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INSIDE THIS ISSUE

- Why Larger Firms Produce Higher Value Inventions
- The Loss of the Bison and the Well-Being of Indigenous Nations
- Long-Term Effects of Aid for Children in Low-Income Families
- Age-Friendly Jobs on the Rise, and Not Just for Older Workers
- Managing Foreign-Currency Reserves in Emerging Markets

Labor Market Effects of Machine Tool Automation

Significant changes in manufacturing in the twentieth century were driven by the advent and diffusion of automated machine tools. In [Automation after the Assembly Line: Computerized Machine Tools, Employment, and Productivity in the United States](#) (NBER Working Paper 30400), Leah Platt Boustan, Jiwon Choi, and David Clingingsmith find that industries that were more exposed to computer numerical control (CNC) machines from 1970 to 2010 increased capital investment more rapidly, and experienced higher labor productivity, than industries without such exposure.

CNC machines automate manufacturing machinery using computer programs and servomechanisms. High-skilled workers are required to install, program, and repair these machines, and to use them to fulfill customized orders. The machines displace semi-skilled workers who used hand-operated machine tools to cut and bend metal.

CNC technology

was invented in the early 1950s but was not widely commercially available until the late 1970s. Japan, Germany, the United States, and

Automation of machine tool functions resulted in employment gains for college graduates and losses for high school graduates and dropouts.

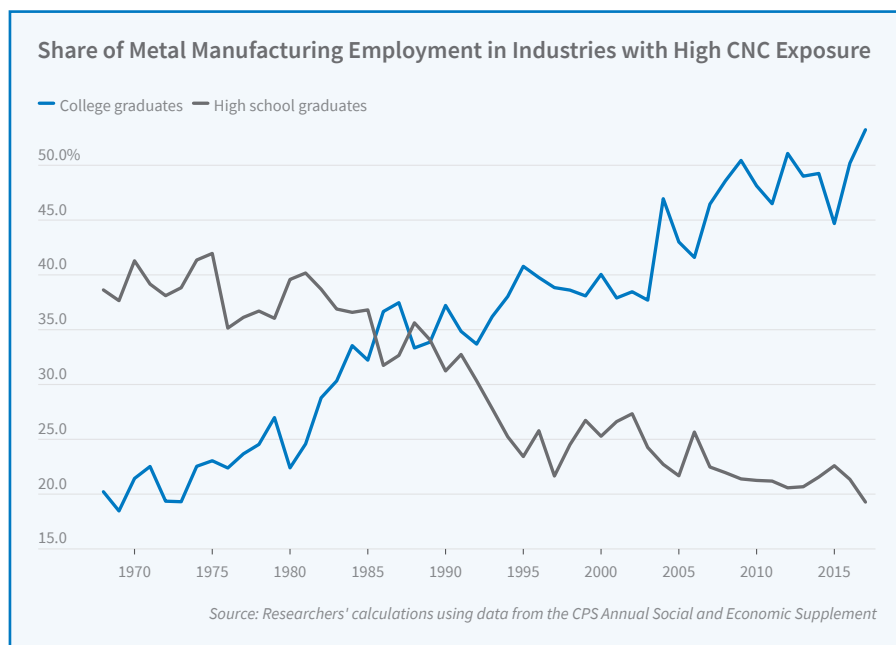
Italy were the largest producers of machines that embodied this technology. Because of a variety of difficulties in automating certain tool types, different tools transitioned from primarily hand-operated to CNC at varying

times and rates. Additionally, industries varied in their use of different tools. For example, aircraft manufacturers relied heavily on boring

machines while farm machine producers were heavy users of gear-cutting machines.

The researchers construct a measure of an industry's exposure to CNC that combines two metrics. First, they compute the share of each tool type in each industry's tool base in 1958, using data from the *American Machinist Inventory of Metalworking Equipment*. Second, for each tool, they collect the CNC share of each non-US country's exports from the *Economic Handbook of the Machine Tool Industry* as a tool-level measure of transition to CNC technology. They also use data from the NBER-CES Manufacturing Industry database and the Current Population Survey.

The researchers find that a 10 percentage point



increase in CNC exposure corresponds to a 29 percent increase in annual capital expenditures, a 20 percent increase in value added, a 1.6 percent decline in the share of revenue paid to labor, and a 25 percent rise in overall employment. They report employment gains of 86 percent for college graduates (from a low base), but losses of 7 to 8 percent for high school graduates and dropouts, respectively. They also find employment losses among nonunionized workers, but gains among unionized workers.

Using differences in task content by occupation, the researchers find that the

diffusion of CNC machines resulted in a decline in routine tasks and an increase in abstract and manual tasks. The tasks that became more common were more conceptual and socially connected, and require more training, preparation, and learning, than the ones that declined in importance.

Colleges and universities also responded to the growing use of CNC machines. Using the Higher Education General Information Survey and the Integrated Postsecondary Education Data System, they document the introduction of new degree programs that

taught skills related to CNC technology, finding that a 10 percentage point increase in CNC exposure in an industry was associated with a 2.4 percentage point increase in higher education enrollment in programs related to that industry among prime age male workers without a bachelor's degree.

In contrast to some recent claims that large firms are more likely to invest in industrial robots, the researchers do not find any association between firm size and exposure to CNC technology.

—Whitney Zhang

Why Larger Firms Produce Higher Value Inventions

Larger firms tend to profit more from their inventions than do their smaller counterparts. In *Invention Value, Inventive Capability, and the Large Firm Advantage* (NBER Working Paper 30354), [Ashish Arora](#), [Wesley M. Cohen](#), [Honggi Lee](#), and [Divya Sebastian](#) find that this does not occur because large firms produce inventions of higher technical quality. Rather, it is because they extract more value from their inventions, likely through more effective commercialization, which includes product development, marketing, distribution channels, and manufacturing. The researchers estimate that doubling a firm's size is associated with an increase of between 5 and 16 percent in the value of a given invention, depending on whether or not one controls for the firm's capitalization.

The study analyzed 2,786 manufacturing firms from 1980 through 2015. Sales, various other account-

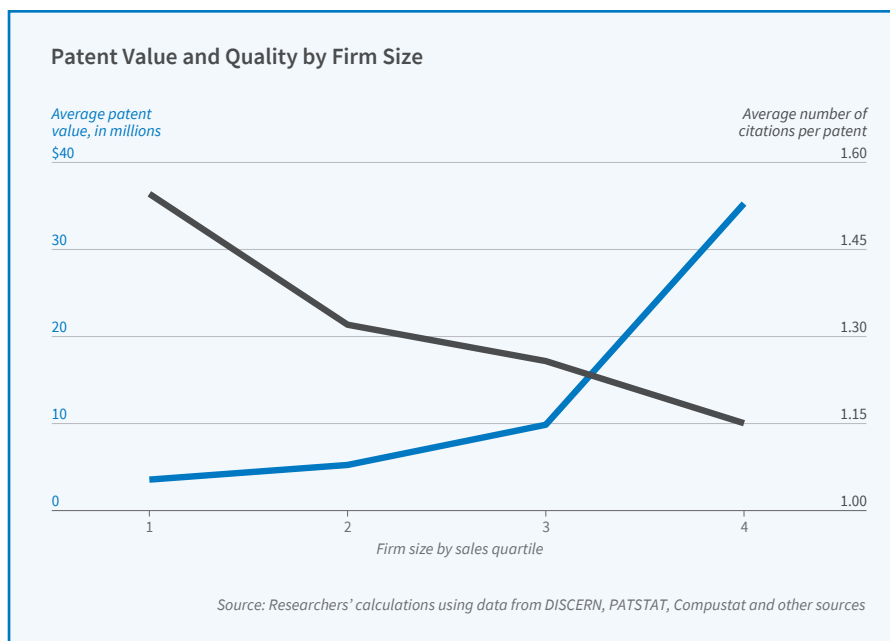
Average invention value increases with firm size even though average invention quality declines because larger firms have a greater capacity to capture value from their inventions.

ing measures, and industry codes were collected from the Standard & Poor's CRSP/Compustat database. The median firm had sales of \$263 million and a market capitalization of \$364 million, while the means were \$3.1 billion and \$4.2 billion, respectively. Information on the patents owned by the US-headquartered public firms was

extracted from the Duke Innovation & Scientific Enterprises Research Network, the US Patent and Trademark Office, and the European Patent Office.

Invention value was measured in two ways. One relied on the rise in the patent-owning firm's stock price just after a patent was issued. The other used the share of inventions patented in multiple jurisdictions. Filing in multiple jurisdictions is costly, and the researchers assume that patent applicants were likely to incur those costs only if they believed a given invention was of high value. Invention quality was measured using the number of forward citations for each patent, reflecting the view that inventions of higher technical quality will induce others to patent similar or follow-on inventions.

While average invention value increased with



firm size, average invention quality declined by an estimated 2.7 percent when firm size doubled. This translated into about 0.04 fewer normalized citations. For comparison, the average number of forward citations of a patent, after normalizing by the mean citation count within each grant year and Cooperative Patent Classification code class pair, was 1.3.

The option to sell or license patents or

access outside commercialization capabilities reduced the large firm advantage. The researchers found that small firms that sell patents to larger firms indirectly take advantage of the commercialization capabilities of their larger counterparts. In industries in which patents are commonly sold, the relationship between firm size and the private value of an invention was about 13 percent weaker, and the relationship between firm

size and invention quality was about 11 percent weaker, than in other industries.

The core finding that larger firms are more adept at capturing an invention's value suggests that larger firms can afford to support lower quality inventions while smaller firms, due to their limited commercialization capabilities, tend to focus their efforts on the highest quality inventions.

—Linda Gorman

The Loss of the Bison and the Well-Being of Indigenous Nations

In the late nineteenth century, unrestricted hunting pushed the North American bison population from nearly 8 million to near extinction. For the Native Americans of the Great Plains, the Northwest, and the Rocky Mountains, this eliminated a resource that had served as their primary source of livelihood for over 10,000 years and that featured in almost every facet of life.

In [The Slaughter of the Bison and Reversal of Fortunes on the Great Plains](#) (NBER Working Paper 30368) [Donn. L. Feir](#), [Rob Gillezeau](#), and [Maggie E. C. Jones](#) show that the bison population reduction immediately lowered the material well-being of bison-reliant nations. This decline has persisted to the present day. The researchers argue that the rapid loss of the bison, combined with limited access to credit, permanently altered bison-reliant nations' dynamic path of development and can help explain the relative poverty today of Indigenous nations in the interior of North America.

The researchers compare individuals who

The bison population's decline led to an immediate and persistent drop in the living standards of bison-reliant Native American societies.

belonged to nations affected by the bison population reduction to those in nations that were never bison reliant. They merge their measures of bison reliance with data on the height, gender, and age of over 15,000 Native Americans. These data, collected between 1889 and 1903 by physical anthropologist Franz Boas, permit comparisons of age-adjusted height trends

comparable to or better than their European contemporaries. The loss of the animals over a period of several decades had substantial and immediate negative effects. Those born in bison-reliant nations after the bison population was severely reduced suffered a 2.5 centimeter decline in height relative to those born in nations that were not bison reliant.

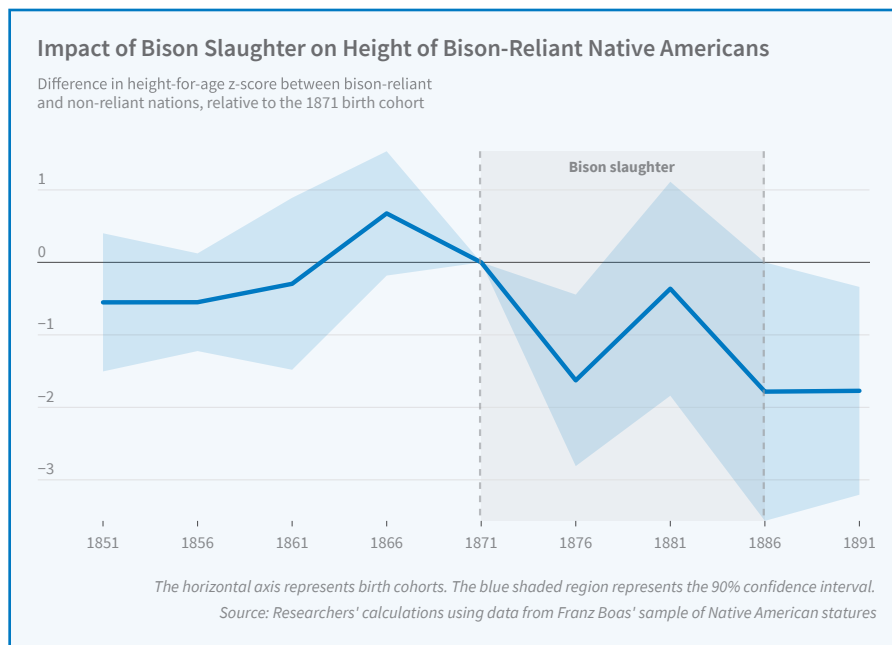
Bison-reliant nations experienced substantially higher rates of skewed sex ratios early in life and an increase in child mortality, both of which indicate maternal deprivation.

Adults in bison-reliant nations also experienced large-scale occupational displacement. Working-age men in these nations were 26 percentage points less likely to report an occupation in the 1900 census compared to similar-aged men in nations that were not reliant on the bison. In the latter half of the twentieth and the early twenty-first centu-

ries, income per capita has averaged 28 percent lower in historically bison-dependent versus nondependent nations. The researchers could not attribute this gap to differ-

ences across birth cohorts of individuals in different Indigenous groups.

Prior to the bison population's decline, bison-reliant societies had living standards



ences in agricultural productivity, self-governance, or application of the Dawes Act, which reduced, complicated, and fractionalized reservation lands.

Bison-reliant nations with greater access to credit have experienced a less persistent decline

in living standards, partially adapting through occupational respecialization and migration. Members of nations that had greater access to credit in 1870 were more likely to enter capital-intensive industries and less likely to enter agriculture, which was encouraged and financed

by the Bureau of Indian Affairs. The experiences of formerly bison-reliant peoples shed light on how the effects of economic shocks can persist for decades in the absence of access to financial resources that enable adaptation.

—Lauri Scherer

Long-Term Effects of Aid for Children in Low-Income Families

Firstborn children in families with incomes below the threshold to qualify for the Earned Income Tax Credit have significantly better outcomes as adults if their parents receive cash transfers following their birth. In *Investing in Infants: The Lasting Effects of Cash Transfers to New Families* (NBER Working Paper 30373), Andrew C. Barr, Jonathan Eggleston, and Alexander A. Smith track the impact of tax refunds in the first year of a firstborn's life.

Drawing on nationwide IRS data for low-income families going back to 1979, the researchers compare firstborn children whose parents were similar in all respects that can be measured in tax return data, except that one set was born in December and the other in January. The researchers omit children born in the eight days before and the eight days after December 31. A December birth made a family eligible for

an additional tax deduction and for a higher Earned Income Tax Credit. The additional benefits averaged 10 percent of family income, with an average transfer among the sample households of \$1,291 in 2015 dollars.

The researchers focus on firstborns because the tax benefits associated with having a dependent child in the household are larger when the tax filer moves from zero to one child

Newborns whose parents received tax relief scored higher on tests when they became schoolchildren and had increased earnings in early adulthood.

than from one to two or other expansions of family size. They link the tax returns on which the newborns were claimed as dependents, which indicate the level of transfers received, with the newborns' own tax returns in adulthood. In their twenties, the December-born children were in households that earned 1 to 2

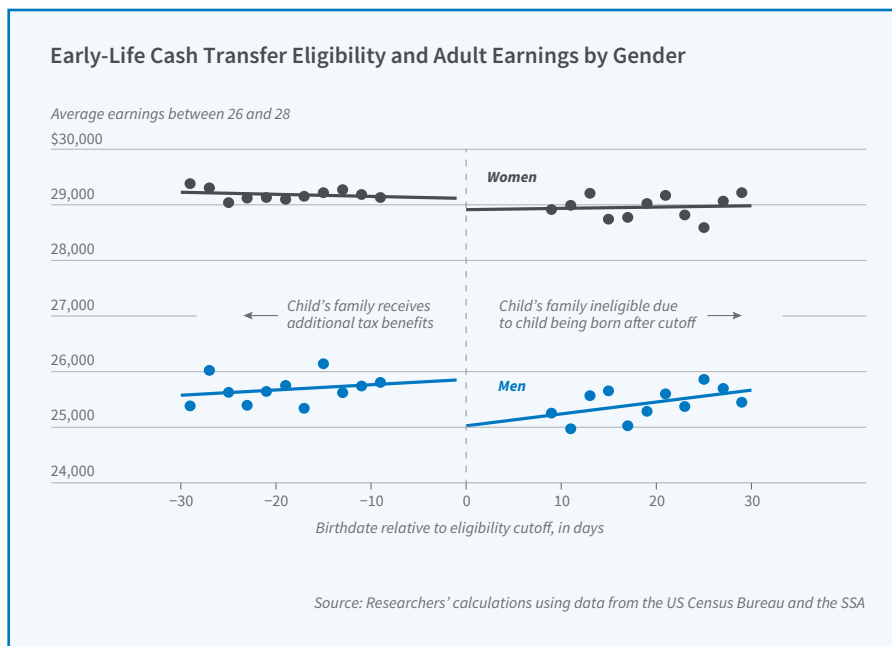
percent more than those born in January. This effect grew to between 2 and 3 percent in their early thirties. The effects were larger for males than for females. The additional earnings generate an increase in federal income tax revenues large enough, in present discounted value, to cover the cost of the higher tax credits for parents with newborns.

The researchers conjecture that the benefits to children are the result of parents' being more resilient in the face of financial shocks that arise during the child's first year.

The researchers also study the impact of eligibility for transfer income in the first year of life using educational data from North Carolina. They find that among children who were eligible for free or reduced-price lunches, a reasonable indicator that their family would be eligible for the Earned Income Tax Credit, those who were born just before the end of the calendar year performed better on standardized math and reading tests, incurred fewer suspensions, and were more likely to graduate high school than their slightly younger, January-born peers.

The researchers caution that their evidence describes the impact of transfers during the first year of a first child's life, but not of the impact of transfers provided at different ages. They also note that their sample is restricted to firstborn children. "With those caveats," they nevertheless conclude, "our results do suggest that additional resource transfers to poor families around the time of a first birth would result in substantial improvements in social mobility."

—Steve Maas



percent more than those born in January. This effect grew to between 2 and 3 percent in their early thirties. The effects were larger for males than for females. The additional earnings generate an increase in federal income tax revenues large enough, in present discounted value, to cover the cost of the higher tax credits for parents with newborns.

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Age-Friendly Jobs on the Rise, and Not Just for Older Workers

As the US population grows older, supporting employment at older ages can be an important contributor to economic growth. In *The Rise of Age-Friendly Jobs* (NBER Working Paper 30463), Daron Acemoglu, Nicolaj Søndergaard Mühlbach, and Andrew J. Scott build an index to assess whether occupations in the US economy have become more accommodating to older workers. Their resulting Age-Friendliness Index (AFI), aggregated across all jobs, increased by 8 percent between 1990 and 2020.

The AFI is created in four steps. First, the researchers use the US Department of Labor's O*NET descriptions of 244 job attributes for each of 873 occupations. Second, they rely on past research on the preferences of older workers to establish weights for these attributes. This involved nine categories: schedule flexibility, telecommuting, physical job demands, pace of work, autonomy at work, paid time off, working in teams, job training, and meaningful work. Absence of physical work, paid time off, and schedule flexibility received the largest weights. Third, they use relative weights reflecting the extent to which older workers' preferences differed from those of younger workers. The fourth step, enabled by machine learning algorithms, correlates 17,000 descriptors for each O*NET occupation with these nine components of age friendliness and builds an overall index using the absolute and relative weights.

The 10 most age-friendly occupations in 2020 were guides, receptionists, ticket agents, secretaries, human resources managers, proofreaders, insurance salespeople,

insurance adjusters, business promotion agents, and vocational and educational counselors. The 10 least age-friendly occupations were concrete and cement work-

Age-friendly jobs offer less physical exertion, greater use of social skills, and less harsh environmental conditions.

ers, carpenters, painters, masons, tool and die makers, library technicians, chemists, furniture and wood finishers, mixing and blending machine operators, and construction laborers.

Ninety-two percent of the increase in the AFI index over the last three decades

favor creation of new, more accommodating jobs for older workers. Indeed, employment of those aged 50 years and above accounts for 28 million of the 42

million worker increase in US employment between 1990 and 2020.

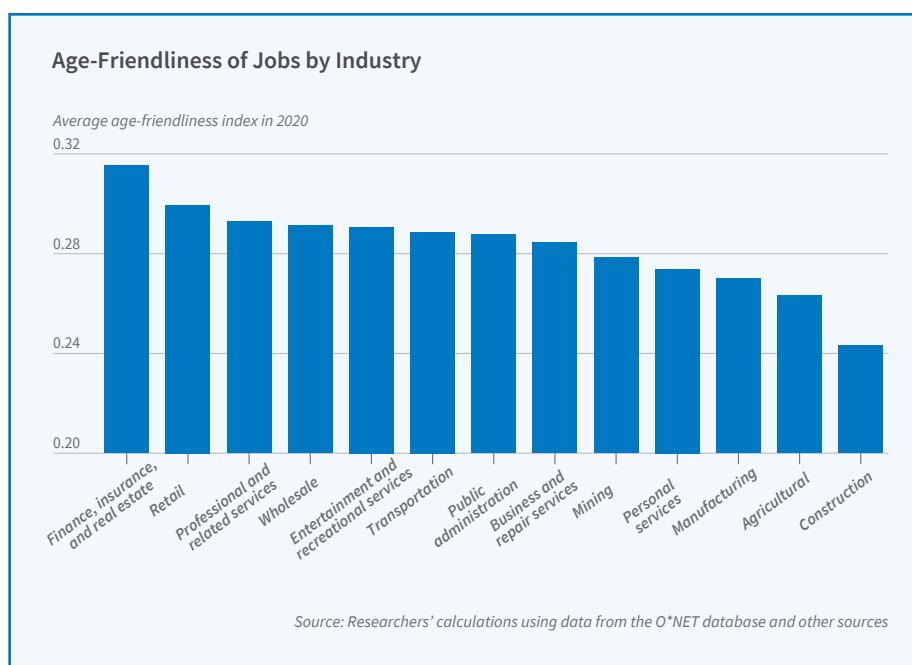
However, closer examination shows that older workers were not the main beneficiaries of the increase in age-friendly jobs. While older female and college-graduate workers have moved into more

age-friendly jobs since 1990, so have women and college graduates of all ages. Men without a college degree have not done so, however. A key explanation for this finding is the large number of these men working in manufacturing and construction, industries with relatively few age-friendly jobs and which have seen the least improvement in their age friendliness. A

related reason for this pattern may be that characteristics that make jobs friendly to older workers also make them attractive to women and college graduates, who may have been able to outcompete older non-graduate men for these jobs.

These results suggest that while the creation of age-friendly occupations is supportive of employment at older ages, relying on the creation of new age-friendly jobs may not be sufficient for boosting employment of older workers.

—Linda Gorman



was due to changes within occupations; the balance was the result of a shifting mix of occupations in the US economy. Employment in above average age-friendly occupations increased by about 44 percent, compared to an increase of 21 percent for below average age-friendly occupations.

Overall, employment in above average age-friendly occupations rose by 49 million workers. Given that the AFI is positively correlated with the share of older workers, these changes appear to

Managing Foreign-Currency Reserves in Emerging Markets

In the past 15 years, a number of emerging nations have gained the ability to borrow abroad in their own currency. Historically, borrowing in foreign currencies created problems when unexpected shocks hit, as in the Latin American crisis in the 1980s or the Asian financial crisis in the late 1990s. Emerging nations prefer to borrow in their local currency because it reduces their exposure to risk. If an adverse shock hits the domestic economy, the currency can depreciate and the government's debt burden will not increase. The problem is that risk-averse international investors charge a premium for debt in local currency.

Pursuit of a credible monetary policy is often cited as a key factor behind foreign investors' increasing acceptance of local-currency borrowing by emerging-market nations. In [Foreign Reserves Management and Original Sin](#) (NBER Working Paper 30418), [Michael B. Devereux](#) and [Steve Pak Yeung Wu](#) find that accumulation and smart management of foreign-currency reserves also contributes to this acceptance. The combination of inflation-fighting monetary policy from central banks and foreign-currency reserves has given foreign investors increasing confidence in the stability of local currencies.

For decades, emerging market countries could only borrow in foreign currency, a risky move that was sometimes called "original sin." In 2005, for example, the median country in the researchers' 24-country sample had only 5 percent of

its external sovereign debt denominated in its own currency. The data sample includes nations in Asia, Europe, the Middle East, and Latin America. By 2018, that median share in this group had increased to 38 percent.

Emerging market governments that purchase foreign currencies when times are good can reduce overborrowing in good times and reduce the risk of currency depreciation following global shocks.

Consider Peru. Its central bank began targeting inflation in 2002. In 2004, the share of government borrowing in local currency began to rise. In 2006, Peru began dramatically boosting its reserves of foreign currency. By the end of 2019, the local currency share of government borrowing was 30 percent.

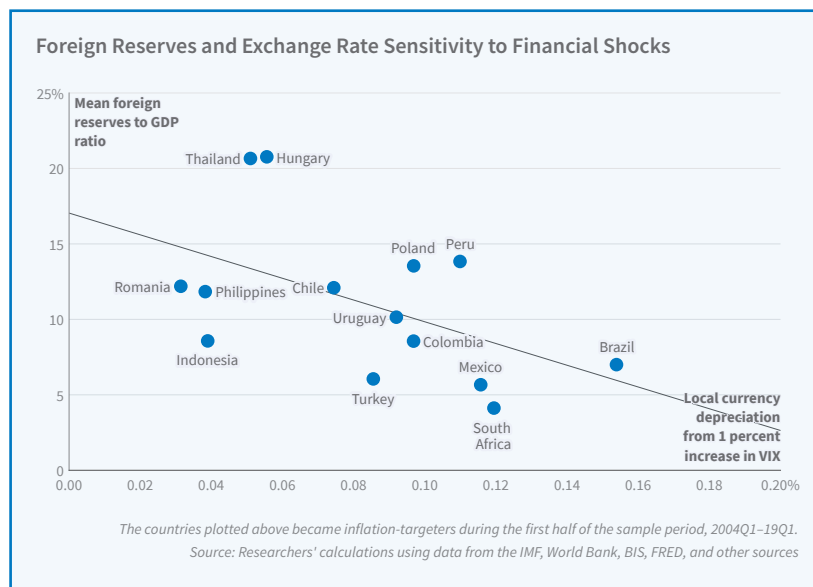
By building a small open-economy model and calibrating it using Brazil's borrowing history, the researchers conclude that two-thirds

of the rise in emerging markets' local-currency borrowing can be attributed to inflation targeting, while the other third is due to foreign-reserve accumulation. And there are additional benefits of holding large reserves of foreign cur-

rencies that inflation targeting cannot achieve.

To secure the full benefits of reserve accumulation, emerging market governments must lean against the global wind. In calm periods, private households may overborrow in foreign currency. When a negative global shock hits, they cut back, causing exchange-rate depreciation. By buying foreign currencies when times are good and private households are overborrowing, the government can prevent the economy from becoming too leveraged. By spending down those reserves when households are cutting back on borrowing, the government keeps the economy from becoming too constrained during global shocks. This smoothing strategy reduces the risk of currency depreciation and explains why the economies of nations with large foreign currency reserves are less sensitive to global forces and pay less of a premium when they borrow in local currency.

—Laurent Belsie



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