The NBER *Digest*

NATIONAL BUREAU OF ECONOMIC RESEARCH

October 2009

Game Theory and Major League Sports

In the perfect world of game theory, two players locked in a zero-sum contest always make rational choices. They opt for the "minimax" solution — the set of plays that minimizes their maximum possible loss — and their play selection does not follow a predictable pattern that might give their opponent an edge. But minimax predictions typically have not fared well in lab experiments. And real-world studies, while more supportive, have often used small samples.

Now a new study, **Professionals Do Not Play Minimax: Evidence from Major League Baseball and the National Football League** (NBER Working Paper No. 15347), looks at two of the biggest high-stakes examples of zero-sum contests: pitch selection in Major League Baseball and play-calling in the National Football League. Authors **Kenneth Kovash** and **Steven Levitt** find that: "Pitchers appear to throw too many fastballs; football teams pass less than they should." They also find that the selection of pitches or plays is too predictable. The researchers conclude that "correcting these decisionmaking errors could be worth as many as two additional victories a year to a Major League Baseball franchise and more than a half win per season for a professional football team."

Kovash and Levitt examine all Major League pitches — more than 3 million of them — during the regular seasons from 2002 to 2006 (excluding extra innings). They categorize them as fastballs, curveballs, sliders, or change-ups. They measure the outcome of each pitch using the sum of the batter's on-base percentage and slugging percentage (a measure they label OPS) and they determine that fastballs lead to a slightly higher OPS than other types of pitches.

If batters are more likely to score runs on fastballs, then minimax theory says that pitchers should adjust. To find out why they haven't, the authors look more deeply into the data, controlling for everything from the inning and number of strikes to the number of runners on base. A key factor, they find, is pitch count. As long as there are fewer than two strikes during an at-bat, the difference in outcome between throwing fastballs and non-fastballs tends to be small. But when there are two strikes, the outcomes diverge dramatically. Fastballs generate an OPS that is more than 100 points higher than non-fastballs. The authors calculate that if a team's pitchers reduced their share of fastballs by 10 percentage points, they would allow roughly 15 fewer runs in a season, about 2 percent of their total runs allowed.

The study then looks at the order of pitches. Because pitch selection can depend on so many variables that the authors cannot measure (pitcher fatigue, whether the curveball is "working" that day, and so on), they limit

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their study to situations where the same pitcher faces the same batter with the same count and the same number of specific pitches but in a different order.

Say, for example, the count is 2-and-1 after two fastballs and a slider — minimax theory predicts that it doesn't matter which pitch the slider was. But the study finds that pitchers are more predictable than that. If the last pitch was a fastball, the likelihood that the next one will be a fastball falls by 4.1 percentage points. If the last pitch was a slider, then it is 2 percentage points less likely that the next one will be a slider. Other patterns also emerge: fastballs are more likely to follow changeups than other types of pitches; curveballs are most likely to follow fastballs and least likely to follow changeups. Based on interviews with MLB executives and some assumptions of their own, the authors estimate that knowing these statistics would boost a batter's OPS by .006 — worth about 10 to 15 runs per team per year.

For the NFL, the study concentrates on 125,000 plays during the 2001 to 2005 seasons when the offense clearly was going to run or pass. The authors construct their own measure of the likelihood of scoring based on the down, the distance to first down, field position, and so on. Then they analyze the change in a team's expected points before and after the play. They find that a pass on average gains .55 yards more than a run, is 9 percentage points more likely to yield a first down, and leads to scores with a 3.8 percent probability. Runs have only a 2.8 percent scoring probability, although in fairness they lead to fewer turnovers. Using an expanded set of measures, the authors find that if a team went from passing 56 percent of the time (the current average) to 70 percent, they would score an additional 10 points over the course of a season — or 3 percent of their total scoring.

Kovash and Levitt then look at the order of plays, and again find patterns that minimax theory would not predict. Conditional on other factors, a team that has passed is 10 percentage points less likely to pass on the next play. After a passing play with a poor outcome, a team is 14.5 percent points more likely to switch from a pass to a run on the next play (or vice versa), even after controlling for the down and distance.

The authors estimate, under some conservative assumptions, that if a defense could better anticipate the play using such offensive tendencies, it would give up an average of 10.8 fewer yards per game. That would translate to a point a game, or half a victory a year — a gain that is slightly larger than that from calling more passing plays.

The authors conclude that "These deviations are not enormous in magnitude — meaning that they might plausibly not have been detected in the smaller datasets that have been available in most prior field research on the topic — but are large enough that a team that successfully exploited these patterns could add one or two season wins and millions of dollars in associated revenue."

— Laurent Belsie

The Global Expansion of Higher Education

In 1970, approximately 29 percent of the world's college students attended school in the United States, even though the United States accounted for only 6 percent of the world's population. Over the last four decades, higher education in the rest of the world has expanded rapidly, so that in 2005–6 the U.S. share of the world's college students had dropped to 12 percent. From 1995–2004, the U.S. share of bachelor's degrees in all fields fell by 5.5 percent and the share in natural science and engineering declined by 1.3 percent.

In 1966, 23 percent of science and engineering PhDs awarded by U.S. universities went to students who were born outside the United States. By 2006, that proportion had increased to 48 percent. In 2004, the European Union granted 78 percent more science and engineering Ph.D.s than the United States. By 2010, China is expected to graduate more science and engineering doctorates than the United States.

In **What Does Global Expansion of Higher Education Mean for the U.S.?** (NBER Working Paper No. 14962), author **Richard Freeman** observes that the foreign-born are "an important source of immigrant scientists and engineers" in the United

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States. Historically, about 75 percent of foreign-born doctoral recipients have pursued post-doctoral employment in the United States. This highlights the United States's reliance on immigration to maintain its lead position in science and technology. While foreign-born scientists and engineers who remain in the United States contribute to U.S. economic growth, they also reduce the payoff for investing in higher education in science and technology for those born in the United States.

In the short-term, the growing number of college students in other countries increases the demand for places in U.S. graduate and professional schools. If U.S. graduate schools admit applicants without regard for their country of origin, and available places in graduate schools grow more slowly than demand, then the proportion of U.S. students admitted to U.S. graduate programs is likely to decline in future years. In the longer term, rising quality at foreign universities will increase the competition for U.S. universities that are seeking to attract the most talented students, regardless of their country of origin.

Freeman concludes that the worldwide increase in the number of highly educated engineering and science workers will raise productivity in countries outside the United States, accelerating worldwide technological and economic progress but eroding the

comparative advantage of the United States in the R and D that produces innovative products. Over the long term, Freeman predicts that the prices paid for U.S. exports in high tech and other knowledge-intensive sectors will decline.

Although U.S. consumers of high tech and knowledge intensive goods will benefit from lower prices, the United States also may "lose its position as the major producer of high tech goods or of the research and development on which they are based" to countries with highly educated workers and lower labor costs. Freeman concludes that since "most of the rest of the world is in catch-up mode in mass higher education, the decline in the U.S. advantage in the proportion of the population with university training is likely to continue for some time."

— Linda Gorman

Federal Life Sciences Funding and University R and D

Federal spending on R and D spurs funding from the private sector and from state and local governments, according to researchers **Margaret Blume-Kohout**, **Krishna Kumar**, and **Neeraj Sood.** In **Federal Life Sciences Funding and University R and D** (NBER Working Paper No. 15146), the researchers estimate that a one dollar increase in federal funding leads to a 33-cent increase in non-federal funding at U.S. universities. This may be because the non-federal funders interpret successful applications for federal funding as a signal of quality. There is a greater increase in non-federal funding per federal dollar received among those universities that do not grant Ph.D.s, among lower ranked universities, and among universities that have historically received less funding — institutions for which the signaling value of receiving federal funding may be greater.

Federal agencies spend billions of taxpayer dollars funding academic research each year. Especially in the life sciences, funding for academic research has risen rapidly over the last decade. In 2007, total federal obligations for R

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and D at academic institutions totaled over $25 billion, of which $15.5 billion was provided by the National Institutes of Health (NIH), primarily to support basic and applied research in the biomedical sciences.

The American Recovery and Reinvestment Act of 2009 (ARRA) provided an additional $8.2 billion to NIH to fund extramural life sciences R and D. This spending was justified as a means to speed economic recovery and on the grounds that it would promote long-term scientific progress, but some critics suggested that it might crowd out funding from other sources.

The authors use a panel of 272 U.S. universities, with data on federal and non-federal life sciences R and D funding spanning nearly a decade, to explore this issue. In contrast to the claims of crowd-out, their findings suggest that federal funding "crowds in" other spending. These findings differ in scale from previous studies, which find only an additional eight cents in academic spending, compared with the 33 cents found here. The use of the university as a unit of analysis, and a reliance on cross-sectional as well as time-series variation (as opposed to aggregate time-series variation alone) might partly account for this difference.

— Lester Picker

The Geography of Venture Capital Expansion

Relative to the amount of capital invested, venture capital backed companies have disproportionately contributed to the creation of jobs, market value, and revenue to their local economies. As a result, states and municipalities are competing for the establishment of venture capital investors' offices in their communities.

In **Buy Local? The Geography of Successful and Unsuccessful Venture Capital Expansion** (NBER Working Paper No. 15102), authors **Henry Chen**, **Paul Gompers**, **Anna Kovner,** and **Josh Lerner** examine the location decisions of venture capital (VC) firms and the impact that venture capital firm geography has on investments and outcomes. They analyze data for 2,039 VC firms in the period 1975 to 2005, including their office loca-

tions and that of the businesses in their investment portfolios.

Currently, about half the VC firms and an equal percentage of the U.S.-based companies that they finance are concentrated in just three metropolitan areas — San Francisco/San Jose, Boston, and New York, which the authors refer to as "venture capital centers." Those VC firms outperform VC firms based elsewhere, regardless of the stage of the investment. These superior returns may result in part from the most successful venture capital firms being located in these three cities, with their reputations allowing them to be among the first to see the most interesting investment opportunities, regardless of the geographic region of the company.

VC firms tend to open satellite offices in cities where other VC firms already operate, rather than in regions with few other VC firms. This is consistent with VC firms chasing the success of other VC firms. "In fact, one of the most important determinants of the number of VC offices in a region is success rate for all previous VC investments in that region," the authors write.

However, "much of the VC outperformance in these venture capital centers arises from their non-local investments," that is investments outside of the three VC centers. That may be because VC firms apply more rigorous standards when considering new investments further away from their office base, since they expect to incur a higher monitoring cost of that business.

The location decisions of VC-backed businesses are affected by a number of factors. Entrepreneurs seeking VC capital may choose to locate their businesses in areas that are close to potential VC funding sources, but they also may be attracted to regions with pools of talented employees and academic researchers, which have been shown to result in a higher success rate for new ventures.

This study finds that one VC-backed success in a new geographic area usually leads to additional VC investment in other businesses in the region. "We find evidence that a venture capital firm's existing investments in a region affect expected success on other deals in that region, (so) bringing first-time venture capital investors

to a region may be more effective than subsidizing existing investors."

Another interesting finding is that "some of the performance disparity between local and non-local investments disappears when the venture firm does more than one investment in a region, suggesting that (as) the

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marginal monitoring cost falls, venture capital firms may reduce their expected success rate for investment in a distant geography."

Therefore, if local governments outside the nation's three VC centers seek to attract VC branch offices, one strategy they might consider is providing support to VC-backed businesses in their communities. The study concludes that "…anything that policymakers do that contributes to an increase in the number of successful venture-backed investments in a region will also increase the probability of a venture branch office opening in that region."

— Frank Byrt

The Roots of Protectionism in the Great Depression

The Great Depression was a breeding ground for protectionism. Output fell, prices declined, and unemployment rose, pressuring governments to do something to revive their economies, even if that meant limiting imports. But contrary to popular perception, some countries went much further down this protectionist road than others, according to **The Slide to Protectionism in the Great Depression: Who Succumbed and Why?** (NBER Working Paper No. 15142). Co-authors **Barry Eichengreen** and **Douglas Irwin** conclude that a key factor behind this variation in trade policies was nations' adherence to the gold standard. Those countries that clung to the gold standard were more likely to restrict trade than those that abandoned it.

Previous research has shown that countries that remained on the gold standard tended to endure sharper and longer downturns than those that allowed their currencies to depreciate.

Eichengreen and Irwin offer an important trade-policy corollary: without the flexibility to depreciate their currencies, many gold-standard nations turned to trade restrictions in hopes that these would boost their domestic industries and curb unemployment. Thus, the 1930s' rush to protectionism was not so much a triumph of special-interest politics as it was a result of second-best macroeconomic policies, the authors write. Their study "suggests that had more countries been will-

ing to abandon the gold standard and use monetary policy to counter the slump, fewer would have been driven to impose trade restrictions."

Eichengreen and Irwin focus on three groups of countries that emerged from the wreckage: Britain and the sterling bloc, which abandoned gold and largely avoided boosting trade barriers; France and the gold bloc, which stayed on the gold standard and resorted to protectionist measures; and a group of countries led by Germany that imposed draconian controls on trade and payments in a way that also effectively protected their economies from imports. By looking at three measures of commercial policy — import tariffs, import quotas, and exchange controls — the authors are able to gauge how these blocs reacted to the pressures facing them as trade began to collapse in mid-1931.

Although each measure is relatively crude, all three paint the same broad picture. Between 1928 and 1938, the average tariff (as a percentage of the value of imports) did not change in any major way for three of the four sterling-bloc nations. (The exception, Britain, raised tariffs for internal political reasons, the authors contend). By contrast, the average tariff soared between 1928 and 1935 for all four gold-bloc countries (France, Belgium, the Netherlands, and Switzerland) and three of the five exchange-control nations (Austria, Germany, and Italy). The two exceptions — Czechoslovakia and Hungary — had such rigid foreign-exchange controls that they didn't need high tariffs to keep out imports.

League of Nations data on import quotas for eight nations in 1937 points to the same trend: the sterling-bloc countries relied on them less than gold-bloc countries did. Similarly, few sterling-bloc and other currency-depreciating nations imposed exchange controls while those that stuck with the gold standard often did. Between 1928 and 1935, exchange-control nations on average reduced imports some 26 percent more than what would be expected from the change in their real GDP, the authors calculate. "This suggests that controls were a significant factor in reducing international trade," they write.

In a more detailed analysis of changes in tariffs and exchange rates for a group of 21 mostly European nations and a larger sample of 40 countries between 1928 and 1935, the authors find the same trend: those that abandoned the gold standard were less likely to increase import tariffs. There is fair bit of variation from the average, though, partly because of certain national idiosyncrasies (such as Britain's internal political dynamics), partly because of additional factors across countries (such as whether they were international financial centers or had recently experienced high inflation). Either of these latter factors would have made a nation more reluctant to abandon the gold standard, the authors argue. Indeed, when they control for these factors, the results reinforce the conclusion that there is a strong relationship between the change in the exchange rate and the change in import tariffs.

Remaining on the gold standard fueled protectionism, but the countries that left the gold standard began to liberalize their trade policies. The

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United States, for example, delinked in 1933 and a year later enacted the Reciprocal Trade Agreements Act, which gave the President the authority to trim import duties in foreign-trade agreements. Once France went off gold in 1936, it began eliminating import quotas.

Parallels between the Great Depression and today have raised fears of a new slide toward protectionism. But the policy tools in the modern era are different, the authors write. In the 1930s, stimulus meant monetary stimulus, which tended to depreciate the nation's currency and make its products cheaper in export markets. Such moves tempted other nations to impose trade barriers. Today, besides monetary stimulus, nations are using fiscal stimulus that boosts domestic demand and helps not only the nation that uses it but also those countries that export to it. Thus, the temptation to restrict imports now rests with nations enacting such stimulus. The "Buy America" provisions in the 2009 U.S. federal stimulus package are one example.

—Laurent Belsie

World Markets for Mergers and Acquisitions

While a significant proportion of mergers involve private firms from different countries, the economic research on the subject had largely focused on domestic deals, or on cross-border mergers involving public firms from the United States. Now, writing in **World Markets for Mergers and Acquisitions** (NBER Working Paper

No. 15132), co-authors **Isil Erel**, **Rose Liao**, and **Michael Weisbach** characterize the patterns of cross-border mergers and acquisitions and how they affect world markets and both public and private firms. They rely on a sample of over 56,000 cross-border mergers that occurred between 1990 and 2007. A large majority of these deals targeted a non-U.S. firm, or did not involve a U.S. firm as an acquirer; and nearly all of the mergers had either private acquirers or private targets.

The authors first identify the patterns of who buys whom. They conclude that geography matters: firms are much more likely to merge with a counterpart in a nearby country than in a country far away. Moreover, the majority of acquirers are from developed countries — around 90 percent— and they tend to purchase firms in countries with lower investor protection and accounting standards.

Exploring what determines acquisition patterns, the authors find that valuation differences due to relative currency movements and to relative stock market returns are important drivers of cross-border merger activity. While it has been shown that differences in valuation between poten-

tial acquirers and targets are a motive for domestic mergers, it turns out that these valuation differences are even more important in an international context — movements in country-level stock markets and currencies

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provide additional sources of valuation differences.

Currency movements significantly affect the likelihood of a cross-border merger. A target firm is more likely to be acquired by a firm from a country whose currency has appreciated relative to the target's currency. A 75 percent appreciation of one country's currency relative to another's leads to a 50 percent increase in the number of acquisitions of firms in the country with the relatively depreciated currency.

Currency movements predict mergers mostly for within-region country-pairs and appear to be most important when the acquiring country is wealthier than the target. Firms in wealthier countries purchase firms in nearby poorer countries because

they are relatively inexpensive after currency depreciation.

Economy-wide factors reflected in the country's stock market returns are also an important determinant of a merger. The acquirer is likely to come

from a country whose stock market has outperformed the target country's stock market. A 100 percent difference in country-level stock returns between two countries leads to a 17 percent increase in the expected number of acquisitions of the worse performing country's firms by the better performing country's firms.

Both the currency and the stock market effects may reflect errors in valuation or wealth explanations of what is happening. The authors find that the evidence is more consistent with the wealth explanation — an increase in wealth leads to improved ability of a firm to finance acquisitions.

— Claire Brunel