II to avoid any unusual productivity effects of wartime production. If these years are included, the average annual labour productivity growth rate from 1932-1947 is still substantially higher than 1924-1932, at 2.4 per cent.

working in this literature. While it is not certain that this divergence will continue, it should be a priority to find out if it will. And if it does, we need to have more to say about its economic implications.

Potential Future Productivity Growth in Semiconductor Manufacturing

In the final section, the authors take a more optimistic note for the future of IT-driven productivity growth based on their assessment of technological progress in semiconductor manufacturing. One of the most important determinants of semiconductor manufacturing productivity growth is the size of the transistors etched on microchips. As the machines that make semiconductors become able to etch smaller and smaller transistors, manufacturers can place more transistors on a given chip. A higher transistor density translates into more operations per unit time—that is, higher performance. The faster the arrival of new vintages of semiconductor manufacturing capital, the faster the growth of semiconductor performance (this is a key force behind Moore's Law).

The authors point out that recent data indicates that new vintage adoption has continued at the relatively high rate of the past two decades, and there are no indications this will slow in the near future. They further bolster their case for optimism by arguing that the Bureau of Labor Statistics producer price index for microprocessors — which has recently shown only small price declines, suggesting a technological slowdown in the industry — suffers from measurement problems. When the authors apply their corrections to the series, implied prices instead continue to fall at a fast rate.

I would just like to sound a small note of pessimism in this case. My concern is based on recent work by Pillai (2013), who has closely studied the economics of semiconductor manufacturing and its relation to technological progress in the industry.

Pillai's analysis actually agrees with the authors' contention that transistor density growth has not slowed. However, he marshals evidence that semiconductor performance has nevertheless decelerated since about 2001 because, while chip designers have had more and more transistors to work with on a given chip, they have been unable to extract as many operations per transistor as before. The industry trade press reports power consumption problems as a primary reason for this slowdown in calculation efficiency. Essentially, transistor density has led to chips that produce too much heat in too little area. This causes overheating and defects unless transistors' clock rates are slowed.

To the extent the authors' hedonic corrections to the Bureau of Labor Statistics microprocessor price index account for this broader measure of performance, their analysis will account for this additional influence on microprocessor performance. It is not apparent from what is reported in the description of their analysis whether such accounting is made, however. In any case, Pillai's study sounds a note of caution regarding any analysis that focuses only on changes in transistor size or density.

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Productivity or Employment: Is It a Choice?

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ABSTRACT

Traditionally, shocks to total factor productivity (TFP) are considered exogenous and the response of employment is determined by their effect on aggregate demand. We approach the relationship between TFP and labour input differently, raising the possibility that in response to labour supply shocks firms adjust production efficiency. TFP would, thus, be endogenous to firms' production decisions. We present cross-country evidence of a strong negative correlation between growth in TFP and labour inputs over the medium to long run. This result is robust to changing datasets, sample periods, and industry composition. To address the question of causality, we use instruments to capture changes in hours worked that are independent of TFP movements and find that TFP growth falls (increases) following a pickup (decline) in hours growth. These results have important policy implications.

RÉSUMÉ

Traditionnellement, les chocs de la productivité totale des facteurs (PTF) sont considérés exogènes, et la réponse de l'emploi est déterminée par leur effet sur la demande agrégée. Nous abordons la relation entre la PTF et l'apport de travail différemment, en soulevant la possibilité qu'étant donné les chocs sur l'offre de main-d'œuvre, les entreprises réduisent leurs efforts visant à accroître l'efficacité. La PTF serait par conséquent endogène aux décisions de production des entreprises. Nous présentons des preuves, sur plusieurs pays, d'une forte corrélation négative entre la croissance de la PTF et les intrants de travail à moyen et à long terme. Ce résultat résiste à l'évolution des ensembles de données, des périodes d'échantillonnage et de la composition des industries. Pour remédier à la question de la causalité, nous utilisons des instruments pour saisir l'évolution des heures travaillées indépendament des mouvements de la PTF et constatons que la croissance de la PTF diminue à la suite d'un gain de la croissance du nombre d'heures. Ces résultats ont d'importantes incidences de politique.

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OVER THE PAST DECADE, policymakers in Canada have expressed concern about the country's slow rate of productivity growth. Indeed, total factor productivity (TFP) growth in Canada has consistently underperformed that of the other G-7 economies. Output growth, however, has been relatively stronger, reflecting a higher-than-average pace of employment growth over the last 40 years. Given the strong performance of output, how worried should policymakers be about the weaker TFP growth? In traditional economic theory, changes in TFP are a key driver of economic growth and, to a great extent, are considered exogenous. However, the experience of Canada leads to questions about the traditional view. More specifically, could TFP respond endogenously to the availability of labour? Instead of taking TFP as given, can firms and industries vary TFP and employment depending on factor endowment and labour costs – essentially "choosing" an optimal tradeoff between TFP and labour intensity on the production frontier?

In this article, we examine the exogeneity of TFP to changes in labour use in the production process. We begin by establishing a negative historical relationship between productivity and labour input across industrial countries. In particular, we find a negative correlation between TFP growth and hours growth from 1970 to 2007 across the main OECD economies. Countries that have stronger growth rates of TFP tend to have lower hours growth. This result is robust across databases, holds up over smaller time periods, is not driven by the business cycle, and does not reflect differences in industry composition across countries. Related research documents a similar relationship between labour productivity and labour input, although in this case the negative correlation is expected to be temporary and part of the hiring and firing process (Estevão, 2007, and Dew-Becker and Gordon, 2012). Nonetheless, we document that all the basic results showing a negative relationship between TFP growth and hours growth in themedium-to-long run remain if labour productivity growth is used to measure changes in production efficiency.

We then turn to the question of causality. While it is difficult to believe that countries such as Canada, the United States, and Germany have significantly different technological capacity or knowledge, they do have different labour endowments, immigration policies, regulations, and tax policies. We exploit these differences to assess the response of TFP growth to exogenous movements in labour supply. In particular, we instrument for the growth in hours using taxes and population growth, both of which should be independent of TFP. Using these instruments, we find a continued significant negative correlation between TFP growth and growth in total hours; a result that is robust to many variations, including using labour productivity growth as a proxy for changes in production efficiency and dropping particular countries from the sample.[2]

These results raise interesting and important policy questions. For instance, should countries with strong employment growth,

2 Measurement issues could also be behind some of the differences in TFP growth across countries in our sample. For instance, Diewert and Yu (2012) argue that TFP growth could have averaged 1.0 per cent from 1961 to 2011 in Canada, as opposed to the 0.3 per cent calculated by Statistics Canada. The authors arrived to this conclusion by estimating a much slower capital services growth for a given GDP growth path than implied by the official series. This adjustment puts Canada nearer to the middle of the TFP range for our sample and time period, but it does not invalidate the main finding of this article. More generally, the negative relationship between TFP growth and hours growth does not appear to depend on the experience of a particular country or particular measurement errors.

Table 1
Data Sources

Database		Sectoral Data	Variable Coverage	Country Coverage	Period Coverage
Conference Board: Total Economy Database		No	Total Employment Total Hours Worked Population TFP	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States	1950-2011 (1970-2011 for TFP)
KLEMS	EU	Yes	Total Employment Total Hours Worked TFP	Australia, Belgium, Denmark, Finland, Japan, Netherlands	1980-2007
	World			Austria, Canada, France, Germany, Italy, Spain, United Kingdom, United States	
AMECO		No	Total Employment TFP	Canada, France, Germany, Italy, Japan, United Kingdom, United States	1960-2013
United Nations		No	Population	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States	1950-2020
McDaniel		No	Tax rates	Australia, Austria, Belgium, Canada, Finland, France, Germany, Italy, Japan, Netherlands, Spain, Sweden, Switzerland, United Kingdom, United States	1950-2010

such as Canada, worry less about their relatively weaker TFP? To what extent can policy influence the tradeoff between TFP and labour usage? And are there social welfare implications for such a choice? In response to aging populations, will countries experience rising TFP as firms find ways to utilize existing workers more effectively? The case of Japan, with its low employment growth and relatively weak TFP growth, suggests other factors may be at play. Therefore, can policies such as increasing labour and product market flexibility influence the ease with which industries can move from one TFP/labour mix to another in response to shocks?

The first section of the article describes the datasets used. Section two presents our results while section three discusses additional robustness checks. The fourth and final section concludes with a discussion of the implications of our results for policy and future research.

Data Sources

To examine the relationship between productivity and labour input, we use several databases that allow for cross-country comparisons over long time periods. The main data sources are the Total Economy Database (TED) from the Conference Board and World KLEMS (Table 1). Both databases provide cross-country measures of output and input (such as GDP, employment, and hours) as well as derived variables (such as TFP) using standard growth accounting methodology. TED is constructed to enhance international comparability and spans over 123 countries from 1950 to 2011. While TED contains information only for the aggregate economy, World KLEMS also includes a breakdown at the industry level. However, World KLEMS generally covers only the 1980-2009 period and data for some countries of interest are missing or incomplete; moreover, the dataset is still a

Chart 1
Relationship between TFP Growth and Hours Growth, 1970-2007
(average annual rate of change)

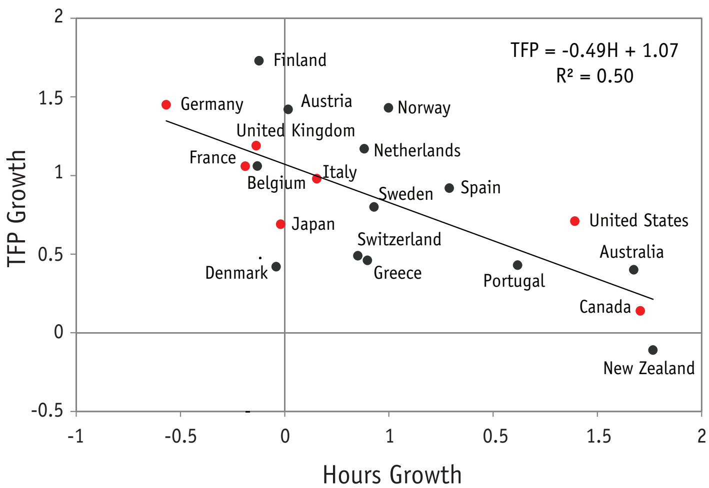
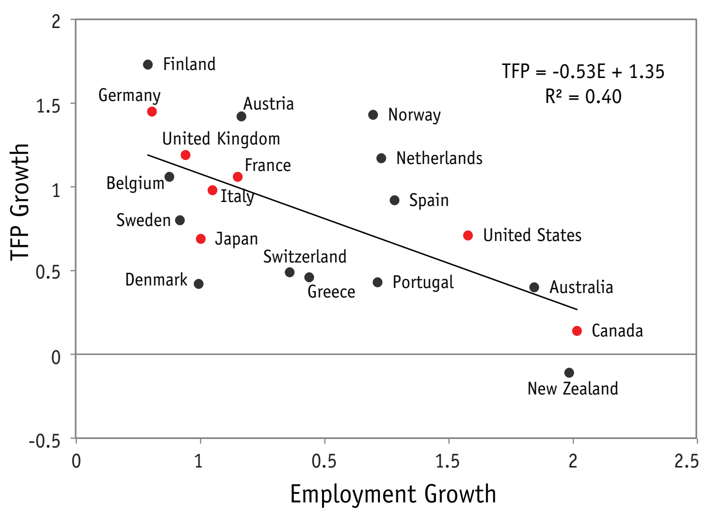


Chart 2
Relationship between TFP Growth and Employment Growth, 1970-2007
(average annual rate of change)



work in progress and thus international comparability is more problematic. To address some of these limitations, we integrate World KLEMS with data from the original European Union (EU) KLEMS initiative, which focused on European countries and for which data are available only up to 2007.[3] We also use the EU AMECO dataset to check for the robustness of some results.

In our baseline analysis, we examine 20 OECD-member countries over the period 1970-2007.[4] Though data for a few additional countries are available, we restrict our analysis to a set of countries which we consider to be relatively close to their respective technical frontiers and thus for which it is reasonable to discuss a tradeoff between employment and technology growth. We also do not consider the Great Recession and subsequent recovery in our baseline case, in part because data would not be available for some countries but also because our study focuses on a long-run relationship. That said, although the dynamics of TFP, employment, and hours have been different than typically seen during recessions – particularly because of the depth of the recession and evidence of greater-than-usual labour hoarding by firms in some countries, as documented in van Ark *et al.* (2011) – our main results hold if we extend our analysis beyond the Great Recession.

We also used data on population and taxes (Table 1). Population estimates come from TED and the United Nations (UN) Department of Economic and Social Affairs. Tax data come from the 2010 update of McDaniel (2007).

3 TED, World KLEMS, and EU KLEMS are all publically available at http://www.conference-board.org/data/economydatabase, http://www.worldklems.net, and www.euklems.net, respectively. For a review of how these datasets have been assembled and used, see van Ark *et al.* (2011), Jorgenson (2012), Jorgenson *et al.* (2010), O'Mahony and Timmer (2009), and Timmer *et al.* (2010).

4 Country coverage for Austria, Canada, France, Germany, Italy, Spain, the United Kingdom, and the United States is available in World KLEMS. EU KLEMS is used to supplement this list, adding Australia, Belgium, Denmark, Finland, Japan, and the Netherlands to the dataset. Data for these 14 countries and an additional six (Greece, New Zealand, Norway, Portugal, Sweden, and Switzerland) from 1970-2011 are included in TED, though only at the total economy level.

Results: Negative Link between TFP Growth and Labour Input Growth

Basic results and some robustness tests

Using the data described above, we begin by calculating the simple long-run relationship between TFP and labour input for the countries in our sample. Chart 1 shows a scatter plot of the average annual per cent change in TFP on the per cent change in total hours for 20 OECD countries from 1970 to 2007 using TED. The fitted line through the country averages shows a negative relationship, with a 1 percentage-point increase in the growth rate of hours related to a 0.5 percentage-point decline in TFP growth. The relationship holds when only the G-7 countries are included, shown in red, suggesting that the most advanced economies – the countries closest to the technological frontier – have variation in TFP growth that is negatively related to labour input.

This negative relationship is robust to a broad range of factors. First, although we have chosen to use the most comprehensive measure of labour input – total hours – in our calculations, there is also a negative correlation between TFP growth and employment growth of roughly the same magnitude (Chart 2). TFP growth is also negatively correlated with the rate of change of hours per capita (not shown), but we expressly chose to not conduct our analysis in per capita terms because, as we will argue later, population growth may be one of the factors driving the tradeoff between productivity and labour input.

Second, measurement issues are always a concern when calculating an unobservable or residual such as TFP. Indeed, TFP measures tend to be pro-cyclical, as labour hoarding at the beginning of recessions depresses observed TFP, while a more intensive use of incumbent workers during the initial phase of expansions boosts measured TFP (Comin, 2008, and Basu, 1996). Cyclical changes in the quality of the employed pool also affect measured TFP. However, these cyclical effects should not be at play in correlations between averages over 40 years. Also, the results survive robustness tests, including the exclusion of countries and the utilization of different databases. Table 2 underlines these points by showing estimates for the basic regression of hours (and employment) growth on TFP growth using TED and KLEMS. Across databases, the long-term negative correlation remains robust and quite similar.

Third, although we are focusing on average relationships across the last 40 years rather than cyclical patterns, the negative correlation between TFP growth and hours growth holds up across shorter time periods. Table 3 presents

Table 2

Labour Input Growth versus TFP Growth by Database

Database Input	TED Employment	KLEMS[1] Employment	TED Hours	KLEMS[1] Hours
Constant	1.35***	0.86***	1.07***	0.74***
	(0.17)	(0.18)	(0.10)	-0.12
Coefficient	-0.53***	-0.36*	-0.49***	-0.37**
	(0.15)	(0.17)	(0.11)	(-0.09)
Observations	20	14	20	14
Adjusted R^2	0.36	0.21	0.48	0.33

1 KLEMS data span the 1980-2007 period; TED data span the 1970-2007 period.

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Sources: Total Economy Database, EU KLEMS, and World KLEMS.

Table 3

Hours Growth versus TFP Growth by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	1.07***	1.67***	1.01***	0.60***	0.91***
	(0.10)	(0.13)	(0.13)	(0.15)	(0.22)
Hours Growth	-0.49***	-0.57***	-0.41***	-0.19	-0.63***
	(0.11)	(0.13)	(0.13)	(0.18)	(0.18)
Observations	20	20	20	20	20
Adjusted R^2	0.48	0.49	0.33	0.01	0.36

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: Total Economy Database.

Table 4
Relationship between TFP Growth and Labour Input Growth Excluding Recessions[1]

Database	TED		KLEMS*	
Input	Hours	Employment	Hours	Employment
Constant	1.56***	1.87***	1.22***	1.37***
	(0.12)	(0.17)	(0.17)	(0.21)
Coefficient	-0.42***	-0.54***	-0.47***	-0.48***
	(0.10)	(0.12)	(0.12)	(0.14)
Observations	20	20	14	14
Adjusted R^2	0.48	0.52	0.51	0.46

* KLEMS data span the 1980-2007 period; TED data span the 1970-2007 period.

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Sources: Total Economy Database, EU KLEMS, and World KLEMS.

1 Sample period excludes all years with at least one month of recession.

Table 5
Relationship between TFP Growth and Hours Growth Excluding Recessions[1]

Period	1970s	1980s	1990s	2000-2007
Constant	2.49***	1.53***	1.12***	1.53***
	(0.16)	(0.18)	(0.19)	(0.24)
Hours Growth	-0.64***	-0.35**	-0.24*	-0.91***
	(0.15)	(0.13)	(0.13)	(0.17)
Observations	20	20	20	20
Adjusted R^2	0.48	0.25	0.12	0.60

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: Total Economy Database.

1 Sample period excludes all years with at least one month of recession.

estimates of the correlation using the TED database for the entire period and for each decade individually. Generally, the coefficients are significant, negative, and remarkably similar across decades, although the relationship is less negative and notably weaker in the 1990s. This exception could be the result of a widespread slowdown in European TFP and a pick-up in U.S TFP growth in the 1990s.

Fourth, we also examine whether the negative relation between TFP growth and hours growth is driven by fluctuations around business cycle peaks. To this end, we repeat the exercises described above excluding the years an economy was in recession for at least a month, a procedure which reduces the sample period by about 25 per cent.[5] The results in Tables 5 and 6 show that the relation holds also for the restricted sample. Indeed, the estimated coefficient is not greatly different than for the full sample, and the fit is somewhat better. In sum, our basic result does not seem to be driven by fluctuations in the business cycle, supporting our intuition that the negative trade-off between TFP and hours is driven by medium- to long-run factors.

Industry-level evidence

There is considerable variation in the relationship between TFP and hours growth by industry. Combining the EU and World KLEMS databases, we are able to construct correlations of TFP growth and hours growth across decades by industry for 14 countries.[6] The data are classified into 10 major industry groups: agriculture, mining, manufacturing, electricity, construction, wholesale and retail trade, transportation, hotels and restaurants, finance, and other services (including education and health). Table 6a presents the industry results together with those for the total economy. The industries are arranged from most negative to least negative correlation between TFP and hours growth. The hotels and restaurants sector appears to have the largest and most significant negative correlation followed by manufacturing and other services. At the other end of the range, TFP and hours in the transpor-

5 In the tables presented here, we removed all years which contained at least 1 month of recession. An alternative exercise that excludes only those years with at least 6 months of recession finds similar results and removes 17 per cent of the sample.

6 The 14 countries are Austria, Canada, France, Germany, Italy, Spain, the United Kingdom, and the United States from the World KLEMS database and Australia, Belgium, Denmark, Finland, Netherlands, and Japan from the EU KLEMS database.

Table 6a
Relationship between TFP Growth and Hours Growth by Sector, 1980-2007 (OECD 14)

Industry	Coefficient		Constant		Adjusted R^2
Hotels and Restaurants	-0.60**	(0.26)	0.28	(0.49)	0.25
Manufacturing	-0.46	(0.35)	1.19**	(0.49)	0.05
Total Economy	*-0.37***	*(0.14)*	*0.74****	*(0.12)*	*0.33*
Other Services	-0.35*	(0.19)	0.11	(0.30)	0.15
Wholesale and Retail	-0.33	(0.48)	1.31***	(0.40)	-0.04
Financial Services	-0.23*	(0.12)	0.39	(0.41)	0.18
Electricity	-0.23	(0.26)	0.81**	(0.30)	-0.02
Agriculture, Forestry, Fishing	-0.21	(0.31)	2.77***	(0.81)	-0.04
Construction	-0.15	(0.19)	0.24	(0.25)	-0.03
Mining and Quarrying	-0.13	(0.28)	0.43	(1.04)	-0.06
Transportation	-0.11	(0.37)	1.37***	(0.42)	-0.08

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Number of observations: 14.

Sources: World KLEMS, EU KLEMS.

Table 6b
Relationship between TFP Growth and Hours Growth by Sector, 1980-2007 (G7)

Industry	Coefficient		Constant		Adjusted R^2
Hotels and Restaurants	-0.99**	(0.27	1.07*	(0.50)	0.67
Other Services	-0.72	(0.36)	0.72	(0.50)	0.33
Wholesale and Retail Trade	-0.49	(0.48)	1.74***	(0.39)	0.01
Manufacturing	-0.48***	(0.12)	1.12***	(0.19)	0.73
Total Economy	*-0.47***	*(0.15)*	*0.78****	*(0.11)*	*0.59*
Electricity	-0.42	(0.44)	0.41	(0.47)	-0.02
Construction	-0.35	(0.38)	0.02	(0.43)	-0.03
Mining and Quarrying	-0.18	(0.24)	-1.20	(0.96)	-0.08
Agriculture, Forestry, Fishing	-0.17	(0.66)	3.06	(1.86)	-0.19
Financial Services	-0.16	(0.19)	0.08	(0.60)	-0.06
Transportation	0.16	(0.69)	0.98	(0.79)	-0.19

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

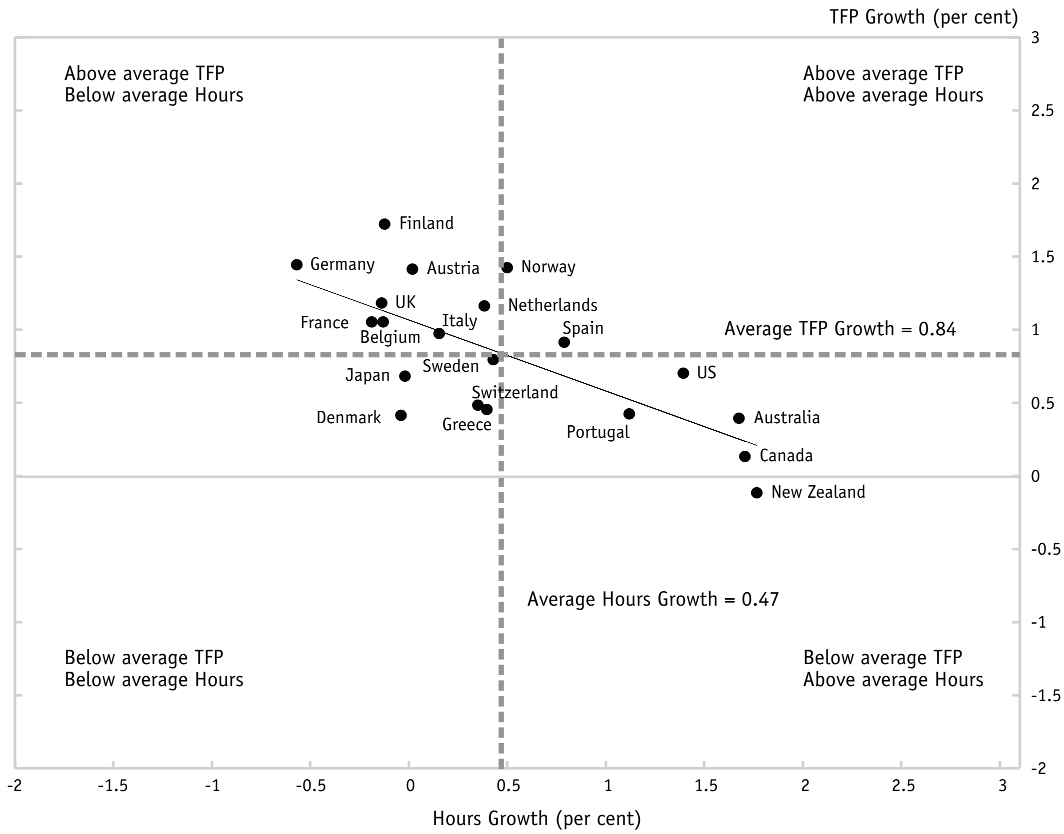
Number of observations: 7.

Sources: World KLEMS, EU KLEMS.

tation, mining, and construction industries are negatively correlated, but the coefficients are much smaller and not different from zero statistically. These results vary somewhat by country group and labour input, as can be seen, for example, in Table 6b which presents results for the G-7 countries alone. However, the basic result remains the same: while the cross-country relationship between TFP and labour input is not constant across sectors, it is almost always negative.

The variance across sectors suggests that one possible reason for the long-term divergences across countries in the tradeoff between TFP and hours growth could be differences in countries' industry composition. To check for this effect, we hold industry composition constant by constructing aggregate measures of TFP and hours growth for each country weighting both hours and TFP by the industry value-added shares for the United States. The results in Table 7 show that holding sectoral composition

Chart 3a
Relationship between TFP Growth and Hours Growth by Quadrant, 1970-2007



--- Dotted lines represent the averages over 1970-2007

Table 7
Relationship between TFP Growth and Hours Growth with U.S. Sectoral Value-Added Weights

	Baseline	U.S. time-varying weights
Constant	0.74***	0.82***
	(0.12)	(0.13)
Hours Growth	-0.37**	-0.38***
	(0.14)	(0.09)
Observations	14	14
Adjusted R^2	0.33	0.56

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Sources: Authors' calculations and World KLEMS, EU KLEMS.

fixed across countries does not change the size and increases the statistical significance of the correlation. This result implies that within-industry differences across countries (rather than differences in industry composition) are driving the dispersion in the relationship between TFP growth and hours growth, at least at the level of disaggregation considered in our analysis.[7]

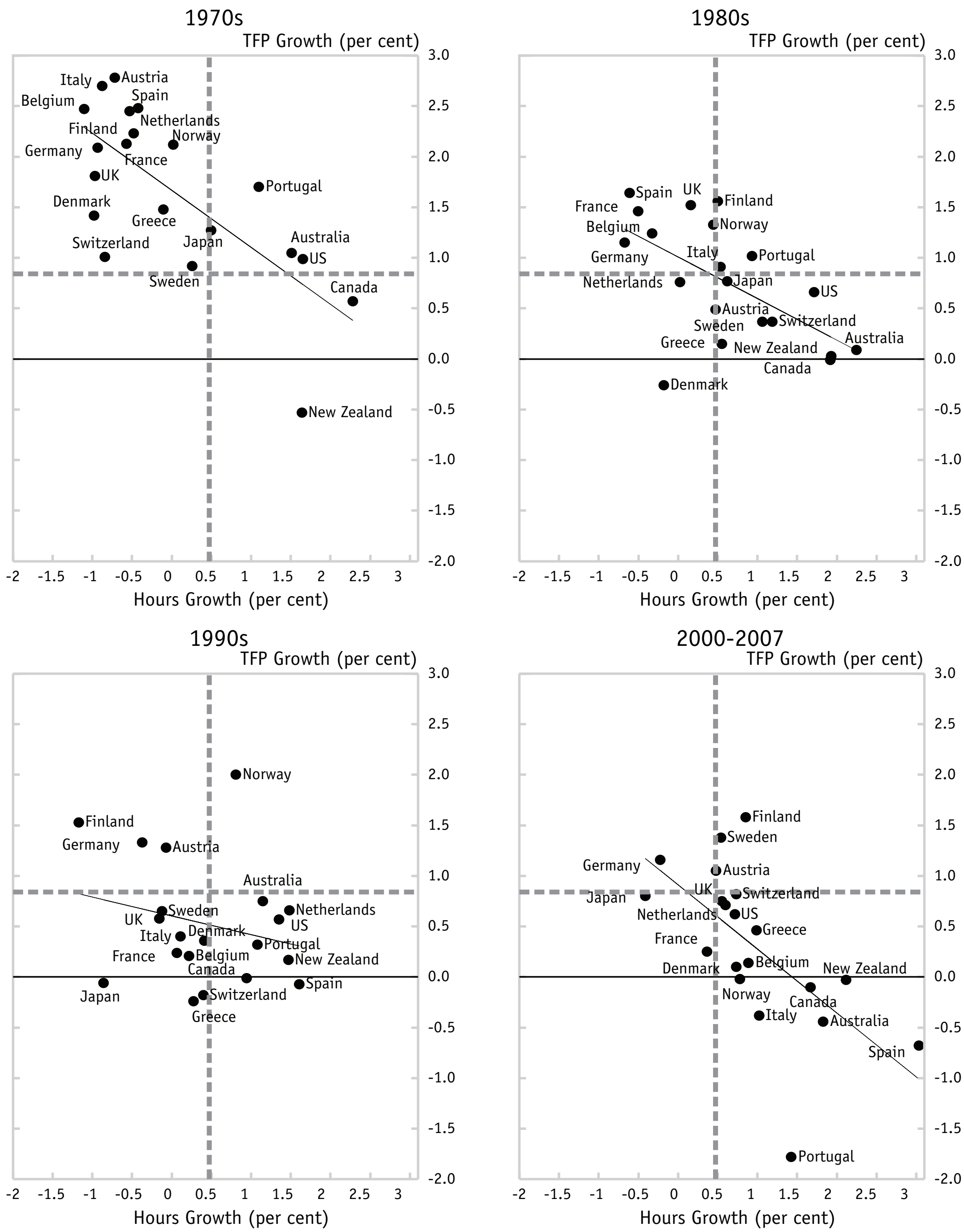
Stability of country positions

We can divide the set of countries into quadrants based on where they fall relative to the sample averages of TFP growth and hours

7 We have also conducted a similar exercise using more disaggregated sectors (with 28 sectors rather than 10) for a smaller set of countries, using the EU KLEMS database only. We find that the negative relation between TFP growth and labour input growth holds and the size of the coefficient does not significantly change.

Chart 3b

Relationship between TFP Growth and Hours Growth by Quadrant and by Decade



Dotted lines represent the averages over 1970-2007 on all charts

growth (Chart 3a). Specifically, a number of European countries, importantly Germany and France, have above average TFP growth but below average hours growth. In contrast, countries primarily outside Europe, such as Canada and the United States, have below average TFP growth but stronger-than-average hours growth over the full sample. In the other quadrants, Japan stands out as having both low TFP and hours growth.

These groupings are fairly robust across decades (Chart 3b). For the most part, countries do not switch their quadrants dramatically over the almost four decades of our sample. However, there is a notable shift of European countries, even Germany, toward greater employment growth and weaker TFP growth over time. Increased labour utilization and reduced labour productivity growth in Europe have been well documented and have been partly attributed to policies to liberalize labour markets, which reduced labour costs to the firm and lowered disincentives to work resulting in an overall positive labour supply shock (Jackman *et al.*, 2005).

Negative Relationship between Exogenous Changes in Labour Input and TFP Growth

The results above suggest a robust negative relationship between TFP growth and labour input growth, but they do not provide any indication of causality. Does the negative correlation reflect the fact that exogenous changes in TFP fail to increase aggregate demand and thus result in a decline in hours, as there is less need for labour? Or, do positive changes in hours – possibly through reductions in labour cost or the available supply of labour – lead firms to deemphasize efficiency? To address these questions, we start by trying to identify shocks to hours growth that are independent of TFP growth and use those to instrument for labour input in our baseline regressions.

First, we consider the role of taxes. There is evidence that taxes play an important role in determining the utilization of labour (e.g. Prescott, 2004). By driving a wedge between the marginal product of the worker and the marginal cost of the firm as well as between the marginal effort of the worker and the marginal benefit the worker receives, taxes can reduce both the demand and the supply of labour. Ohanian *et al.* (2008) find that differences in the tax wedge – a broad measure of taxes that encompasses taxes on income, payroll and consumption – account for much of the variance in hours worked across countries and over time.[8] However, labour taxes should not directly affect the growth of TFP. With this in mind, we calculate the average tax wedge for each country and use it as an instrument for hours growth. As defined, an increase in our measure of the tax wedge reflects a reduction in the underlying income, payroll, or consumption taxes. As such, an increase in the tax wedge should cause labour input to rise as firm costs or worker disincentives are reduced. Step 1 regression in Table 8 shows that the tax wedge is a good predictor of hours worked, with a highly significant coefficient.[9] In addition, the sign comes in as expected; lowering taxes, increases the wedge, and increases the growth rate of hours. Moreover, as shown in step 2, our measure of predicted hours using the tax wedge as instrument is significantly negatively correlated with TFP growth. The final table shows that the tax wedge does not have an inde-

8 More formally, the tax wedge $1-\tau_t$ is defined as: $1-\tau_t = \dfrac{1-\tau_{ht}}{1+\tau_{ct}}$,

where τ_{ht} stands for labour income (including payroll) tax and τ_{ct} for consumption tax. Ohanian *et al.* (2008) show that in a standard one-sector real business cycle growth model $1-\tau_t$ is equal to the ratio of the marginal rate of substitution between consumption and leisure to the marginal product of labour. Thus, the wedge measures the percentage deviation between the marginal rate of substitution and the marginal product of labour.

9 Data on the tax wedge for 1970-2007 are available for only 15 of the 20 OECD countries earlier considered.

Table 8

Relationship between TFP Growth and Hours Growth Using Tax Wedges as an Instrument, 15 OECD Countries

Step 1 Regression

Hours Growth vs. Average Tax Wedge by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	-2.42**	-4.21**	-2.88*	-1.61	-0.23
	(1.00)	(1.82)	(1.35)	(1.19)	(1.33)
Average Tax Wedge	4.52**	6.15**	5.51**	3.23	1.82
	(1.60)	(2.69)	(2.14)	(1.96)	(2.21)
Adjusted R^2	0.33	0.23	0.29	0.11	-0.02

Step 2 Regression

TFP Growth vs. Predicted Hours Growth by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	1.22***	1.73***	1.08***	0.75***	1.46
	(0.11)	(0.16)	(0.20)	(0.17)	(0.84)
Predicted Hours Growth	-0.71***	-0.83***	-0.37	-0.73*	-1.13
	(0.19)	(0.27)	(0.26)	(0.37)	(0.97)
Adjusted R^2	0.49	0.37	0.07	0.17	0.09

TFP Growth vs. Hours Growth and Average Tax Wedge by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	2.18***	3.55***	0.63	1.69*	1.59*
	(0.54)	(1.09)	(0.67)	(0.79)	(0.79)
Hours Growth	-0.31**	-0.40**	-0.53***	-0.14	-0.56***
	(0.12)	(0.14)	(0.12)	(0.17)	(0.17)
Average Tax Wedge	-1.79*	-2.66	0.86	-1.89	-1.03
	(0.90)	(1.60)	(1.11)	(1.34)	(1.35)
Adjusted R^2	0.64	0.60	0.63	0.14	0.46

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Number of observations: 15.

The tax wedge is equal to (1- tax rate on labour income)/(1 + tax rate on consumption expenditures).

Sources: Authors' calculations using TED and McDaniel (2007) datasets.

pendent effect on TFP growth for the 1970s, 1980s, and the 2000-2007 period. However, the tax wedge has a small independent effect – significant only at the 10 per cent level – for the full sample period of 1970-2007, which might invalidate it as an instrument for hours of work in the baseline regression. It is not clear why labour taxes should affect the growth rate of TFP; it may be that our tax wedge variable marginally captures taxes that affect the firm's choice of capital or labour efficiency independent of the cost of labour.

To provide additional support to these results, we use total population growth as an alternative instrument. Demographics have long been understood to be an important driver of labour supply; as such, firms located in countries with faster population growth may choose more hours independently of the technology available to them. However, in principle, population growth should not be linked to changes in total factor productivity. The step 1 results in Table 9 indicate that population growth is a good predictor of hours

Table 9

Relationship between TFP Growth and Hours Growth Using Population Growth as an Instrument, 20 OECD Countries

Step 1 Regression

Hours Growth vs. Population Growth by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	-0.55***	-1.31***	-0.15	-0.27	0.12
	(0.16)	(0.28)	(0.23)	(0.31)	(0.17)
Population Growth	1.80***	1.96***	1.58***	1.22**	1.58***
	(0.24)	(0.36)	(0.38)	(0.46)	(0.27)
Adjusted R^2	0.75	0.61	0.46	0.24	0.64

Step 2 Regression

TFP Growth vs. Predicted Hours Growth by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	1.07***	1.67***	0.97***	0.53**	0.90***
	(0.11)	(0.16)	(0.18)	(0.20)	(0.28)
Predicted Hours Growth	-0.47***	-0.52**	-0.34	-0.02	-0.62**
	(0.15)	(0.20)	(0.21)	(0.34)	(0.25)
Adjusted R^2	0.33	0.24	0.07	-0.06	0.21

TFP Growth vs. Hours Growth and Population Growth by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	1.03***	1.52***	0.94***	0.47	0.90***
	(0.21)	(0.39)	(0.18)	(0.28)	(0.24)
Hours Growth	-0.53**	-0.63***	-0.48**	-0.25	-0.65*
	(0.24)	(0.22)	(0.18)	(0.21)	(0.33)
Population Growth	0.10	0.22	0.22	0.28	0.04
	(0.49)	(0.54)	(0.41)	(0.48)	(0.63)
Adjusted R^2	0.45	0.46	0.31	-0.03	0.32

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Number of obsservations: 20.

Sources: Authors' calculations using TED and United Nation datasets.

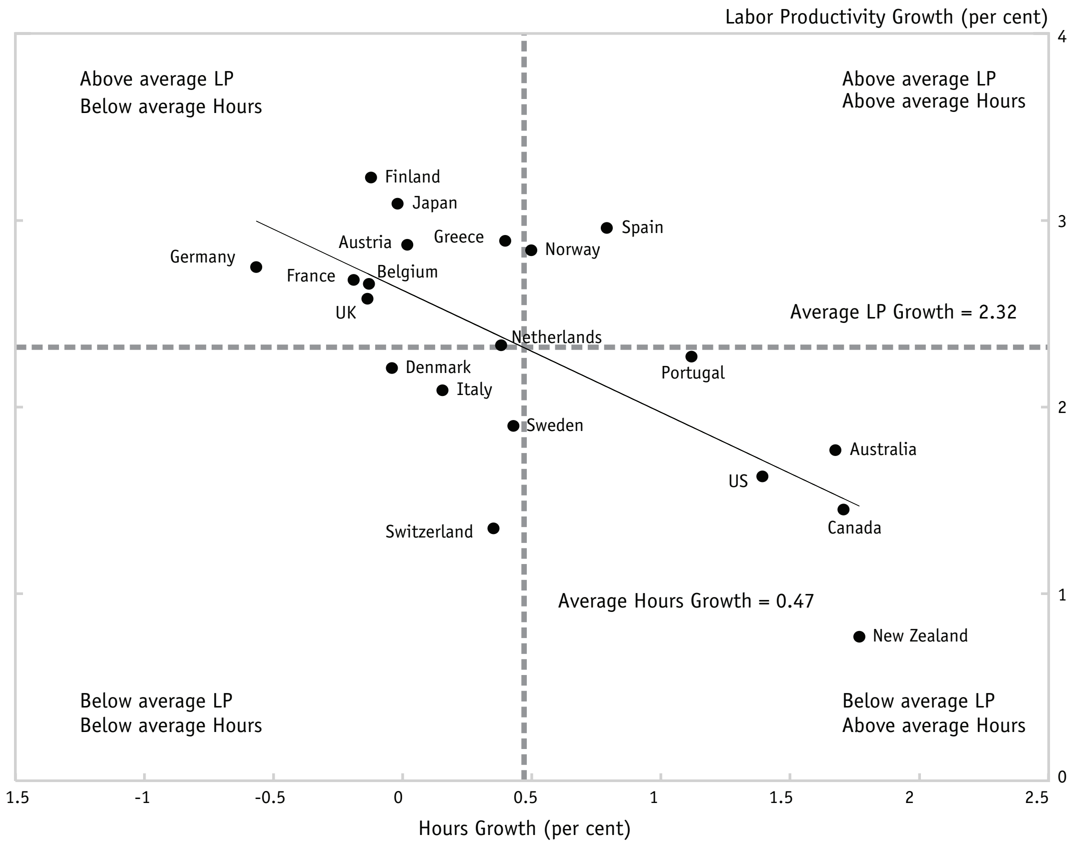
growth. In step 2, we generally find a negative coefficient on hours growth, although it is a bit smaller (in absolute value) than in the baseline OLS regression (Table 2) using the TED data. In addition, as seen in the third set of results in Table 9, population growth is not statistically significant once it is paired with hours growth as an explanatory variable of TFP growth, indicating that population affects TFP only through hours worked and, thus, appears to be a good instrument for TFP.[10]

All told, we find evidence pointing to causality going from hours growth to TFP growth. In particular, it appears that faster population growth leads firms to choose to use more work hours while stressing efficiency less. The evidence from using tax wedge as instrumental variable is a bit more mixed but still supportive. We believe these results call for future research to further confirm the direction of causality between these key macroeconomic variables and the reasons behind it.

10 We also duplicated this result using working age population, rather than total population.

Chart 4a

Relationship between Labour Productivity Growth and Hours Growth by Quadrant, 1970-2007



--- Dotted lines represent the averages over 1970-2007

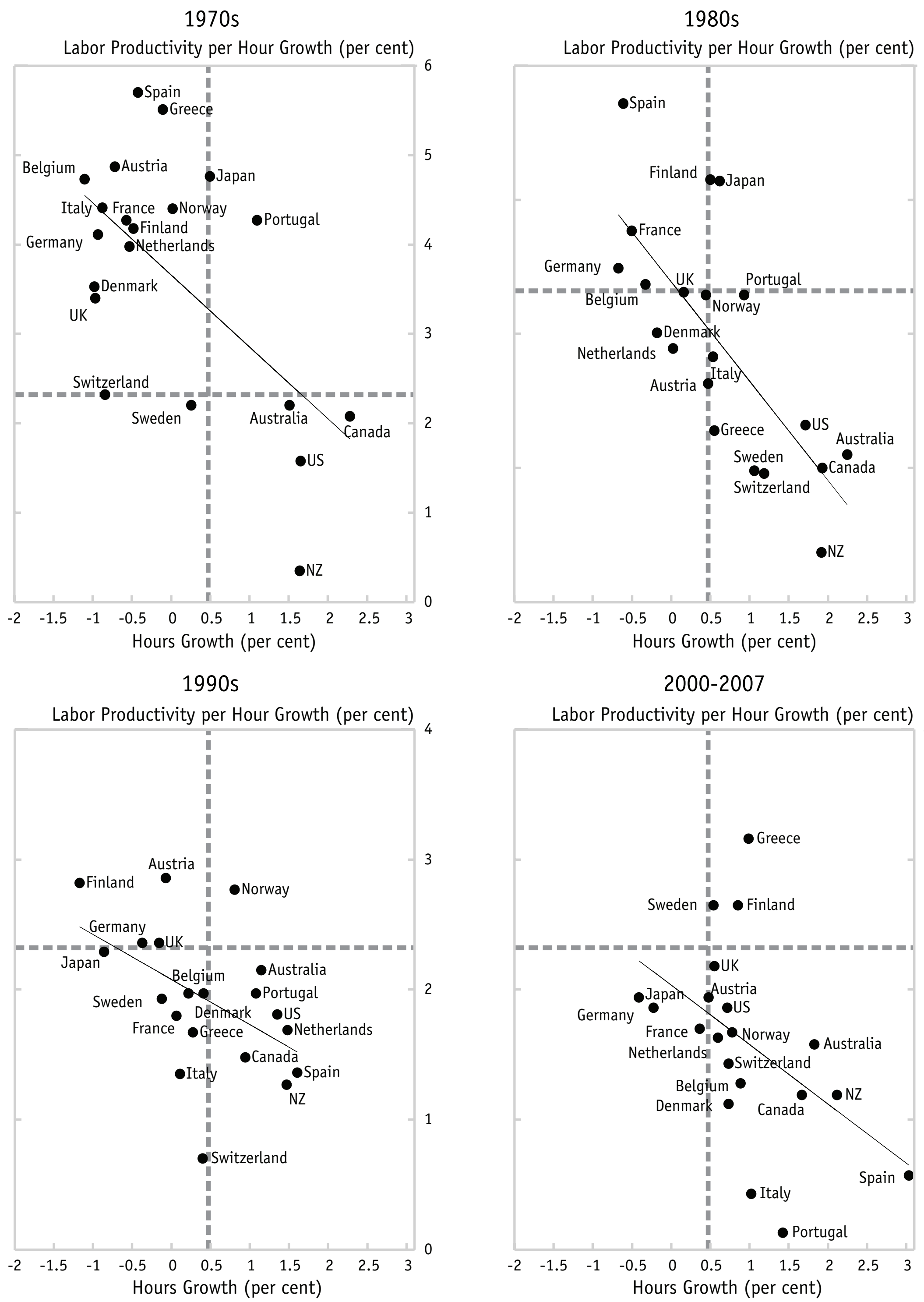
Robustness Check: Replacing TFP by Labour Productivity

Throughout the article we have focused on TFP growth as the best empirical representation of what macroeconomic theory considers "production efficiency." However, TFP is a derived measure and, even though we believe measurement errors are not driving our results, alternative efficiency measures could generate different results. An easy robustness check is to proxy changes in production efficiency by labour productivity growth, defined as GDP per hour worked.

Labour productivity could be negatively correlated to changes in hours worked in the short-run as labour input is more volatile than capital and underlying TFP changes, but there is no reason to assume that this correlation would be maintained in the medium- to long-run. For instance, as hiring increases following a reduction in unions' wage demands, labour productivity growth would decline. As firms adjust investment to return capital-labour ratios to steady-state values, this initial slowdown in labour productivity would be reversed (Blanchard, 1997, and Estevão, 2007). In this example, the initial wage shock would raise hours growth during the transition phase but keep medium-term labour productivity growth unchanged. In contrast, a negative relationship between the growth in hours and labour productivity growth could remain in the medium term, if, as we argue here, there is a tradeoff

Chart 4b

Relationship between Labour Productivity Growth and Hours Growth by Quadrant and by Decade



Dotted lines represent the averages over 1970-2007 on all charts between investing in efficiency gains (i.e. making TFP grow faster) and using the newly available labour.

Indeed, Chart 4a shows that labour productivity growth is negatively correlated to changes in hours worked in the long run. Moreover, the country ordering in Chart 4a is similar to the ordering in Chart 1, indicating a close mapping from the relationship between TFP growth and hours growth shown earlier. Chart 4b illustrates the same pattern of movement to the lower right quadrant of high hours growth-low productivity growth in the latter part of the sample period as observed in Chart 3b. Our basic instrumental variable regressions for labour productivity growth produce a comparable negative result to the estimations using TFP growth as dependent variable, reaffirming that exogenous changes in hours worked are negatively related to improvements in production efficiency. Using tax wedges (Appendix Table 1) or population growth (Appendix Table 2) as instrumental variables, growth in hours of work affects labour productivity growth negatively for the whole sample period, 1970-2007. The negative relationship is maintained within each of the four decades, although the hours growth coefficient is not always statistically significant.

The sectoral regressions are also similar (Appendix Tables 3a and b), although the coefficients of hours growth tend to be larger and more significant, and the ordering of the sectors changes. As it was the case when using TFP to measure production efficiency, controlling for sectoral composition across countries does not affect the aggregate negative relationship between hours growth and labour productivity growth.[11]

Conclusion

As economists, we are used to thinking about total factor productivity — a catch-all term for technological advances and improvements in firms' management and organization — as an exogenous determinant of economic growth. Canonical research by Robert Solow over 50 years ago linked TFP to long-run per capita GDP growth and to differences in growth rates across countries (Solow, 1956). Since then, much research has focused on identifying factors that affect TFP such as funding for research and development, barriers to entrepreneurship, and the degree of market regulation.[12] The labour market impact of TFP growth has been less certain. Traditionally, the response of labour input to changes in TFP depends on a variety of factors, including whether the change is labour saving or labour augmenting and whether the shock in TFP raises aggregate demand (Blanchard *et al.*, 1995). Real business cycle literature has argued that TFP is positively correlated with hours worked, possibly because of labour hoarding or variation in the rate of capacity utilization (Burnside *et al.*, 1995). Other work more related to ours often finds a short- to medium-run negative relationship between hours and labour productivity (not TFP) suggesting that sometimes aggregate demand or investment may not adjust or adjust quickly enough to bring labour productivity growth back to previous rates.[13]

11 All sectoral results are available upon request.

12 See for example, Romer (1990), Holmes and Schmitz (2001), and Acemoglu *et al.* (2007).

13 For instance, Estevão (2007) shows that the rapid increase in employment in several euro-area countries following a period of wage moderation in the mid-1990s was the main factor behind slower labour productivity growth in the region. However, using a similar framework to the one proposed in Blanchard (1997), the same paper shows that as low wages raise profit rates to a level above the (exogenously given) user cost of capital, investment would rise, capital deepening would speed up, and labour productivity growth would return to its original steady state pace. Dew-Becker and Gordon (2012) documents that investment rates in several euro-area countries have not quite recovered from the wage moderation process, resulting (so far) in a more subdued labour productivity growth path.

The results in this article tell a somewhat different story. The long-run negative correlation we find between TFP growth and hours growth raises questions about how conclusive Solow's earlier result is in explaining cross-country differences in output performance over the long run. The relatively strong growth performance of Canada in the face of weak TFP growth is a case in point. More generally, the finding that cross-country variance in technology (a key determinant of TFP growth) is significantly greater than the variance in output performance (Comin *et. al*, 2006) suggests that other factors besides TFP growth must be at play in determining long-run output growth.

Our results also raise questions about the factors that influence TFP growth. We are not arguing that TFP is entirely determined by labour endowment. However, our instrumental variable results point to channels through which firms, industries, and countries may vary the intensity and efficiency with which they utilize labour, depending on labour cost and labour availability. Put another way, the results suggest that studies trying to explain TFP growth by focusing on R&D investment and institutions could be missing an important variable: the availability of inputs. For instance, having abundant labour could tilt business decisions toward not paying the costs of implementing innovations or reorganizing production that would ultimately result in faster TFP growth. In fact, past work has discussed how the process of introducing new technologies could be costly and interact in nontrivial ways with demographic forces (e.g., Beaudry *et al.*, 2005), but more research on the topic is clearly needed.

These results also suggest that for countries, like Canada, close to the technological frontier with good institutions and adequate support for research, development, and entrepreneurship, concerns about slow TFP growth may be less pressing as long as labour input growth remains strong. In addition, they also suggest that countries which enact policies to reduce the cost of labour or increase immigration should not necessarily be alarmed to find TFP growth slowing—as was the case for a number of European countries during the 1990s. However, if there is a tradeoff between TFP growth and hours growth, as countries face the aging of their population, like Japan, every effort should be made to boost immigration of well-qualified foreign workers and to create an environment where firms and industries can improve technology easily.

Finally, if under certain circumstances there is a tradeoff between TFP growth and hours growth, such as for countries near the production frontier, then there may be social welfare implications of pursuing policies that favor TFP growth over that of hours. Policies that increase production efficiency at the expense of hours of work and/or employment may result in increased unemployment, loss of income for workers, and reduced overall well-being. Indeed, a budding literature (e.g. Layard, 2005) has stressed the large negative effects of joblessness on human happiness.

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Appendix

Appendix Table 1

Relationship between Labour Productivity Growth and Hours Growth Using the Tax Wedge as an Instrument, 15 OECD Countries

Step 1 Regression

Hours Growth vs. Average Tax Wedge by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	-2.42**	-4.21**	-2.88*	-1.61	-0.23
	(1.00)	(1.82)	(1.35)	(1.19)	(1.33)
Average Tax Wedge	4.52**	6.15**	5.51**	3.23	1.82
	(1.60)	(2.69)	(2.14)	(1.96)	(2.21)
Adjusted R^2	0.33	0.23	0.29	0.11	-0.02

Step 2 Regression

Labour Productivity per Hour vs. Predicted Hours Growth by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	2.60***	3.59***	2.19***	2.11***	2.19**
	(0.20)	(0.32)	(0.35)	(0.19)	(0.79)
Predicted Hours	-0.63*	-0.78	-0.27	-0.60	-0.64
	(0.35)	(0.56)	(0.46)	(0.43)	(0.92)
Adjusted R^2	0.14	0.06	-0.05	0.06	-0.04

Labour Productivity per Hour vs. Hours Growth and Average Tax Wedge by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	2.74**	3.75	0.22	2.53***	2.25**
	(1.02)	(2.37)	(1.12)	(0.81)	(0.88)
Hours Growth	-0.57**	-0.75**	-0.95***	-0.34*	-0.42**
	(0.24)	(0.30)	(0.20)	(0.18)	(0.18)
Average Tax Wedge	-0.28	-0.23	3.78*	-0.84	-0.40
	(1.72)	(3.49)	(1.87)	(1.38)	(1.50)
Adjusted R^2	0.37	0.32	0.61	0.22	0.21

Note: The tax wedge is equal to (1- tax rate on labour income)/(1 + tax rate on consumption expenditures).

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Number of observations: 15.

Sources: Authors' calculations using TED and McDaniel (2007) datasets.

Appendix Table 2

Relationship between Labour Productivity Growth and Hours Growth Using Population Growth as an Instrument, 20 OECD Countries

Step 1 Regression

Hours Growth vs. Population Growth by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	-0.55***	-1.31***	-0.15	-0.27	0.12
	(0.16)	(0.28)	(0.23)	(0.31)	(0.17)
Population Growth	1.80***	1.96***	1.58***	1.22**	1.58***
	(0.24)	(0.36)	(0.38)	(0.46)	(0.27)
Adjusted R^2	0.75	0.61	0.46	0.24	0.64

Step 2 Regression

Labour Productivity per Hour vs. Predicted Hours Growth by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	2.60***	3.65***	2.26***	2.05***	2.07***
	(0.16)	(0.31)	(0.27)	(0.18)	(0.28)
Predicted Hours Growth	-0.61***	-0.56	-0.52	-0.27	-0.50*
	(0.21)	(0.37)	(0.31)	(0.31)	(0.25)
Adjusted R^2	0.28	0.06	0.08	-0.01	0.13

Labour Productivity per Hour vs. Hours Growth and Population Growth by Period

Period	1970-2007	1970s	1980s	1990s	2000-2007
Constant	2.50***	2.78***	2.19***	2.02***	2.06***
	(0.28)	(0.71)	(0.21)	(0.23)	(0.26)
Hours Growth	-0.80**	-1.23***	-0.96***	-0.38**	-0.38
	(0.33)	(0.40)	(0.22)	(0.18)	(0.35)
Population Growth	0.35	1.31	0.69	0.13	-0.18
	(0.68)	(0.99)	(0.49)	(0.40)	(0.68)
Adjusted R^2	0.43	0.36	0.55	0.16	0.14

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Number of observations: 20.

Sources: Authors' calculations using TED and United Nation datasets.

Appendix Table 3a

Relationship between Labour Productivity Growth and Hours Growth by Sector, 1980-2007 (OECD 14)

Industry	Coefficient		Constant		Adjusted R^2
Financial Services	-0.73***	(0.18)	3.42***	(0.64)	0.53
Transportation	-0.70***	(0.19)	2.38***	(0.21)	0.51
Total Economy	*-0.56****	*(0.16)*	*2.24****	*(0.14)*	*0.46*
Agriculture, Forestry, and Fishing	-0.54**	(0.19)	0.29	(0.50)	0.35
Wholesale and Retail	-0.53*	(0.27)	2.17***	(0.23)	0.18
Hotels and Restaurants	-0.51**	(0.20)	2.38***	(0.37)	0.30
Electricity	-0.49*	(0.23)	2.79***	(0.27)	0.21
Other Services	-0.32	(0.21)	1.82***	(0.33)	0.09
Manufacturing	-0.31	(0.24)	1.91***	(0.33)	0.05
Construction	-0.20	(0.12)	1.74***	(0.17)	0.11
Mining and Quarrying	0.10	(0.40)	4.03**	(1.50)	-0.08

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Number of observations: 14.

Sources: World KLEMS, EU KLEMS.

Appendix Table 3b

Relationship between Labour Productivity Growth and Hours Growth by Sector, 1980-2007(G7)

Industry	Coefficient		Constant		Adjusted R^2
Financial Services	-0.99**	(0.26)	4.19***	(0.81)	0.70
Wholesale and Retail	-0.86*	(0.39)	2.23***	(0.32)	0.38
Hotels and Restaurants	-0.84**	(0.27)	2.78***	(0.50)	0.59
Electricity	-0.76*	(0.33)	2.93***	(0.35)	0.42
Transportation	-0.75***	(0.18)	2.19***	(0.20)	0.74
Total Economy	*-0.68***	*(0.25)*	*2.29****	*(0.19)*	*0.52*
Other Services	-0.55	(0.40)	2.33***	(0.57)	0.12
Agriculture, Forestry, Fishing	-0.49	(0.26)	0.51	(0.72)	0.31
Manufacturing	-0.29	(0.26)	1.78***	(0.42)	0.04
Construction	-0.29	(0.26)	1.60***	(0.30)	0.03
Mining and Quarrying	-0.27	(0.34)	2.38	(1.36)	-0.07

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Number of observations: 7.

Sources: World KLEMS, EU KLEMS.

Comments on "Productivity or Employment: Is It a Choice?"

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Abstract

These comments express caution regarding the results of the article "Productivity or Employment: Is It a Choice?" by Andrea De Michelis, Marcello Estevão, and Beth Anne Wilson and recommend further investigation of the relationship between productivity and employment growth before definitive conclusions are reached. In particular, the authors are encouraged to attempt to take account of the age and educational attainment distribution of the workforce within a country in attempting to explain TFP growth.

Résumé

Ces commentaires expriment certaines réserves face aux résultats de l'article « Productivity or Employment: Is It a Choice? » de Andrea De Michelis, Marcello Estevao and Beth Anne Wilson, et recommandent une analyse approfondie de la relation entre croissance de la productivité et croissance de l'emploi avant d'arriver à des conclusions définitives. En particulier, les auteurs sont encouragés à prendre en compte l'âge et le niveau de scolarité de la main-d'œuvre à l'intérieur d'un pays dans leur tentative d'expliquer la croissance de la PTF.

THE ARTICLE "Productivity or Employment: Is it a Choice?" by Andrea De Michelis, Marcello Estevão, and Beth Anne Wilson contends that there is a tradeoff between growth in hours and productivity. The authors argue that for countries such as Canada, which are operating near the efficiency frontier, low rates of productivity growth should not be a concern as long as hours growth is robust. Growth from any source matters.

The authors ran their basic regression including and excluding recession years in order to determine if a recession effect dominates their sample. Recession and recovery effects are two-fold: at the beginning of a recession firms typically hoard labour as they do not wish to lay off their most valuable employees until it is absolutely clear that it is necessary. During this phase, productivity growth tends to be negative as output is decreasing with hours stable or slightly increasing. As recovery begins, firms are slow to rehire workers as they are uncertain about the strength of the economy. During this phase, productivity growth tends to be high as output is increasing with hours stable or slightly increasing.

As the coefficients with recession years omitted are fairly similar to those with recession years included, it is safe to conclude that their conclusions are not compromised by business cycles effects.

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The sector results raise concerns. Models were estimated for the G7 countries and for 14 OECD countries for the years 1980-2007 for ten sectors and for the total economy.[2] In these results, the hotel and restaurant sector played a prominent role. This sector coefficient was significant at a .05 level of significance or less in both models and was the largest of any coefficient in absolute value terms, including that for the total economy. Other than hotels and restaurants, the only other statistically significant coefficients at that level were for manufacturing and the total economy (G7) or for the total economy only (OECD 14). Since hotels and restaurants are part of the difficult to measure service sector, I question the validity of these results without a validating story and an examination of this sector's data and the underlying measurement methodology.

Weighting hours and total factor productivity at the sector level by U.S. value-added shares seems very similar to a reallocation decomposition. The authors state that this weighting was done to remove the effect of industry composition. Reallocation explains the difference between aggregate total factor productivity estimated from an aggregate production function growth and sectoral productivity growth estimated from sectoral production functions in terms of reallocation of value-added, capital, and labour. An aggregate production function assumes industry composition makes no difference, whereas sectoral production functions allow for differences in industries and captures movements of factors and the corresponding value-added across sectors. The weighting of hours and total factor productivity may be largely picking up reallocation effects as opposed to cleanly removing the effect of industry composition.[3]

Both the age and education distribution of a country's working age population can have a significant impact on total factor productivity. The authors recognize age as a factor when they state "In response to aging populations, will countries experience rising TFP as firms find ways to utilize existing workers more effectively?" (De Michelis, Estevão, and Wilson, 2013:43) In addition, they conclude that "population affects TFP only through hours worked and, thus, appears to be a good instrument for TFP" (De Michelis *et al.*, 2013:52). I suspect such a conclusion could not be reached if population distributions were used instead of total population.

Charts 1 and 2 illustrate the significant differences in age and educational attainment distributions across countries.[4] For the working age population, the charts show significant differences between countries. Countries with a larger proportion of younger and highly educated individuals are more likely to experience higher total factor productivity growth. Accordingly, using total population growth can hide important factors which could affect total factor productivity directly.

Questions from the floor during discussing at the AEA session where the paper was presented raised additional factors which could influence the relationship between hours and

2 The OECD 14 countries are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Spain, United Kingdom and the United States.

3 The reallocation equation is found in Jorgenson, Gollop, and Fraumeni (1987:312-313).

4 The charts are derived from data underlying Li (2011), Li *et al.*, (2013), and Liu (2011). Australia, Canada, Denmark, France, Israel, Italy, Japan, Korea, Netherlands, Norway, New Zealand, Spain, the United Kingdom, and the United States are in the charts and included in the De Michelis *et al.* (2013). Belgium, Finland, Germany, Greece, Portugal, Sweden, and Switzerland are included in the De Michelis *et al.* (2013), but not in the charts. China, Poland, and Romania are in the charts, but are not included in De Michelis *et al.* (2013).

Chart 1
Working Age Population Shares by Age Group, 2006

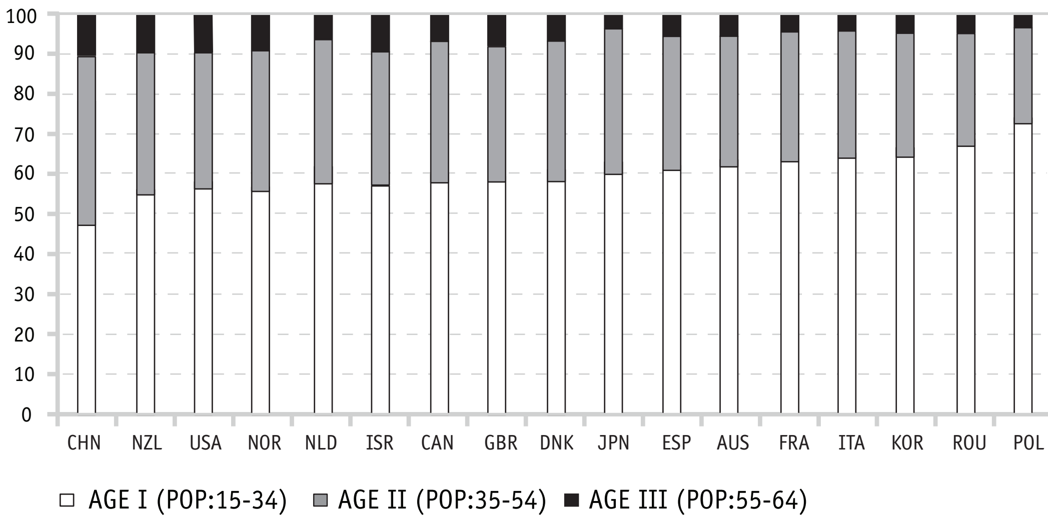
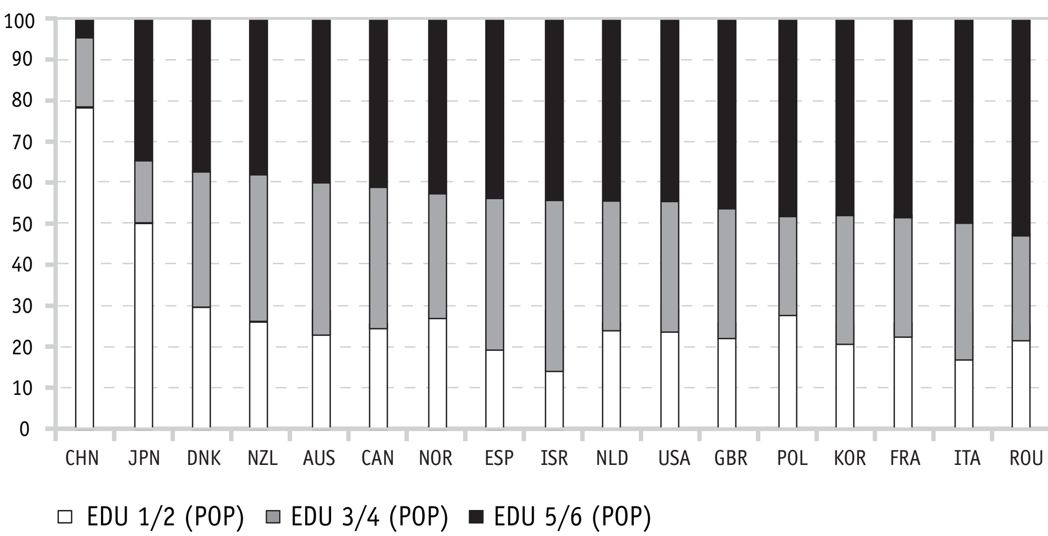


Chart 2
Working Age Population Shares by Educational Level, 2006



Note: Following the International Standard Classification of Education (ISCED), EDU 0/1/2 includes those with at most primary or junior middle school levels of attainment (grades 1-9), EDU 3/4 includes those with at most senior middle school grade (grades 10-12) or post-secondary non-tertiary education levels of attainment, and EDU 5/6 includes those with at least one year of higher (tertiary) education.

total factor productivity. These questions should be followed up.

In conclusion, this article has established an important relationship between hours and total factor productivity. I would like the nature of this relationship investigated further. My comments have suggested some directions for this investigation. An important result is that for a country experiencing growth, the focus of concern should not be limited to total factor productivity.

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European Productivity Growth Since 2000 and Future Prospects

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Abstract

This article revisits the issue of Europe's growth slowdown, taking into account the latest experiences from the recession and the debt crisis since 2008. There are few, if any, signs of even the beginnings of a reversal in the slowing growth trend, which is primarily driven by the weak productivity performance in most European countries. Recently, slow productivity growth has broadened from the services sector to the goods sector for most European economies. Output growth projections out to 2025 show a deceleration in Europe's growth trend compared to the pre-recession period, and even compared to the latest period, 2006-2012, there are no signs of significant acceleration in the growth trend. Demographic structures and continued slow total factor productivity growth are both dampening trend output growth, although there will be large variation between different EU economies.

Résumé

Le présent article revient sur la question du ralentissement de la croissance de la productivité en Europe et tient compte des dernières expériences de la récession et de la crise de l'endettement depuis 2008. Il y a peu ou pas de signe d'un renversement de la vapeur pour ce qui est du ralentissement de la croissance, causé principalement par la faible productivité dans la plupart des pays européens. Le faible taux de croissance de la productivité s'est récemment répandu, du secteur des services au secteur des biens, dans la plupart des pays européens. Les prévisions concernant la croissance de la production jusqu'en 2025 ne démontrent aucun signe d'accélération importante par rapport à la tendance actuelle. Les structures démographiques et la faible croissance de la productivité totale des facteurs entravent la croissance de la production, quoique l'écart sera vaste entre les différents pays de l'UE.

Like elsewhere in the advanced world, the financial crisis and recession in 2008-09 and its aftermath have significantly affected the growth performance of European economies. To understand how the recovery will evolve, who will benefit and what the timing will be, it

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is important to distinguish between cyclical recession and recovery effects, and the structural impact of the crisis. It is therefore important to not only look at the most recent changes and detect the green shoots of recovery, but also to take a comparative view at the pre- and post-crisis trends in productivity growth.

Thanks to two datasets that are now being updated and extended on a regular basis, we have recent data series on the latest productivity developments in a comparative perspective. On the basis of the most recent update of *The Conference Board Total Economy Database* (January 2013) and the *EUKLEMS Growth and Productivity Accounts* (November 2012), we can review the impact of the crisis by looking at Europe's growth and productivity performance during the last decade

In this article we first review the latest macroeconomic output, input and productivity estimates for 2011 and 2012. We then take a closer look at two sub-periods, 2001-2005 and 2006-2012. This latter sub-period is of course strongly affected by the 2008-09 recession, but by including the peak year 2007 and the recovery years 2010 and 2011, it provides a good comparison with the first sub-period. In addition to estimates of labour productivity, we decompose output growth into the contributions of growth in hours worked, labour composition, capital (both IT and non-IT) and total factor productivity (TFP). TFP growth, in turn, can also be broken down to the sector level, using updated EUKLEMS data, to look at shifts in productivity dynamics between the goods sector, market services and non-market services. Finally, we provide productivity growth projections for 2013, as well as for 2014-2018 and 2019-2025.

Productivity Growth Estimates for 2011 and 2012

Following a rapid recovery in 2010 during the immediate aftermath of the 2008-09 recession, productivity growth slowed down significantly in 2011 and 2012 as seen in Table 1 (all tables can be found at the end of the article; for earlier year estimates, see http://www.conference-board.org/data/economydatabase/).[2] Our estimates include both labour productivity growth, measured as the change in real (i.e. inflation-adjusted) aggregate GDP per hour worked, and TFP growth, which represents the change in real GDP not explained by the change in an index of combined labour and capital input.[3]

At the time of writing, the estimates for 2012 are preliminary, and partially still based on projections of output and employment growth awaiting more comprehensive GDP and labour input data which are fully integrated in a national accounts framework. Still, it is clear that, on average, the productivity slowdown in 2012 in mature economies was entirely due to slower output growth.

For example, in the Euro Area,[4] labour productivity growth fell off from 1.2 per cent in 2011 to 0.6 per cent in 2012. Output actually declined 0.5 per cent in 2012, after increasing 1.4 per cent in 2011, signaling that the Euro

2 The aggregate productivity estimates in this article are for the total economy, including the non-business sector. Later in this article we distinguish between the market sector (both goods and services) and the non-market sector (primarily government, educational services, and health care industries). For an international comparison of productivity trends, the total economy is the appropriate aggregate measure as the size of the business sector relative to the total economy and its composition varies across countries.

3 Both labour productivity and TFP are value-added measures, and therefore do not take into account intermediate inputs, such as energy, materials and service inputs, as required in a full-fledged KLEMS (capital-labour-energy-materials-services) framework.

4 The Euro Area currently includes the following 17 countries: Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia, and Spain.

Area was heavily affected by the intensification of the financial and fiscal crisis during late 2011 and early 2012. At -1.1 per cent, total hours worked contracted much more sharply than output, resulting in the 0.6 per cent increase in output per hour. However, the efficiency of production factor use, as measured by TFP, declined by 0.8 per cent, meaning that labour and capital in the Euro Area were allocated less efficiently in 2012 compared to previous years. This decline in efficiency probably resulted from less productive companies clinging to resources, especially labour, together with failing to bring new innovations to market given the lack of demand.

For comparison, in the United States, the growth of labour productivity experienced a comparable fall, but to an even lower growth rate than in Europe, down from 0.8 per cent in 2011 to only 0.2 per cent in 2012. However, the underlying dynamics of output and hours growth in the United States were the opposite of the Euro Area. There was a slight improvement in U.S. GDP growth from 1.8 per cent in 2011 to 2.2 per cent in 2012, but total hours growth gained more traction as it doubled from 1.0 per cent to 2.0 per cent. This labour market improvement was thus accompanied by dismal productivity performance. The 2012 productivity growth performance is one of the slowest observed during the post-World War II period in the United States — output per hour only grew slower than 0.2 per cent in 1974 (-1.0 per cent) and 1982 (-0.8 per cent). The slowdown in U.S. labour productivity growth is due to a combination of weak investment growth, held back by low levels of business confidence (in part related to the fiscal crisis), and few efficiency gains (as measured by TFP growth at 0.2 per cent).

Within the Euro Area, there was an unusually large variation in productivity growth rates between economies, reflecting the different impacts of the debt crisis in 2012. Spain, for example, registered the highest growth rate in labour productivity, at 2.3 per cent in 2012. This resulted from a sharp contraction in total hours worked (-3.7 per cent), much greater than the fall in GDP (-1.4 per cent). This is a very different outcome from, for example, Greece where labour productivity fell 1.3 per cent, one of the biggest declines in the Euro Area in 2012. The difference in how the two economies are adjusting to the crisis is also clearly reflected in TFP, which is estimated to have declined 4.3 per cent in Greece compared to a 0.2 per cent decrease for Spain.

In Germany and France, the growth rates in output per hour have also fallen considerably in 2012, that is, to 0.4 per cent (down from 1.6 per cent in 2011) for Germany and to -0.2 per cent (down from 1.4 per cent in 2011) for France. In Germany, even though employment expanded significantly at 1.0 per cent in 2012, total working hours increased by only 0.3 per cent, due to less overtime and more vacation days. Still, Germany's employment growth seemed beyond what could be supported by the growth in output. Its strong export performance outside the EU was balanced by increased weakness among its major Euro Area trading partners, including France, Italy and Spain. Also domestic consumption and investment in Germany, which are the components of aggregate demand that generate the most jobs, did not grow as rapidly as the export sector. In France, job growth was much slower than in Germany but total working hours still increased by 0.4 per cent, which was faster than France's output growth at 0.2 per cent. Of greater concern is that TFP declined 0.4 per cent in Germany and 1.0 per cent in France. The widespread weakness of TFP growth among major European countries, points to ongoing structural rigidities in labour, capital, and product markets, as reflected in the incomplete single market in Europe (especially for services) and the lack of true mobility of labour within and between European economies.

The developments in the EU-27 are similar to those in the Euro Area (which includes only 17 of the 27 EU member states), although several Central and Eastern European (CEE) economies, which are somewhat less exposed to the fallout from the Euro Area crisis, showed less of a decline in output and hours. The largest economy in the region, Poland, saw a slowdown in output and total hours growth, but still performed solidly in 2012 with a 2.2 per cent increase in labour productivity. However, at only 38.7 per cent of the U.S. output per hour level, there is still much scope for improvement in Poland's productivity performance, as there is in the other CEE economies.

In contrast to Central and Eastern Europe, the United Kingdom showed a much weaker economic growth performance than anticipated in 2012, with GDP falling 0.3 per cent. Growth in total hours remained fairly stable at 1.0 per cent, indicating significant labour hoarding in times of serious austerity. As a result, labour productivity growth in the UK declined dramatically by 1.3 per cent. Also, the UK's level of output per hour remains at 80.4 per cent of the U.S. level, well below that of its main continental counterparts, France and Germany.

On average, the level of productivity in the Euro Area, measured as output per hour in U.S. dollars (after adjustment for differences in relative price levels using purchasing power parities) is much lower than in the United States — just 80.9 per cent of the U.S. level in 2012. But this average hides a very large variation reflecting the different levels of development and economic structure (such as the share of manufacturing in the economy) among Euro Area countries.

Major European economies such as Germany and France have higher labour productivity levels than the Euro Area average at 89.9 per cent and 93.1 per cent, respectively, of the U.S. level, whereas economies like Spain and Italy are at 76.3 per cent and 71.8 per cent, respectively. The productivity level of Greece and Portugal is much lower still at just 50.3 per cent and 42.0 per cent of the U.S. level. As these Mediterranean economies showed much larger employment losses than the northern economies in Europe, the share of labour in Euro Area countries with high productivity levels increased significantly. This boosted the average productivity growth rate of the Euro Area by 40 per cent, resulting in a growth rate of 0.6 per cent in 2012.[5]

Changing Dynamics of Productivity Growth before and after the Great Recession

When looking at the impact of the Great Recession on Europe's growth, it is useful to look at aggregate GDP, GDP per capita and labour productivity together to better capture and understand the effects of changes in the labour market. We find that GDP and per capita growth about halved in the aggregate EU-27 between 2001-2005 and 2006-2011 (Table 2).[6] In the "old" EU-15, representing the member states before 2004, both GDP growth and GDP per capita growth fell between periods in all economies, except Germany and the Netherlands. For the new member states (EU-12), only Poland (and Malta) saw an increase in GDP growth and GDP per capita growth. Certain Central and Eastern European countries were severely hurt because of their export dependence on the rest of Europe.

5 For 2012, 0.25 percentage points (42 percent of the 0.6 percent increase in output per hour) resulted from a reallocation effect, given more weight to productivity growth in Euro Area economies with higher productivity levels. The remaining 0.33 percentage points resulted from within-country growth in labour productivity.

6 Here we have chosen to take the data up to 2011 only, as the comparison between the two periods could be affected by the preliminary nature of the 2012 estimates.

The slowdown in labour productivity growth after 2005 was more moderate than for per capita income, especially in the Euro Area economies, pointing at a drop in the employment/population rate, which has resulted from a combination of higher unemployment and lower labour force participation.

Underlying the slowdown in labour productivity growth are stark differences between countries. The biggest declines in labour productivity growth in EU-15 countries between periods were seen in Sweden, Luxembourg, and, not surprisingly, Greece. These productivity declines were related to their large decline in GDP growth beyond the decline in employment growth. In Germany, despite a rise in GDP and per capita income growth between 2001-2005 and 2006-2011, labour productivity growth fell by 0.4 percentage points, suggesting strong labour hoarding effects as a result of short-time working programs. In contrast, labour productivity growth increased in Poland between the 2001-2005 and the 2006-2010 periods, which resulted from an expansionary growth process. Spain also saw an acceleration in labour productivity growth, but, in contrast to Poland, it cut hours even more than GDP.

Using a growth accounting framework, Tables 3a and 3b decompose the growth of aggregate GDP into the contributions of labour, capital and TFP for both sub-periods. On average, hours worked in the "old" EU-15 contributed less to growth from 2006 to 2011 than from 2001 to 2005, although the picture is very mixed between economies. Germany, Sweden and Luxembourg showed the largest gains in hours worked between periods while, not surprisingly, the "troubled" economies (Greece, Spain, Portugal, Italy and Ireland) showed the weakest labour market performance.

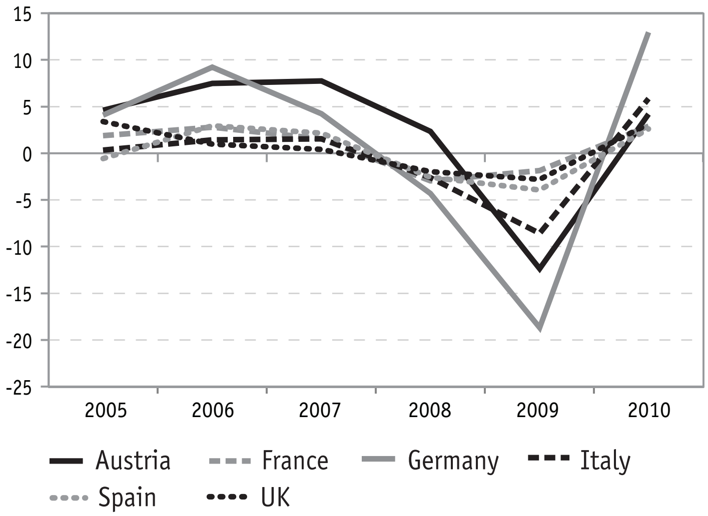
On average, hours in the “new” EU-12 countries contributed more to growth in 2006-2011, especially because of a better labour market outcome in Poland and the Slovak Republic. Labour markets in the Baltic States and Hungary were much more severely affected by the crisis.

Capital growth was the main driver of labour productivity growth in the aggregate EU estimates in both sub-periods, split between ICT and non-ICT capital. In the EU-15, the growth contribution of ICT capital has stayed relatively high in most countries, especially in the Nordic countries but also in the "troubled" economies (including Ireland). Non-ICT capital growth accounted for the largest part of capital growth in the new EU-12 countries in the 2006-2011 period. Ireland maintained a relatively rapid growth in non-ICT capital, probably as a result of the construction boom.

TFP has emerged as the Achilles’ heel of Europe’s growth performance. In the "old" EU-15, all countries had negative TFP growth in 2006-2011, except for Germany, Austria and the Netherlands. In the "new" EU-12, TFP growth remained positive, except in Bulgaria, Hungary and Slovenia, but it was very weak in the Baltic States.

Overall, TFP growth has been the main source behind the slowdown in Europe’s growth for all of the past decade, but the problem has become worse during the second half of the 2000s. The continuation of the slowing trend in TFP growth points at a range of possible explanations. Beyond the temporary impact from the recession, it can be a sign of weakening innovation and technological change. But for the TFP growth rate to turn negative, as turned out to be the case for most “old” EU-15 economies, additional explanations are needed. First, it could signal increasing rigidities in labour, product and capital markets, causing increased misallocation of resources to low-productive firms. Second, and related to the first, there might be a negative reallocation effect, with more

Chart 1
TFP Growth in the Goods Sector in Select European Countries, 2005-2010
(per cent)



Source: EU KLEMS Database, update November 2012..

resources going to the less productive sectors in the economy.[7]

A Sectoral Perspective on the Productivity Slowdown in Europe

To test the hypothesis of negative reallocation effects as a source of the slowdown in aggregate productivity growth in Europe between 2001-2005 and 2006-2010, we look at a breakdown for TFP growth between three major sectors of the economy: 1) goods production, including agriculture, mining and manufacturing; 2) market services, including wholesale and retail trade, transportation and warehousing; among other services; and 3) non-market services, which include community, personal and social services (including education, health care and public administration).[8] So far, industry-level growth accounting results extend to 2010, and could be obtained for the five largest European economies (France, Germany, Italy, Spain and the United Kingdom) as well as Austria, using the updated EU KLEMS database (November 2012), with additional updates for 2010 by the authors.

Tables 4a and 4b show that most differences in growth performance across sectors come from TFP. In the goods sector, TFP growth was positive (except for Italy) during the 2001-2005 period, but weakened during the 2006-2010 period. The biggest decline in goods sector TFP growth occurred in the United Kingdom and, perhaps surprisingly, in Germany. The dynamics, however, were quite different between the two countries. In the UK, most of the decline was due to a decline in output growth since 2006, which was already negative in the earlier half of the decade. In Germany the slowdown in output was much more moderate, and it was primarily the retaining of labour and postponement of investment which created a temporary setback for TFP growth. In 2010, TFP growth in the goods sector in Germany rebounded 13.0 per cent after plummeting 18.7 per cent in 2009. In the UK, TFP fell by only 2.8 per cent in 2009 and showed a moderate recovery of 3.1 per cent in 2010 (Chart 1).

TFP growth was weaker in market services than in goods production in 2001-2005, and the situation worsened in 2006-2010. France and the United Kingdom suffered the largest declines, as inputs did not adjust as much for the rapid decline in market services output. The latter results align with recent evidence in the United Kingdom of slow productivity

7 For a brief review of the literature on the relationship between productivity, resource allocation and competition, see Timmer *et al.* (2010:265-267).

8 Measurement problems with regard to output in non-market services are large and the productivity estimates should therefore be interpreted with caution. Real estate activities are also included with non-market services, as the output measure includes imputed rents on owner-occupied dwellings, making the interpretation of the productivity measure problematic.

growth, despite decent employment growth. However, Germany's TFP growth rate in market services increased from 0.8 per cent per year in 2001-2005 to 1.2 per cent in 2006-2010, recovering from a very weak output growth rate, from 0.3 per cent per year in 2001-2005 to 2.0 per cent in 2006-2010.

In non-market services, TFP growth was zero or negative in all six European economies for both the 2001-2005 and the 2006-2010 periods. While the measurement of real output in non-market services is fraught with problems, which are only slowly being resolved, it is important to understand the dynamics of change in the sector, which accounts for up to 30 per cent of employment in most European economies. Output growth in non-market services remained relatively stable in most countries between 2001-2005 and 2006-2010, except for Italy and the United Kingdom where it dropped by 1.1 percentage points and 2.1 percentage points per year, respectively. Spain and the UK saw the largest downward adjustments in total hours growth in non-market services, but for all six economies the growth rate remained positive. The fall-off in TFP growth between periods was strongest in the UK. In fact, Spain and Austria saw significant improvements in TFP growth, though the TFP growth rate remained negative in both cases. Non-market services typically show weak productivity growth, as the Baumol "cost-disease" hypothesis in services applies mostly to non-market services. However, the potential for technology applications, as attested by the relatively strong continued increases in ICT capital, and presumed cost savings in non-market services remains strong.

Overall, the sectoral growth accounts show considerable declines in TFP growth across the board between 2001-05 and 2006-10, so that labour input shifts to less productive activities do not materialize as the main explanation for the slowing trend at the aggregate level. Services — and especially non-market services — posted most of the negative TFP growth rates throughout the period. Slow productivity growth in services partly results from slower adjustments and misallocations of inputs, which may point to the need for continued structural reforms in labour and product markets. However, ongoing investments in capital, especially in ICT capital, may also signal a drive towards better innovation performance with potential productivity gains in the services sector. One hypothesis may be that stronger intra-European competitiveness is beginning to emerge as a positive source for growth in Europe's market services.

Productivity Growth Projections

Even though projections of productivity growth are complex, because of the need to forecast several variables, including labour, capital and TFP, we have undertaken an effort to do this in order to provide a perspective on the timing of a growth rebound. For 2013, we rely largely on forecasts for GDP and employment, including assumptions on the growth in hours per person employed, whereas we developed a growth accounting projection model for the medium-term.

Using *The Conference Global Economic Outlook* (Chen *et al.*, 2012). The projections cover the period 2013-2025, with separate projections for the medium term (2013-2018) and for the long term (2019-2025).[9] Projections for labour and capital inputs use the framework developed in Jorgenson, Ho and Stiroh (2005) and Jorgenson and Vu (2008), but with several improvements, especially for the estimation of capital services and TFP.

9 The November 2012 version of the outlook covers 55 major economies across 11 global regions, including 33 advanced economies (the United States, Europe, Japan and other advanced economies) and 22 emerging and developing economies.

For labour quantity, the measures are primarily based on projections for the working age population (age of 15-64) from the *International Data Base of the U.S. Census Bureau*. Labour composition estimates are based on projections of population by level of education attainment, age and sex (Bonthuis, 2011). Capital and TFP growth are estimated by a system of equations for which we utilize standard statistical measures and economic variables. We estimate three endogenous variables: TFP growth, the savings rate, and capital services growth. The savings rate is an important addition, because it is closely related to investment capital that determines the growth of capital services. All other variables are either exogenous or predetermined. The regression approach to measure capital services and TFP growth also makes it possible to include the link to several demand-side related variables, such as trade openness, and the share of the manufacturing and services sectors in the economy.

The trend growth rates that are obtained from this exercise are adjusted for possible deviations between actual and potential output for the 2013-2018 period (Chen *et al.*, 2012).

In 2013, Euro Area output growth is projected to contract at a slower pace than in 2012 (-0.1 per cent versus -0.3 per cent), but as the labour market recovery typically lags, the growth in output per hour may drop to 0.2 per cent in 2013 compared to 0.6 per cent in 2012 (Table 5). If total hours growth in 2013 falls at more than 0.3 per cent, there could be a slightly more positive effect on productivity, making the picture look more like 2012. By comparison, in the United States labour productivity growth is expected to see a moderate improvement to 0.6 per cent in 2013 compared with 0.2 per cent in 2012. However, a slower recovery of the U.S. labour market, beyond the currently projected 1.1 per cent employment growth (and 1.2 per cent growth in total hours) in 2013, may have only a limited impact on GDP growth because it might be offset by slower productivity growth, as happened in 2012.

As both Germany and France are expected to see no growth in terms of total working hours in 2013, all output growth for 2013 will be the result of productivity growth. Germany is expected to have GDP and productivity growth at 0.8 per cent and France at 0.2 per cent. Productivity growth in Spain is expected to advance only 0.4 per cent (compared to 2.3 per cent in 2012) as the contraction continues even though the labour market may have its largest shakeouts behind it.

In Central and Eastern Europe, the biggest productivity gains in 2013 are foreseen for the Baltic States — Estonia (1.9 per cent), Latvia (2.4 per cent) and Lithuania (2.6 per cent) — as these economies are still benefiting from fairly solid growth in their largest trading partner, Russia.

In 2013, the United Kingdom is expected to return to positive growth territory with 0.9 per cent GDP growth, a growth rate that is considerably faster than the Euro Area average (-0.1 per cent). Assuming that total hours growth remains positive at around 1 per cent, labour productivity growth is likely to remain flat. A weakening labour market, however, may push productivity growth back into positive territory. However, TFP growth, which measures the rise in the productivity of combined labour and capital inputs, may remain negative until demand for products and services accelerates, allowing for a bigger contribution from TFP growth.

The largest positive productivity effects in Europe need to come from an acceleration in investment and a more efficient allocation and use of resources. Many of those potential gains will arise from the finalization of a single market in Europe, where labour, capital, products and services can flow freely through trade, harmonized banking rules, greater migration, and cross-border investment. Such sustainable productivity gains will likely take longer to achieve along Europe's path to recovery from the crisis.

A full breakdown by major growth source for all European countries included in the Global Economic Outlook for 2013-2018 and 2019-2025 is given in Tables 6a and 6b, respectively. The growth performance in EU-27 shows a deceleration relative to the pre-recession trend. Even compared to the 2006-2011 period the projections show virtually no acceleration (1.1 percent GDP for the EU-27 from 2006-2011 in Table 2b as well from 2013-2018 and 1.2 percent from 2019-2025). A breakdown into the old EU-15 and the new EU-12 shows that the difference in the long term growth trend for the two regions will remain more or less the same at 1.1-1.2 percent for the "old" EU15 compared to 1.8 percent for the "new" EU-12.

Among the large "old" EU economies various key differences emerge. As described above, Germany has picked up on growth since the mid-2000s, as result of major reforms in labour and product markets that supported a better performance in market services. In addition, the strong performance of Germany's manufacturing sector helped the country to accelerate the trend since the mid-2000s, and effective cyclical policies during the recession helped to sustain the advantage. Despite offsetting effects from weaker growth rates of working age population (when compared to, for example, France), Germany shows the strongest performance based on faster TFP growth, which allows for more productive investment. However, in the long term, Germany will ultimately converge to the trend growth rate of the Euro Area as a whole at 1.3 per cent from 2019-2025.

During the late 1990s, Spain and the UK enjoyed trend growth advantages over the other large EU-15 economies, related to convergence (in Spain) and economic restructuring (in the UK). During the 2000s both countries gradually began to return to the "old" EU-15 growth average. However, Spain already saw large productivity declines especially in services, providing early signs of the unsustainability of its growth model. In addition, the country was hit much harder by the crisis that the other major European economies. Eventually, however, Spain is expected to recover its trend growth to 1.7 per cent for the period 2019-2025, helped by slightly more positive population growth effects — in contrast to most other Mediterranean economies including France — and potential for investment in ICT. However, Spain's projections do not show a rebound in TFP growth, similar to other Mediterranean economies including France. Strikingly, the United Kingdom also fails to rebound in terms of TFP growth.

The smaller economies in the "old" EU-15 also show large differences in growth trends. For example, the Irish economy has shown most growth volatility, as it benefited during the 1990s from the accession to the EU, its specialization in producing high-tech IT equipment, and reforming the domestic labour and product markets. Despite the recession, Ireland is likely to retain many of those growth strengths in the coming decade, returning the economy to a trend growth of about 3 per cent. In contrast the economies of the Netherlands and Sweden will recover to long term growth trends of 1.5-1.7 per cent, while Austria settles at a lower growth trend of only 0.7 per cent due to a greater decline in its working age population and slower projected TFP growth.

In Central and Eastern Europe, most economies will be able to generate higher TFP growth than the EU-15, despite sizeable negative effects from slower population growth on the economies' labour forces. Competitive advantages in the foreign sector of the economy and structural changes in the domestic sector will continue to generate higher productivity growth. The three large countries in the new EU-12 (Czech Republic, Hungary and Poland) have all seen a significant acceleration in growth trend during the 1990s and 2000s, following the collapse of the socialist planned economies and the accession to the European Union. However, Poland, which is the largest economy in the new EU-12, has shown a different timing and level in its growth path than the Czech Republic and Hungary. Poland has benefited more from catching-up effects given its low starting level and it has benefited from a strong increase in its integration of the value chain with Germany, both in manufacturing as well as in services (transportation). In the longer term, however, Poland is likely to settle at a slower growth trend (at 1.5 percent from 2019-2025) than the Czech Republic and Hungary (both at 2.4 percent), because of the smaller size of the foreign sector and the lower level of education.

Conclusion

In this article, we find that the 2008-09 recession has hit European economies across the board, but the impact on productivity has differed significantly between countries, over time and across sectors. Policy makers in individual European countries have reacted differently to the immediate impact of the crisis, ranging from temporary labour hoarding to avoid a rise in unemployment (as in the Germany) to more or less deep cuts in government spending (as in the "troubled" economies and the UK), with vastly different effects on productivity. The goods sector in most economies was particularly strongly hit by the crisis, but also has seen the largest recovery effects. In contrast, the long term slowing trend in productivity in the services sector, which has been extensively documented before the Great Recession hit, has continued during the crisis. Some countries, however, including Germany, show the beginning of recovery in market services growth, driven by TFP. In non-market services, the trend of slowing productivity growth is worrying, given the increased share of the sector, which includes government, education and healthcare, in the economy.

The growth projections generally show continued weak TFP growth for the medium- and long-term among European countries. However, investment remains a key driver and differentiator of growth between European economies. If such investment goes together with better functioning labour, product and capital markets, capital and other sources of growth will more easily flow to the most productive industries, thus providing an upside scenario for Europe's future growth performance. One key factor in this respect is the completion of a single market in Europe, which will especially benefit productivity growth in the services sector.

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Table 1

Total Economy GDP, Hours Worked, Total Input, GDP per Hour and Total Factor Productivity in Europe, 2011 and 2012

(per cent change)

	2012	2011					2012				
	GDP/hour as a % of US	GDP	Hours	All Inputs	GDP/Hour	TFP	GDP	Hours	All Inputs	GDP/Hour	TFP
EU-27	*71.4*	*1.5*	*0.3*	*1.1*	*1.2*	*0.4*	*-0.3*	*-0.6*	*0.5*	*0.3*	*-0.7*
Euro Area	*80.9*	*1.4*	*0.2*	*1.0*	*1.2*	*0.4*	*-0.5*	*-1.1*	*0.3*	*0.6*	*-0.8*
EU-15	*81.8*	*1.3*	*0.3*	*1.0*	*1.0*	*0.3*	*-0.4*	*-0.7*	*0.3*	*0.3*	*-0.8*
Luxembourg	118.5	1.7	2.7	3.3	-1.0	-1.6	0.4	1.9	3.3	-1.6	-2.8
Belgium	97.8	1.8	1.4	1.8	0.4	0.0	-0.2	0.2	1.1	-0.4	-1.3
Netherlands	96.0	1.0	0.8	0.9	0.2	0.1	-0.3	0.4	0.8	-0.7	-1.1
France	93.1	1.7	0.3	1.2	1.4	0.5	0.2	0.4	1.2	-0.2	-1.0
Ireland	90.2	1.4	-2.2	-0.1	3.7	1.6	0.4	-0.1	0.9	0.5	-0.4
Germany	89.9	3.0	1.4	1.6	1.6	1.4	0.7	0.3	1.1	0.4	-0.4
Sweden	86.1	3.7	2.3	2.7	1.4	1.0	1.1	-0.2	1.2	1.4	0.0
Austria	85.9	2.7	2.2	2.1	0.4	0.6	0.8	0.3	1.1	0.5	-0.3
Denmark	81.3	1.1	-0.2	0.4	1.3	0.7	0.6	0.0	0.7	0.5	-0.1
United Kingdom	80.4	0.8	0.5	0.8	0.3	-0.1	-0.3	1.0	1.2	-1.3	-1.5
Finland	76.9	2.7	1.3	2.0	1.4	0.7	0.1	-0.1	1.4	0.1	-1.3
Spain	76.3	0.4	-0.9	0.4	1.4	0.0	-1.4	-3.7	-1.2	2.3	-0.2
Italy	71.8	0.4	0.3	0.5	0.2	0.0	-2.3	-2.4	-1.3	0.1	-1.0
Greece	50.3	-7.1	-4.6	-2.1	-2.6	-5.1	-6.0	-4.8	-1.8	-1.3	-4.3
Portugal	42.0	-1.6	-2.1	-0.2	0.5	-1.4	-3.0	-3.5	-1.3	0.6	-1.7
EU-12	*36.4*	*3.2*	*0.4*	*2.1*	*2.8*	*1.1*	*1.1*	*-0.1*	*2.0*	*1.2*	*-0.9*
Slovenia	58.6	0.6	-1.6	-0.4	2.2	1.0	-2.3	-1.7	-0.3	-0.6	-1.9
Malta	54.2	1.6	2.5	1.3	-0.9	0.3	1.0	0.6	0.1	0.4	0.9
Cyprus	52.4	0.5	0.3	1.0	0.2	-0.5	-2.3	-1.6	-0.2	-0.8	-2.1
Slovak Republic	51.7	3.2	1.0	2.2	2.2	1.0	2.6	0.8	3.1	1.8	-0.4
Czech Republic	47.8	1.9	1.3	2.2	0.6	-0.3	-1.3	-0.4	1.0	-0.8	-2.3
Lithuania	39.0	5.9	0.7	1.0	5.2	4.8	2.9	0.6	0.9	2.3	2.0
Poland	38.7	4.3	0.9	3.0	3.4	1.3	2.4	0.2	3.0	2.2	-0.6
Hungary	38.3	1.6	1.2	2.3	0.4	-0.6	-1.2	-1.3	1.2	0.2	-2.4
Estonia	36.2	8.3	9.5	5.8	-1.1	2.3	2.5	0.6	1.6	2.0	0.9
Latvia	32.4	5.5	-7.3	-3.8	13.8	9.6	4.3	0.7	0.2	3.6	4.2
Bulgaria	26.5	1.7	-4.3	0.7	6.2	1.0	0.8	-1.9	2.2	2.7	-1.4
Romania	21.8	2.2	0.4	1.0	1.7	1.1	0.8	0.4	1.3	0.3	-0.5
United States	100.0	1.8	1.0	1.2	0.8	0.6	2.2	2.0	2.0	0.2	0.2

Source: The Conference Board, Total Economy Database, January 2013.

Table 2

GDP, Per Capita Income and Labour Productivity in Europe, 2001-2005 and 2006-2011

(average annual rate of change)

	GDP		GDP per Capita		GDP per Hour	
	2001-2005	2006-2011	2001-2005	2006-2011	2001-2005	2006-2011
EU-27	*2.0*	*1.1*	*1.7*	*0.8*	*1.7*	*0.9*
Euro Area	*1.6*	*0.9*	*1.1*	*0.6*	*1.1*	*0.9*
EU-15	*1.8*	*0.8*	*1.3*	*0.5*	*1.3*	*0.8*
Sweden	2.7	2.0	2.5	1.9	2.9	0.6
Luxembourg	3.6	1.9	2.2	0.7	1.7	-0.8
Germany	0.6	1.7	0.5	1.9	1.4	1.0
Austria	1.7	1.6	1.5	1.6	1.5	1.4
Netherlands	1.3	1.3	0.9	1.0	1.6	0.6
Belgium	1.6	1.3	1.4	1.2	0.6	0.4
Finland	2.6	1.3	2.4	1.1	2.2	0.7
France	1.6	0.8	1.0	0.2	1.4	0.7
Spain	3.3	0.8	1.7	-0.3	0.5	1.5
Ireland	5.0	0.7	3.1	-1.1	2.5	2.7
United Kingdom	3.0	0.6	2.5	0.0	2.5	0.7
Portugal	0.8	0.2	0.4	-0.1	0.9	1.1
Denmark	1.3	0.2	0.9	-0.1	1.2	0.3
Italy	1.0	-0.1	0.6	-0.6	0.2	0.1
Greece	4.0	-1.1	3.8	-1.2	2.5	0.1
EU-12	*4.2*	*3.1*	*4.4*	*3.3*	*4.5*	*2.5*
Poland	3.1	4.7	3.1	4.7	2.1	2.6
Slovak Republic	4.9	4.5	4.8	4.4	4.8	3.3
Romania	5.7	2.7	6.0	2.9	9.0	2.7
Bulgaria	5.5	2.6	6.5	3.5	3.7	3.1
Czech Republic	4.1	2.6	4.2	2.7	4.7	2.0
Lithuania	7.8	2.2	8.1	2.5	6.6	3.2
Cyprus	3.2	2.1	1.3	0.4	1.0	1.0
Malta	1.3	2.0	0.8	1.6	1.16	0.6
Estonia	7.2	1.8	7.9	2.5	5.7	2.7
Slovenia	3.6	1.7	3.6	1.8	3.4	1.6
Latvia	8.2	0.7	9.0	1.4	7.0	5.1
Hungary	4.2	0.2	4.4	0.3	4.9	0.8

Notes: 1) Countries are ranked on the basis of their GDP growth in 2006-2011 (see Table 3b); 2) The base year for the 2001-2005 period is 2000, while the base year for the 2006-2011 period is 2005.

Source: The Conference Board, Total Economy Database, January 2013.

Table 3a

Growth Contributions by Supply-Side Sources of Growth in Europe, 2001-2005

(average annual rate of change and percentage point contributions)

				Labour productivity contributions from			
	Growth Rate of GDP	Hours Worked	Labour Productivity	Labour composition	ICT capital per hour	Non-ICT capital per hour	TFP growth
	1=2+3	2	3=4+5+6+7	4	5	6	7
	(average annual rate of change)			(percentage points)			
EU-27	*2.0*	*0.4*	*1.6*	*0.3*	*0.4*	*0.6*	*0.3*
Euro Area	*1.6*	*0.4*	*1.1*	*0.3*	*0.4*	*0.6*	*-0.1*
EU-15	*1.8*	*0.4*	*1.3*	*0.3*	*0.4*	*0.6*	*0.1*
Sweden	2.7	-0.2	2.9	0.3	0.3	0.7	1.6
Luxembourg	3.5	1.8	1.7	0.2	0.0	1.4	0.2
Germany	0.6	-0.8	1.4	0.1	0.4	0.3	0.5
Austria	1.7	0.2	1.5	0.3	0.3	0.4	0.5
Netherlands	1.3	-0.3	1.6	0.5	0.4	0.4	0.2
Belgium	1.6	1.0	0.6	0.2	0.3	0.4	-0.4
Finland	2.6	0.3	2.3	0.2	0.7	0.3	1.0
France	1.6	0.2	1.4	0.2	0.4	0.9	-0.1
Spain	3.2	2.8	0.5	0.6	0.2	0.5	-0.8
United Kingdom	2.9	0.5	2.4	0.5	0.6	0.5	0.9
Portugal	0.8	0.0	0.9	1.0	0.6	0.9	-1.7
Ireland	4.8	2.4	2.4	0.5	0.6	1.5	-0.1
Denmark	1.2	0.0	1.2	0.2	0.6	0.4	0.1
Italy	1.0	0.8	0.2	0.2	0.1	0.6	-0.7
Greece	4.0	1.5	2.4	0.8	0.5	1.4	-0.2
EU-12	*4.1*	*0.0*	*4.1*	*0.4*	*1.1*	*0.8*	*1.8*
Poland	3.0	1.0	2.1	0.3	0.6	0.5	0.7
Slovak Republic	4.8	0.1	4.7	0.2	0.9	0.7	2.9
Bulgaria	5.3	1.7	3.6	0.3	1.3	3.2	-1.3
Czech Republic	4.0	-0.6	4.6	0.4	0.6	1.7	1.9
Romania	5.6	-3.0	8.6	0.3	2.6	-0.8	6.5
Malta	0.9	0.2	0.7	0.3	0.0	0.2	0.3
Cyprus	3.2	2.2	1.0	0.4	0.0	-0.3	0.9
Lithuania	7.5	1.1	6.4	0.1	0.0	1.9	4.3
Slovenia	3.6	0.2	3.4	0.8	0.6	1.4	0.6
Estonia	6.9	1.3	5.6	0.1	0.0	2.1	3.4
Latvia	7.9	1.2	6.8	0.1	0.0	3.6	3.0
Hungary	4.1	-0.7	4.8	0.7	1.6	1.2	1.2

Notes: 1) Countries are ranked on the basis of their GDP growth in 2006-2011 (see Table 3b); 2) The base year for the 2001-2005 period is 2000.; 3) All rates of change are expressed in log terms.

Source: The Conference Board, Total Economy Database, September 2012 update.

Table 3b

Growth Contributions by Supply-Side Sources of Growth in Europe, 2006-2011

(average annual rate of change and percentage point contributions)

				Labour productivity contributions from			
	Growth Rate of GDP	**Hours Worked**	**Labour Productivity**	**Labour composition**	**ICT capital per hour**	**Non-ICT capital per hour**	**TFP growth**
	1=2+3	**2**	**3=4+5+6+7**	**4**	**5**	**6**	**7**
	(average annual rate of change)			(percentage points)			
EU-27	*1.1*	*0.1*	*1.0*	*0.1*	*0.5*	*0.5*	*-0.2*
Euro Area	*0.9*	*0.1*	*0.8*	*0.1*	*0.5*	*0.4*	*-0.2*
EU-15	0.8	0.1	0.8	0.1	0.5	0.4	-0.2
Sweden	1.9	1.3	0.6	0.1	0.3	0.4	-0.3
Luxembourg	1.8	2.4	-0.6	0.2	0.0	1.0	-1.7
Germany	1.6	0.6	1.0	0.1	0.1	0.2	0.6
Austria	1.6	0.2	1.4	0.0	0.2	0.3	0.8
Netherlands	1.3	0.7	0.6	0.1	0.2	0.2	0.1
Belgium	1.3	0.9	0.4	0.2	0.3	0.4	-0.5
Finland	1.1	0.8	0.3	0.2	0.7	0.2	-0.7
France	0.8	0.1	0.7	0.2	0.4	0.8	-0.6
Spain	0.8	-0.7	1.5	0.3	0.8	1.1	-0.7
United Kingdom	0.6	-0.3	0.9	0.1	0.4	0.6	-0.2
Portugal	0.1	-0.9	1.0	0.6	0.9	0.4	-0.9
Ireland	0.0	-2.1	2.1	0.2	0.9	2.1	-1.0
Denmark	0.0	-0.1	0.1	0.1	0.8	0.1	-0.8
Italy	-0.1	-0.2	0.1	0.1	0.3	0.3	-0.6
Greece	-1.0	-1.3	0.4	0.3	5.6	-3.5	-2.1
EU-12	*3.0*	*0.6*	*2.5*	*0.2*	*0.6*	*1.3*	*0.4*
Poland	4.5	1.9	2.6	0.1	0.4	1.1	1.0
Slovak Republic	4.3	1.1	3.2	0.1	1.0	0.3	1.8
Bulgaria	2.5	-0.5	3.0	0.4	1.6	3.9	-2.9
Czech Republic	2.5	0.0	2.5	0.1	0.3	1.4	0.7
Romania	2.5	-0.1	2.5	0.3	0.1	0.7	1.4
Malta	2.2	1.4	0.9	0.2	0.0	-0.3	1.0
Cyprus	2.0	1.1	1.0	0.4	0.0	0.5	0.1
Lithuania	1.8	-1.2	3.0	0.2	0.0	2.8	0.0
Slovenia	1.6	-0.2	1.8	0.3	0.8	0.8	-0.1
Estonia	1.2	-1.2	2.4	0.2	0.0	2.0	0.2
Latvia	0.3	-4.6	4.9	0.1	0.0	4.6	0.1
Hungary	0.1	-0.6	0.7	0.2	1.6	0.4	-1.5

Notes: 1) Countries are ranked on the basis of their GDP growth in 2006-2011; 2) The base year for the 2006-2011 period is 2005; 3) All rates of change are expressed in log terms.

Source: The Conference Board, Total Economy Database, September 2012 update.

Table 4a

Contributions to GDP Growth in the Goods, Market Services, and Non-Market Services Sectors in Six EU Countries, 2001-2005

(percentage points contributions)

	GDP	Hours	Labour Composition	Non-ICT Capital	ICT Capital	TFP Growth
	1=2+3+4+5+6	2	3	4	5	6
Austria						
Goods	1.8	-0.8	0.5	0.2	-0.2	2.1
Market Services	1.7	-0.1	0.2	0.4	0.1	1.0
Non-Market Services	2.0	1.1	0.2	0.3	1.1	-0.8
France						
Goods	0.8	-1.7	0.5	0.1	0.1	1.7
Market Services	2.2	0.7	0.2	0.2	0.5	0.6
Non-Market Services	1.3	0.4	0.2	0.3	0.8	-0.4
Germany						
Goods	1.5	-1.6	0.3	0.1	0.0	2.7
Market Services	0.3	-1.2	0.2	0.2	0.2	0.8
Non-Market Services	1.2	0.4	0.2	0.3	0.6	-0.4
Italy						
Goods	-0.4	-0.6	0.3	0.1	0.4	-0.6
Market Services	1.5	0.8	0.2	0.1	1.0	-0.7
Non-Market Services	1.4	0.8	0.2	0.3	0.9	-0.8
Spain						
Goods	0.4	-0.8	0.3	0.2	0.6	0.2
Market Services	4.3	2.1	0.2	0.5	2.1	-0.6
Non-Market Services	3.2	3.1	0.3	0.4	1.5	-2.0
United Kingdom						
Goods	-0.9	-3.2	0.2	0.1	-0.4	2.3
Market Services	3.7	0.5	0.2	0.9	0.8	1.3
Non-Market Services	3.4	2.1	0.1	0.5	0.7	0.0
Aggregate 6 EU Countries						
Goods	0.5	-1.5	0.3	0.1	0.1	1.5
Market Services	2.2	0.5	0.2	0.4	0.6	0.4
Non-Market Services	1.9	1.1	0.2	0.3	0.7	-0.5

Note: 1) Non-market services includes Community, Social and Personal Services; 2) The base year for the 2001-2005 period is 2000; 3) All rates of change are expressed in log terms.

Source: EU KLEMS Database, update November 2012.

Table 4b

Contributions to GDP Growth in the Goods, Market Services, and Non-Market Services Sectors in Six EU Countries, 2006-2010

(percentage point contributions)

	GDP	Hours	Labour Composition	Non-ICT Capital	ICT Capital	TFP Growth
	1=2+3+4+5+6	2	3	4	5	6
Austria						
Goods	1.1	-1.1	0.2	0.1	0.0	1.9
Market Services	0.9	0.0	0.2	0.2	0.1	0.2
Non-Market Services	1.8	0.5	0.3	0.2	0.8	-0.1
France						
Goods	-0.8	-2.0	0.5	0.1	0.2	0.5
Market Services	0.6	0.5	0.4	0.1	0.4	-0.9
Non-Market Services	1.1	0.3	0.3	0.1	0.8	-0.5
Germany						
Goods	0.8	-0.7	0.6	0.1	0.1	0.7
Market Services	2.0	0.1	0.2	0.2	0.3	1.2
Non-Market Services	1.0	0.8	0.2	0.2	0.6	-0.8
Italy						
Goods	-1.6	-1.6	0.3	0.0	0.2	-0.5
Market Services	-0.1	0.0	0.2	0.1	0.5	-0.9
Non-Market Services	0.3	0.4	0.2	0.1	0.4	-0.8
Spain						
Goods	-2.0	-3.0	0.2	0.1	0.4	0.2
Market Services	0.7	-1.0	0.2	0.2	1.5	-0.2
Non-Market Services	2.8	1.9	0.1	0.2	1.4	-0.8
United Kingdom						
Goods	-2.6	-2.4	0.0	0.0	-0.2	-0.1
Market Services	0.0	-0.3	0.5	0.2	0.6	-1.1
Non-Market Services	1.3	0.6	0.4	0.2	0.7	-0.6
Aggregate 6 EU Countries						
Goods	-0.7	-1.8	0.3	0.1	0.1	0.6
Market Services	0.7	-0.1	0.4	0.2	0.5	-0.1
Non-Market Services	1.2	0.7	0.3	0.2	0.7	-0.6

Note: 1) Non-market services includes Community, Social and Personal Services; 2) The base year for the 2006-2010 period is 2000; 3) 3) All rates of change are expressed in log terms.

Sources: EU KLEMS Database, update November 2012; with updates by the authors to include 2010.

Table 5

Projections for GDP, Hours Worked, and GDP per Hour Growth in Europe, 2013

(per cent change)

	GDP	Hours	GDP/Hour
EU-27	*0.3*	*0.0*	*0.3*
Euro Area	*-0.1*	*-0.3*	*0.2*
EU-15	*0.2*	*-0.1*	*0.3*
Luxembourg	0.7	1.9	-1.2
Belgium	0.7	0.4	0.4
Netherlands	-0.5	-0.4	-0.1
France	0.2	0.0	0.2
Ireland	1.1	0.8	0.3
Germany	0.8	0.0	0.8
Sweden	1.9	0.3	1.6
Austria	0.9	0.6	0.2
Denmark	1.6	0.7	0.9
United Kingdom	0.9	0.9	0.1
Finland	0.8	-0.4	1.2
Spain	-1.4	-1.9	0.4
Italy	-0.7	0.1	-0.8
Greece	-4.2	-2.9	-1.4
Portugal	-1.0	0.1	-1.1
EU-12	*1.5*	*0.5*	*1.0*
Slovenia	-1.6	-1.0	-0.6
Malta	1.6	1.1	0.5
Cyprus	-1.7	0.6	-2.2
Slovak Republic	2.0	0.6	1.3
Czech Republic	0.8	0.1	0.7
Lithuania	3.1	0.5	2.6
Poland	1.8	0.4	1.4
Hungary	0.3	0.3	0.0
Estonia	3.1	1.2	1.9
Latvia	3.6	1.3	2.4
Bulgaria	1.4	-0.2	1.6
Romania	2.2	1.1	1.0
United States	1.8	1.2	0.6

Source: The Conference Board, Total Economy Database, January 2013.

Table 6a

Projections for GDP Growth and Sources of GDP Growth in Europe, 2013-2018

(average annual percentage point contributions)

	GDP Contribution from				
	Rate of GDP Growth	**Persons employed**	**Labour composition**	**Capital**	**Total Factor Productivity**
	1=2+3+4+5	**2**	**3**	**4**	**5**
EU-27	*1.1*	*-0.1*	*0.1*	*0.9*	*0.2*
Euro Area	*1.1*	*-0.1*	*0.1*	*0.9*	*0.2*
EU-15	*1.1*	*-0.1*	*0.1*	*0.9*	*0.1*
Sweden	1.9	-0.2	0.1	1.5	0.5
Luxembourg	2.2	0.4	0.1	1.1	0.6
Germany	1.6	-0.3	0.1	1.3	0.6
Austria	1.1	-0.2	0.1	1.1	0.2
Netherlands	1.0	0.0	0.0	0.6	0.3
Belgium	1.4	-0.2	0.2	1.0	0.4
Finland	0.9	-0.5	0.2	1.1	0.2
France	0.9	-0.1	0.1	0.8	0.0
Spain	0.8	0.1	0.1	0.5	0.1
Ireland	2.5	0.4	0.1	1.5	0.5
United Kingdom	0.8	0.1	0.2	0.7	-0.1
Portugal	0.8	0.0	0.3	0.5	0.1
Denmark	1.6	0.0	0.1	1.2	0.3
Italy	0.5	0.0	0.0	0.5	0.0
Greece	-0.4	0.0	-0.1	-0.3	0.0
EU-12, of which	*1.8*	*-0.4*	*0.1*	*1.4*	*0.7*
Poland	1.9	-0.4	0.1	1.5	0.6
Czech Republic	1.9	-0.5	0.1	1.3	1.0
Cyprus	0.7	0.3	0.1	0.2	0.2
Malta	1.9	-0.3	0.2	1.1	0.9
Hungary	1.8	-0.3	0.2	1.2	0.8

Note: 1) Countries are ranked on the basis of their GDP growth in 2006-2011 (see Table 2); 2) The base year for the 2013-2018 period is 2012.

Sources: The Conference Board, Global Economic Outlook 2013; Chen *et al.* (2012).

Table 6b

Projections for GDP Growth and Sources of GDP Growth in Europe, 2019-2025

(average annual percentage point contributions)

	Growth Rate of GDP, 2019-2025	GDP Contribution from			
		Persons Employed	Labour Composition	Capital	Total Factor Productivity
	1	2	3	4	5
EU-27	*1.2*	*-0.2*	*0.1*	*1.1*	*0.2*
Euro Area	*1.3*	*-0.2*	*0.2*	*1.1*	*0.2*
EU-15	*1.2*	*-0.1*	*0.1*	*1.0*	*0.2*
Sweden	1.7	-0.1	0.1	1.3	0.4
Luxemburg	2.4	0.4	0.1	0.9	1.0
Germany	1.3	-0.6	0.1	1.2	0.5
Austria	0.7	-0.4	0.1	0.9	0.1
Netherlands	1.5	-0.1	0.1	1.0	0.5
Belgium	1.3	-0.4	0.2	1.0	0.4
Finland	0.9	-0.4	0.2	0.9	0.2
France	1.0	0.0	0.2	0.9	0.0
Spain	1.7	0.3	0.3	1.1	0.0
Ireland	3.0	0.5	0.1	1.9	0.5
United Kingdom	0.8	0.2	0.1	0.7	-0.1
Portugal	1.5	-0.1	0.6	0.9	0.1
Denmark	1.3	-0.1	0.1	1.1	0.3
Italy	0.9	-0.1	0.1	1.0	-0.1
Greece	1.5	-0.2	0.3	1.2	0.2
EU-12, of which	*1.8*	*-0.5*	*0.1*	*1.5*	*0.7*
Poland	1.5	-0.5	0.1	1.4	0.5
Czech Republic	2.4	-0.4	0.1	1.5	1.2
Cyprus	1.5	0.4	0.2	0.6	0.4
Malta	1.8	-0.3	0.2	1.1	0.8
Hungary	2.4	-0.5	0.2	1.5	1.1

Notes: 1) Countries are ranked on the basis of their GDP growth in 2006-2011 (see Table 2); The base year for the 2019-2025 period is 2018.

Sources: The Conference Board, Global Economic Outlook 2013; Chen *et al.* (2012).

Comments on "European Productivity Growth Since 2000 and Future Prospects"

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ABSTRACT

These comments provide historical and institutional context for the article "European Productivity Growth Since 2000 and Future Prospects", by Bart Van Ark, Vivian Chen and Kirsten Jäger. They identify and discuss the "financialization" phenomenon whereby easy and creative finance led to speculative booms and busts in a number of countries such as Spain. Labour market reform in Germany, which improved that country's competitiveness and increased resilence to recessions, is also discussed.

RÉSUMÉ

Ces commentaires fournissent le contexte historique et institutionnel de l'article «European Productivity Growth Since 2000 and Future Prospects» de Bart Van Ark, Vivian Chen et Kirsten Jäger. Ils identifient et discutent du phénomène de la «financiarisation», dans lequel la finance facile et créative mène à des surchauffes et des ralentissements spéculatifs dans de nombreux pays tel que l'Espagne. Les réformes du marché du travail en Allemagne, qui ont amélioré la compétitivité du pays et sa résilience aux récessions, sont également discutées.

THE ARTICLE "European Productivity Growth Since 2000 and Future Prospects", by Bart van Ark, Vivian Chen, and Kirsten Jäger represents an ambitious and instructive study encompassing an unusually large set of productivity and competitiveness issues facing Europe and its major member states. The article focuses on the 2001-2011 period and analyzes the sources of growth over two sub-periods (2001-2005 and 2006-2011). It shows how the relative positions of France and Germany have been reversing between the first and the second sub-periods. The same reversal has occurred between Spain (initially remarkably successful) and Poland, which in the second sub- period appeared as the new success story.

Success and failure seem to be tied to the ability of total factor productivity (TFP) in the goods sector to bounce back after the 2009 fall. This is especially true for German industry, where TFP was badly hit in 2009 but by 2010 the losses had been more than offset, showing a remarkable capacity to rebound despite the growth environment still prevailing outside Europe.

An analysis of the factors at work in the developed economies in the first decade of the 21st century reveals some major changes in the economic environment. The 2000s are characterized by the major role played by the financial sector. To put it bluntly, in the 1990s the finance sector seemed to play a Schumpeterian role of intermediation, boosting innovations in all sec-

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tors, be it manufacturing or services, with a key role played by the diffusion of ICTs (of which the internet was a rapidly emerging major component). But the successive financial crisis of 1997 (East Asia), 1998 (Long-Term Capital Management) and 2001 (dot.com crisis) led the financial sector to retreat and to promote its own innovations (including securitization) and to expand its range of operations. The entire decade was thus marked by what has been called a "financialization" of the developed economies, echoing the rising importance of short-term financial criteria in most decisions. The introduction of the euro at the very beginning of the period under view acted as a facilitator of this process of financialization across EU countries. As we shall see, this development is not without important consequences for the evolution of European economies, as captured by the data presented in van Ark, Chen, and Jäger (2013).

This turn of events was not the only structural change occurring in developed economies. Another major change, which largely caused the financialization just mentioned, was the liberalization of trade and capital flows, which gained momentum in the early 1980s. This trend put pressure on developed economies to remain competitive faced with low-wage countries that were rapidly catching up in terms of technological capabilities. The resulting shift of wealth in favour of developing economies has been enormous over the last three decades. Economic growth rates have been roughly halved in major OECD countries while a set of emerging economies enjoyed growth rates of an order of magnitude even bigger than those achieved by the OECD countries during the "golden years of capitalism". Overall the rebalancing of the world wide distribution of wealth has been beneficial in reducing absolute poverty and inequality among nations.

But this global shift has been accompanied by a widespread rise in inequality within countries, closely linked to the manner in which countries adjusted to this new environment of more intense international competition. The challenge for high-wage countries became clear, with adjustments varying by country. Some countries such as Germany fundamentally transformed their labour market, while others like France made much more moderate labour market changes. Whether or not these adjustments have been implemented is thus an important element in the assessment of the competitiveness of EU countries.

In addition to the importance of identifying and analyzing structural changes before any diagnosis of productivity and competitiveness trends, it should be noted that the two sub-periods used in the study are rather heterogeneous. The 2001-2005 sub-period starts with a trough, following the dot.com crisis, and ends with a peak in the mid-2000s while the 2006-2011 sub-period goes from a relative peak to a relative trough, following the major financial and economic crisis that occurred in 2008 and 2009 in the middle of the sub-period.

The financialization phenomenon calls for caution regarding the analysis of the trajectories of countries like Spain, celebrated as a "model" up to 2008. Easy and creative finance fuelled a speculative boom in construction in this country, which collapsed once the global financial crisis hit. Other "models", such as Iceland or Ireland, had similar short lives (despite praise by economists). But these "models" were rightly kept out of the analysis undertaken in van Ark *et al.* (2013).

The case of the UK has to be looked at with caution because of the importance of the role played by this country's financial sector in global financial activity. Indeed, the reregulation of finance that is on the agenda at various levels of global and regional governance is bound to be a major determinant of the future of the UK finance industry.

This leaves us with the central issue of the comparison between France and Germany. The bottom line is that France showed itself to be much less recession-proof than Germany, or in other words much less fit to compete in world markets outside the OECD area.

Germany aggressively seized the opportunity presented by the expansion of the EU to Eastern Europe (a move that it strongly supported) and moved parts of its manufacturing production to this region while keeping at home many service activities used to monitor the international value chain thus constituted. This mode of adjustment, which has been called the Bazar economy, is certainly part of the explanation of the shifts we see in the response to foreign demand. The benefits it brought to German manufacturing industries certainly helped these industries develop markets in the faster growing developing world. This development also contributed to Poland's strong economic performance during the 2006-2011 period.

But this is not the end of the story of the comparison between the French and German dynamics in competitiveness in the aftermath of the 2008 financial crisis. Financialization seems to have played a greater role than outlined so far in the differentiation of the two dynamics. A recent study by the Directorate General for Economic and Financial Affairs (DG–ECFIN) on trade surplus countries (European Commission, 2012) is rather telling in that respect. The study examines the factors that explain why after the mid-2000s one group of countries enjoyed a continuously growing trade surplus while another group countries experienced the opposite development. Most analyses of this situation concluded that a permanent competitive advantage enjoyed by the surplus countries accounted for this steady divergence.

This was not exactly the conclusion reached by the DG-ECFIN study, which found both trade deficit and trade surplus countries registered relatively good results in terms of exports. Over the 1999-2007 period trade surplus countries saw exports grow an average of 8.0 per cent per year, only slightly above the 7.5 per cent for trade deficit countries. Rather, the difference that generated the trade gap between surplus and deficits countries came mainly from imports, which grew 7.5 per annum in surplus countries versus 10.0 per cent in deficit countries over the same period.

Thus, the difference between the two groups is much more due to lower domestic demand than export performance, a feature very pronounced in Germany where the contribution of domestic demand to growth was below the contribution of exports. This reflects the pressure on wages induced by the Hartz reform of the German labour market.[2]

The results of the EC study change our understanding of the relative dynamics of developments in manufacturing competitiveness in France and Germany. When one takes into account a broader picture of the context in which the changes in productivity and trade took place over the last decade, the conclusions explaining the different trajectories of major EU members do not boil down to a clear hierarchy of manufacturing competitiveness.

To take the case of Germany, part of its competitiveness in manufacturing owes much to the one-shot opportunity of outsourcing and investing in Eastern Europe. Conversely, buoyant access to the markets of emerging economies may also be a limited opportunity for Germany, resulting from the rapidity of their emergence and of the strong reputation of German products, a non-price competitive-

2 Also referred to as the Agenda 2010 proposed by the Chancellor Schröder in 2003.

ness that the rapid technological catch-up of these countries may erode. The reform of the German labour market may still fall short of allowing sufficient price competitiveness improvement. Not to forget that this labour market reform, which fueled the trade surplus, has a cost. It implied a trade-off between GDP growth and welfare which in the long run could affect worker commitment, which is at the root of the efficiency of the German production system. This observation does not aim to downplay the contribution of the German "model" .

Attention to conditioning factors is essential for the analysis of EU productivity performance. One should identify the general importance of the policy measures that will be taken, regarding the role of finance and how countries adjust to the permanent trend of trade and capital flows liberalization. Thus the outcomes of reregulation of finance at various levels (whether international, regional or national) matter. Conversely, policies to adjust to external competition, according to the place given to solidarity schemes at the regional level, are likely to affect the future of EU member states. The role of the euro is bound to be a decisive factor.

In the race to adjust to a rapidly changing world economy, countries are often led to seek a balance between welfare and growth, choices that have fueled in the past widespread rises in income inequality. Moreover, poor performances in welfare may jeopardize a future where issues of environmental sustainability may call for major collective efforts.

In other words, a focus on the relative competitiveness and productivity of the major EU member states highlights the numerous challenges that these countries will have to face and how their collective policy measures will condition this future.

References

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