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**Article**

## Productivity and misallocation

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that the prevailing norms were encouraging collaboration disproportionately to individual publication.

### What Drives Attribution?

We know from our own experience in evaluating our peers that the process of dividing credit for joint work is not formulaic. In particular, when we are presented with the work of a team, we try to parse the contributions of individual members.

In another collaborative paper, we explore this process by considering again a pioneer and a follow-on scientist.<sup>4</sup> Both can contribute to a project. However, it is the pioneer who determines the prevailing sharing arrangements. When both actually contribute, this increases the likelihood that the project is of high quality. Indeed, we assume that to get very high quality you need both scientists to make a substantive contribution. In this event, the market knows what is going on and so divides attribution between the authors.

Things get tricky if the project is good but not of the highest quality. In that situation, by looking at the output alone, the market for scientific attribution cannot work out the underlying process. The pioneer alone surely could have generated that work. If the pioneer had been a sole author, the market would have given him all of the attribution. But what if there are two names on the paper?

If one scientist has contributed considerably more than the other, “the market” would like to find out who contributed more and attribute more credit to that author. Interestingly, this gives rise to two potential equilibria. In each one, all credit is given to one author or the other. In one of these, the follower scientist only puts in effort if the pioneer has already achieved a promising result, as the follower will share in the reward by also making a significant contribution. However, if the pioneer has

not achieved such a result, the follower puts in no effort and guarantees a low quality result precisely because the market would not attribute any share to either of them. Of course, that assessment is self-fulfilling precisely because the follower does not deserve any credit. A mirror equilibrium holds where the follower receives all of the credit. In each case, the market assessments turn out to be correct because they shape the incentives of scientists to conform to those assessments.

Our principal purpose in this paper is not to consider whether to invite another researcher to become a coauthor but, rather, when to do so. One degree of flexibility pioneer scientists have — if they lead their own labs with some autonomy — is that they can employ junior scientists but can potentially separate that working relationship from the credit or formal attribution that junior scientists receive. Senior scientists might wait until they see their own contribution and that of the junior scientist before inviting the junior scientist to be a coauthor. The senior scientist may never choose to do this, but suppose, perhaps to send a signal to others in their lab, that they commit to putting a junior scientist on the paper only if the junior’s contribution is significant.

While this arrangement might seem precarious for the junior scientist, it facilitates attribution in “the market.” If the market for scientific attribution understands that the junior scientist is only a coauthor on the paper if the junior made a significant contribution, then in the ambiguous range where it would otherwise be hard to tell who was the main contributor, “the market” can now tell. What is more, this all adds up to maximal incentives for the junior scientist to put effort into generating a significant contribution. The junior scientists are better off for this arrangement. We show that, of all of the organizational arrangements that could have been chosen, leaving the decision of whether to credit

the junior scientist until the end is Pareto optimal.

### Conclusion

The research presented here is an initial foray into understanding how the choices of scientific teams are shaped by market assessments of individual performance. It is part of a broader agenda that we think of as the organizational economics of science. By demonstrating that such market assessments are likely to be important, it presents initial insights but also conjectures about what “the market” is. That remains an open theoretical and empirical question. Our work yields some insights but in many respects only highlights the reality that understanding scientific work — in academia and in industry — will require much more research, both theoretical and empirical.

<sup>1</sup> R. Merton, “The Matthew Effect in Science,” *Science*, 159(3810), 1968, pp. 56–63.

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<sup>2</sup> J. S. Gans and F. Murray, “Credit History: The Changing Nature of Scientific Credit,” in A. Jaffe and B. Jones eds., *The Changing Frontier: Rethinking Science and Innovation Policy*, Chicago, University of Chicago, 2014, pp. 107–131.

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<sup>3</sup> M. Bikard, F. Murray, and J. S. Gans, “Exploring Tradeoffs in the Organization of Scientific Work: Collaboration and Scientific Rewards,” *NBER Working Paper No. 18958*, April 2013, and *Management Science*, 61(7), 2015, pp. 1473–1495.

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<sup>4</sup> J. S. Gans and F. Murray, “Markets for Scientific Attribution,” *NBER Working Paper No. 20677*, November 2014.

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## Productivity and Misallocation

Chang-Tai Hsieh and Pete Klenow

The starting point of a large body of recent research on economic growth is the notion that differences in aggregate total factor productivity (TFP) may not be driven solely by technology but rather in part by allocative efficiency. The key building block of this literature is the idea that firms differ, and we do not necessarily want all the resources to be allocated to one firm. For example, suppose that there are a number of firms in a country and the output  $Y_i$  of each firm is given by a standard production function,  $Y_i = A_i F(K_i, L_i)$ , where  $K_i$  is the firm’s capital stock (equipment and structures),  $L_i$  is the firm’s labor input (skill-weighted hours worked by its employees),  $F$  is the production function which combines capital and labor, and  $A_i$  is residual firm productivity.

If each firm produces different products, we do not want all the inputs allocated to the firm with the highest  $A_i$ , as we value having access to a variety of differentiated products. Instead, what we want is for resources to be allocated across firms to equalize the revenue productivity of the firm, or  $P_i A_i$ . Resources are misallocated when revenue productivity differs between

firms. Reallocation increases aggregate TFP and generates growth when resources flow to firms with high revenue productivity.

Micro-data from manufacturing censuses suggest substantial gaps in revenue productivity across firms within India and China.<sup>1</sup> The gaps are also present in U.S. data, but are much smaller. Figure 1 plots the dispersion of revenue productivity in the three countries. In India and China, revenue productivity of firms in the 90th percentile

exceeds that of firms in the 10th percentile by a factor of five. In the U.S., the equivalent gap in revenue productivity is a factor of three. These gaps in revenue productivity between firms may contribute to substantial gaps in aggregate TFP. In a standard model, aggregate TFP would increase by 43 percent in the U.S. in 1997, by 115 percent in China in 1998, and by 127 percent in India in 1994 if resources were to be reallocated to equalize revenue productivity across firms.

We now have a large body of evidence on gaps in revenue productivity at the microeconomic level, largely thanks to the detailed, firm-level data available for a growing number of countries. A project spearheaded by Santiago Levy at the Inter-American Development Bank provides detailed evidence on these gaps for a large number of countries in Latin America.<sup>2</sup> There is similar evidence from microeconomic data for a number of countries in Europe.<sup>3</sup> These studies find wide gaps in revenue productivity, consistent with substantial misallocation.

The literature has largely focused on measuring the static effects of firm-level gaps in revenue productivity, but the firm-level gaps are likely to also have important dynamic effects. If more-efficient establishments face larger distortions, it undermines firms’ incentives to invest in better technology. Put differently, there are two effects of resource misallocation — the static effect and the dynamic effect of resource misallocation on growth in firm productivity. This has been highlighted in several case studies.<sup>4</sup> Evidence from firm-level censuses in India and Mexico is also consistent with the presence of

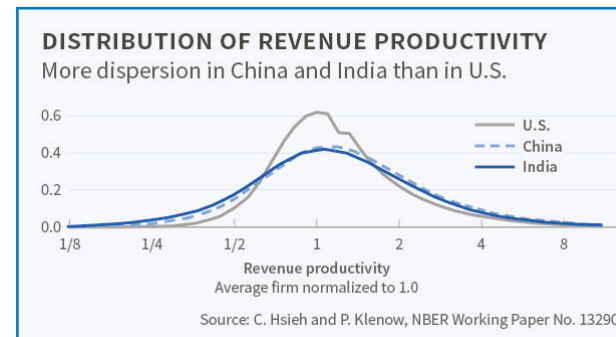


Figure 1



Chang-Tai Hsieh is the Phyllis and Irwin Winkelried Professor of Economics at the University of Chicago’s Booth School of Business. He is the co-organizer, with Nick Bloom and Chris Woodruff, of NBER’s Working Group in Development, Productivity, and Innovation, and a member of the Steering Group of the International Growth Centre at the London School of Economics.

Before joining the faculty at Chicago, he was an associate professor and professor at the University of California, Berkeley, and an assistant professor at Princeton University. He recently served as the coeditor of the *Journal of Economic Perspectives*. He is a fellow of Academia Sinica, a recipient of the Sun Yefang Award from the Chinese Academy of Social Sciences, and a Sloan Foundation Research Fellow. His research focuses on development and economic growth.





**Pete Klenow** is codirector with Mark Gertler of the NBER's Economic Fluctuations and Growth Program. He is the Landau Professor of Economics at Stanford University, and the Gordon and Betty Moore Fellow at the Stanford Institute for Economic Policy Research.

Before joining the Stanford faculty, he was a senior economist at the Federal Reserve Bank of Minneapolis and an assistant and associate professor at the University of Chicago's Booth School of Business. He is currently an associate editor of the *Quarterly Journal of Economics* and *Econometrica*, and previously served on the Board of Editors of the *American Economic Review*.

He is a member of the American Academy of Arts and Sciences, and a fellow of the Econometric Society. He serves as a panelist on the IGM Booth Economic Experts Panel, and a regular visiting scholar at the Federal Reserve Banks of Minneapolis and San Francisco. He is currently a Special Sworn Status researcher at the U.S. Census Bureau, and has previously had Intergovernmental Personnel Act assignments at the U.S. Bureau of Labor Statistics.

Klenow's research uses micro data (on prices and productivity, for example) to try to shed light on macro questions such as the causes of growth and development.

dynamic misallocation.<sup>5</sup> Figure 2 shows that, by the age of 40, U.S. firms grow by a factor of eight while Mexican firms only double and Indian firms do not appear to grow at all.

The challenge that follows from these studies is to identify the precise policies and institutions behind the revenue productivity gaps in the micro data. The potential list of explanations is large. We will limit our discussion to five forces that might be important and for which we have some evidence.

- **Substantial Costs to Adjusting Labor and Capital Inputs<sup>6</sup>**

Evidence on whether adjustment costs might be responsible for the differential gaps in revenue productivity between rich and poor countries is limited. Across a number of countries, the dispersion in capital productivity is correlated with productivity volatility, although the underlying sources of productivity volatility are not known.<sup>7</sup> There is much less volatility in employment in India than in U.S. manufacturing, almost as if Indian firms face large costs to adjusting employment. This is consistent with evidence on the effects of rigid licensing laws in India.<sup>8</sup>

- **Ownership of Firms by the State or the Politically Connected**

State-owned firms in China had substantially lower revenue productivity in the late 1990s than their privately-owned counterparts, but the gap narrowed after the closure and privatization of many state-owned firms. A detailed study in India shows

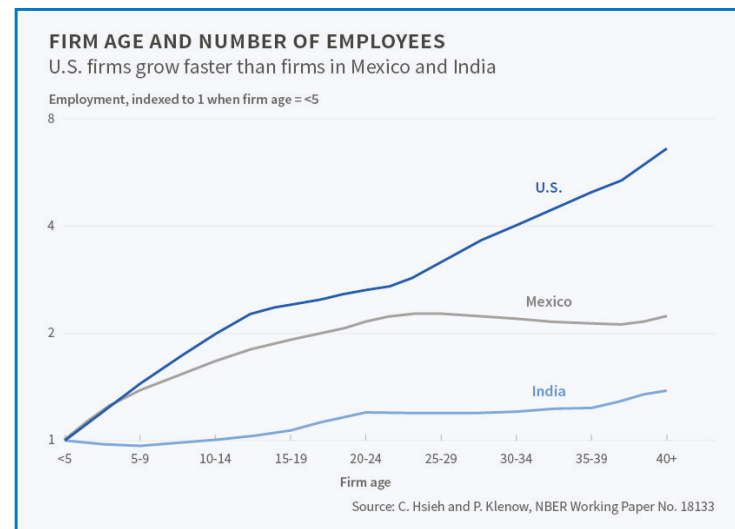


Figure 2

substantial gaps in labor productivity between state-owned firms and privately-owned firms in the same sector.<sup>9</sup> In telecoms, labor productivity is three times higher in private than in state-owned firms. In the retail banking sector, labor productivity is more than five times higher in private than in state-run firms.

- **The Presence of a Large Informal Sector<sup>10</sup>**

This is an important feature of many poor countries. Take retail trade. Modern firms account for 67 percent of retail employment in the U.S. The equivalent numbers are only 21 percent in Brazil, 15 percent in El Salvador, 23 percent in Mexico, 15 percent in the Philippines, and 19 percent in Thailand.<sup>11</sup> In all these countries, labor productivity in modern retail is significantly higher than in informal retail stores. The labor productivity of modern retailers is three times higher than that of informal retailers in Brazil, four times higher in El Salvador, three-and-a-half times higher in Mexico, six times higher in the Philippines, and four times higher in Thailand.

The pervasiveness and low productivity of the informal sector is also seen in manufacturing in India and Mexico. Informal manufacturing establishments in India, defined as establishments that are not formally registered, accounted

for 80 percent of total Indian manufacturing employment in 2005. In Mexico, almost all manufacturing establishments are formal in the sense of being formally registered, but if we define informal firms as those which are not paying Social Security taxes — either legally by only employing unpaid family workers or illegally by explicitly not paying the required social security tax — informal establishments accounted for 30 percent of total Mexican manufacturing employment in 2008. Informal establishments in India and Mexico are significantly smaller than formal establishments.

Figure 3 plots the distribution of establishment size in India and Mexico for informal and formal establishments. The typical informal establishment employs four workers in India and about 10 workers in Mexico, while formal establishments employ 20 workers on average in India and about 50 in Mexico.

All of this suggests that a proximate reason poor countries are poor is that modern formal firms find it difficult to obtain resources and/or capture market share. We still have a very limited understanding, however, of the exact forces behind the prevalence of informal and unproductive establishments. The Inter-American Development Bank, and Levy in particular, have argued that the patterns of informality, at least in Latin America, are due to the nature of the tax systems and social-protection programs.<sup>12</sup> A glance at the World Bank *Doing Business* indicators suggests that high costs of doing business may also be a factor.

- **Social Forces May Distort The Allocation of Talent across Occupations and Firms**

These forces may reflect the legacy of gender and race discrimination in the U.S., caste discrimination in India, discrimination based on economic and ethnic background in some Latin American countries, or the effect of second-generation managers in family firms in many countries.<sup>13</sup> In the U.S., for example, the fraction of white women who work in high-skilled occupations — lawyers,

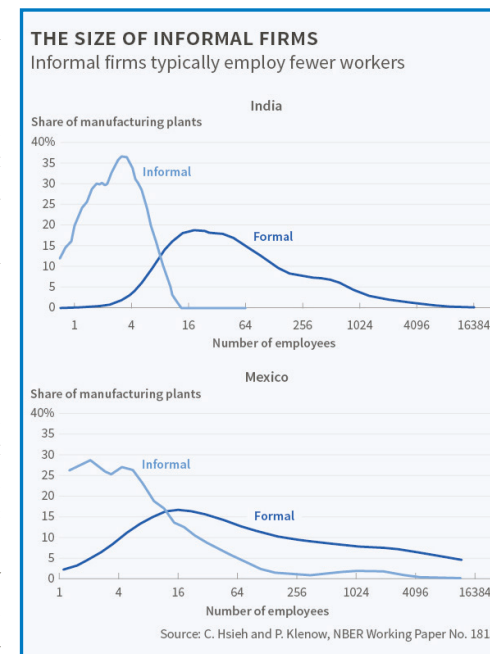


Figure 3

doctors, engineers, scientists, architects, and executives or managers — increased from six percent in 1960 to 21 percent in 2008.<sup>14</sup> The share of black men who work in those high-skilled occupations increased much more modestly, from 20 percent in 1960 to 25 percent by 2008. We estimate that the convergence in occupations between white men and the other groups might explain around 15 percent of the growth in aggregate productivity in the U.S. from 1960 to 2008.

Such forces are surely present, and perhaps even more important, in other countries. In India a generation ago, women from disadvantaged castes completed 4.1 years less schooling than women in non-disadvantaged castes; disadvantaged-caste men completed 2.3 years less school than men from non-disadvantaged castes.<sup>15</sup> The gap is still present today, but has shown a marked

decline. In 2004, the caste schooling gap for women had declined to 2.2 years; for men it had declined to 1.7 years.

- **Internal Trade Barriers Likely Play an Important Role in the Efficiency of Resource Allocation**

Internal trade barriers can be very large in poor countries such as Ethiopia and Nigeria.<sup>16</sup> In the agricultural context, there is evidence that lowering transportation costs led to large gains in agricultural productivity in the U.S. historically, and in places such as Sierra Leone more recently.<sup>17</sup> In the industrial sector, internal trade costs could be similarly costly. If access to input and output markets is critical for modern industrial firms, then barriers that make it difficult for firms to access these networks will affect the incentives of firms to invest in better technology.

This review only touches on a few of the myriad micro forces that may matter for macro productivity. Low allocative efficiency may be “death by a thousand cuts.”<sup>18</sup> If so, no magic bullet or single policy reform is likely to transform productivity. We suspect there is no substitute for investigating and quantifying the micro sources of low allocative efficiency one by one.

<sup>1</sup> C. Hsieh and P. Klenow, “Misallocation and Manufacturing TFP in China and India,” NBER Working Paper No. 13290, August 2007, and *Quarterly Journal of Economics*, 124(4), 2009, pp. 1403–1448.

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<sup>3</sup> E. Bartelsman, J. Haltiwanger and S. Scarpetta, “Cross-country Differences in Productivity: The Role of Allocation and Selection,” NBER Working Paper No. 15490, November 2009, and the



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<sup>4</sup> S. Parente and E. Prescott, Barriers to Riches, Cambridge, MA: MIT Press, 2000; and J. Schmitz, “What Determines Productivity? Lessons from the Dramatic Recovery of the U.S. and Canadian Iron Ore Industries Following Their Early 1980s Crisis,” Journal of Political Economy, 2005, 113(3), pp. 582–625.

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<sup>5</sup> C. Hsieh and P. Klenow, “The Lifecycle of Manufacturing Plants in India and Mexico,” NBER Working Paper No. 18133, June 2012, and Quarterly Journal of Economics, 129(3), 2014, pp. 1035–1084.

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<sup>9</sup> McKinsey Global Institute, “India—From Emerging to Surging,” McKinsey Quarterly 4, Emerging Markets, 2001, pp. 28–50.

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<sup>11</sup> D. Lagakos, “Explaining Cross-Country Productivity Differences in Retail Trade,” forthcoming in the Journal of Political Economy, 2016. <https://sites.google.com/site/davidlagakos/home/research>

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<sup>12</sup> S. Levy, Good Intentions, Bad Outcomes, Washington, DC: Brookings Institution Press, 2008. <http://www.brookings.edu/research/books/2008/good-intentionsbadoutcomes>

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<sup>13</sup> N. Bloom, C. Genakos, R. Sadun,

and J. Van Reenen, “Management Practices Across Firms and Countries,” NBER Working Paper No. 17850, February 2012.

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<sup>15</sup> V. Hnatkowska, A. Lahiri, and S. Paul, “Castes and Labor Mobility,” American Economic Journal: Applied Economics, 4(2), 2012, pp. 274–307.

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## NBER News

### CRIW Members Elect Abraham

The members of the Conference on Research in Income and Wealth (CRIW) have elected Research Associate Katharine Abraham of the University of Maryland, a former Commissioner of the Bureau of

Labor Statistics (1993–2001) and member of the President’s Council of Economic Advisers (2011–13), to succeed Charles Hulten as CRIW chair. The CRIW, whose members number more than 300 research-

ers from colleges and universities, think tanks, and government statistical agencies, organizes an annual conference on economic measurement as well as a session at the NBER Summer Institute.

### 2015 Awards and Honors

Alberto Alesina, Carlo Favero, and Francesco Giavazzi won the Addington Prize for Measurement for their paper on “The Output Effect of Fiscal Consolidations,” which is forthcoming in the *Journal of International Economics*.

Lee J. Alston was named President of the Economic History Association.

Ernst R. Berndt was awarded an honorary doctorate by the Faculty of Economics and Business at the University of Basel.

Francesco Bianchi was awarded the Wim Duisenberg Research Fellowship by the European Central Bank.

David E. Bloom was named an Andrew Carnegie Fellow by the Carnegie Corporation of New York.

Eric Budish received an Alfred P. Sloan Research Fellowship. He also received the 2015 Utah Winter Finance Conference Best Paper Award for “The High-Frequency Trading Arms Race: Frequent Batch Auctions as a Market Design Response,” with Peter Cramton and John Shim.

Gary Chamberlain was named a Distinguished Fellow of the American Economic Association.

Wesley Cohen’s paper “Innovation and Learning: The Two Faces of R&D,” with Dan Levinthal, published in 1989, was named one of the 13 most important papers published in *The Economic Journal*’s 125-year history.

Janet Currie was elected President

of the Eastern Economic Association.

Angus S. Deaton was elected to the National Academy of Sciences and received the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel.

Manasi Deshpande received the 2015 APPAM Best Dissertation Award, the 2015 Upjohn Institute Dissertation Award, and the 2016 NASI John Heinz Dissertation Award.

Susan Dynarski was named one of the *Chronicle of Higher Education*’s top 10 influencers. She also received the NASPAA’s Public Service Matters Spotlight Award, and a special tribute from Michigan Governor Rick Snyder.

Price Fishback was awarded the Jonathan Hughes Prize for Excellence in Teaching Economic History and the Arthur Cole Prize for Best Article in the *Journal of Economic History* for his paper with Valentina Kachanovskaya on “The Multiplier for Federal Spending in the States in the 1930s.”

Kristin Forbes was awarded a Bicentennial Medal from Williams College, which recognizes “outstanding achievement in any field of endeavor.”

Don Fullerton was named a Fellow of the Association of Environmental and Resource Economists (AERE), which recognizes “outstanding contributions to the advancement of the profession of environmental and resource economics.”

Martin Gaynor was elected to the National Academy of Social Insurance.

Matthew Gentzkow was elected a Fellow of the American Academy of Arts and Sciences.

Jeffrey Clemens and Joshua Gottlieb were awarded the Kenneth J. Arrow Award for Best Paper in Health Economics from the International Health Economics Association for their paper “Do Physicians’ Financial Incentives Affect Treatment Patterns and Patient Health?”

Gene Grossman was awarded The Onassis Prize in International Trade. The prize, which recognizes lifetime contributions to this field, is awarded by the Alexander S. Onassis Public Benefit Foundation, the Cass Business School of City University London, and the City of London.

Veronica Guerrieri was awarded the Bernácer Prize for her research applying search theory to explain the emergence of illiquidity and fire sales in different asset markets.

Takeo Hoshi received the Japanese Bankers Academic Research Promotion Foundation Award. This biennial award recognizes a Japanese economist who has made a significant academic contribution in the field of finance and economics.

Amit Khandelwal, Stelios Michalopoulos, and Jonathan Vogel received excellence awards in global economic affairs from the Kiel Institute for the World Economy.

Morris Kleiner was honored by the Labor and Employment Relations