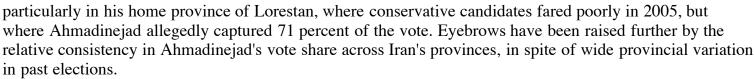# The Washington Post

The Devil Is in the Digits

By Bernd Beber and Alexandra Scacco
Saturday, June 20, 2009 12:02 AM

Since the declaration of Mahmoud Ahmadinejad's landslide victory in Iran's presidential election, accusations of fraud have swelled. Against expectations from pollsters and pundits alike, Ahmadinejad did surprisingly well in urban areas, including Tehran -- where he is thought to be highly unpopular -- and even Tabriz, the capital city of opposition candidate Mir Hussein Mousavi's native East Azarbaijan province.

Others have pointed to the surprisingly poor performance of Mehdi Karroubi, another reform candidate, and particularly in his home province of Lorestan, where conservative candidates fared poorly in 2005, but where Ahmadinejad allegedly captured 71 percent of the vote. Eyebrows have been raised further by the relative consistency in Ahmadinejad's vote share across Iran's provinces, in spite of wide provincial variation in past elections.

These pieces of the story point in the direction of fraud, to be sure. They have led experts to speculate that the election results released by Iran's Ministry of the Interior had been altered behind closed doors. But we don't have to rely on suggestive evidence alone. We can use statistics more systematically to show that this is likely what happened. Here's how.

We'll concentrate on vote counts -- the number of votes received by different candidates in different provinces -- and in particular the last and second-to-last digits of these numbers. For example, if a candidate received 14,579 votes in a province (Mr. Karroubi's actual vote count in Isfahan), we'll focus on digits 7 and 9.

This may seem strange, because these digits usually don't change who wins. In fact, last digits in a fair election don't tell us anything about the candidates, the make-up of the electorate or the context of the election. They are random noise in the sense that a fair vote count is as likely to end in 1 as it is to end in 2, 3, 4, or any other numeral. But that's exactly why they can serve as a litmus test for election fraud. For example, an election in which a majority of provincial vote counts ended in 5 would surely raise red flags.

Why would fraudulent numbers look any different? The reason is that humans are bad at making up numbers. Cognitive psychologists have found that study participants in lab experiments asked to write sequences of random digits will tend to select some digits more frequently than others.

So what can we make of Iran's election results? We used the results released by the Ministry of the Interior and published on the web site of Press TV, a news channel funded by Iran's government. The ministry provided data for 29 provinces, and we examined the number of votes each of the four main candidates -- Ahmadinejad, Mousavi, Karroubi and Mohsen Rezai -- is reported to have received in each of the provinces

-- a total of 116 numbers.

The numbers look suspicious. We find too many 7s and not enough 5s in the last digit. We expect each digit (0, 1, 2, and so on) to appear at the end of 10 percent of the vote counts. But in Iran's provincial results, the digit 7 appears 17 percent of the time, and only 4 percent of the results end in the number 5. Two such departures from the average -- a spike of 17 percent or more in one digit and a drop to 4 percent or less in another -- are extremely unlikely. Fewer than four in a hundred non-fraudulent elections would produce such numbers.

As a point of comparison, we can analyze the state-by-state vote counts for John McCain and Barack Obama in last year's U.S. presidential election. The frequencies of last digits in these election returns never rise above 14 percent or fall below 6 percent, a pattern we would expect to see in seventy out of a hundred fair elections.

But that's not all. Psychologists have also found that humans have trouble generating non-adjacent digits (such as 64 or 17, as opposed to 23) as frequently as one would expect in a sequence of random numbers. To check for deviations of this type, we examined the pairs of last and second-to-last digits in Iran's vote counts. On average, if the results had not been manipulated, 70 percent of these pairs should consist of distinct, non-adjacent digits.

Not so in the data from Iran: Only 62 percent of the pairs contain non-adjacent digits. This may not sound so different from 70 percent, but the probability that a fair election would produce a difference this large is less than 4.2 percent. And while our first test -- variation in last-digit frequencies -- suggests that Rezai's vote counts are the most irregular, the lack of non-adjacent digits is most striking in the results reported for Ahmadinejad.

Each of these two tests provides strong evidence that the numbers released by Iran's Ministry of the Interior were manipulated. But taken together, they leave very little room for reasonable doubt. The probability that a fair election would produce both too few non-adjacent digits and the suspicious deviations in last-digit frequencies described earlier is less than .005. In other words, a bet that the numbers are clean is a one in two-hundred long shot.

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