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# Big Players in Slovenia

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**Abstract.** The subjectivism of Austrian economics helps to explain the statistical fact of long memory in asset prices. The theory of Big Players is an Austrian approach to understanding the effects of discretionary policymaking in markets. It leads to implications that can be tested with statistics. In particular, Big Players induce herding and, thereby, an increase of persistence in asset prices. A recent episode in Slovenian monetary theory provides a case study. This case study adds to a set of similar studies, all tending to support the theory of Big Players.

**Key Words:** Big Players, Slovenia, herding, R/S analysis, monetary policy

**JEL classification:** E58, G12, E42.

One of the principal goals of financial research is to describe the statistical properties of the time-series data generated by asset markets. Persistent dependence in asset prices (explained below) is one such statistical property.[1] Somewhat ironically, perhaps, the subjectivism of Austrian economics helps to explain this statistical fact. The theory of Big Players (explained below) is an Austrian approach to understanding the effects of discretionary policymaking in markets.[2] But it leads to implications that can be tested with statistics.[3] In particular, Big Players induce herding and, thereby, an increase of persistence in asset prices. (As we shall see, this Big Player effect operates through reputation effects in the labor market.) A recent episode in Slovenian monetary theory provides a case study.

Koppl and his co-authors have argued that "Big Players" induce herding in financial markets. This herding increases persistent dependence. They have produced several empirical studies supporting the claim (Ahmed et al. 1997, Gilanshah and Koppl 2001, Koppl and Yeager 1996, Koppl and Sarjanovic 2003). Our study adds to this list. (Broussard and Koppl 1999 and Koppl and Nardone 2001 address different but related questions.) Each of these studies, including ours, combines statistical analysis with qualitative empirical work. In this group of studies, qualitative empirical work is a prerequisite to statistical testing. It bolsters the view that the statistical test and its interpretation are both appropriate. In this paper, our examination of interviews conducted by Draško Veselinovič, together with his own analysis, allow us to identify with some confidence key features of the mental models guiding market participants during the episode we study. Attention to such "agent theories" (Koppl 2002) is characteristic of Austrian economics.

Section 1 reviews the statistical concept of persistent dependence and past explanations for it. Section 2 reviews the theory of Big Players and shows how it offers an alternative explanation for persistence. Section 3 applies the theory of Big Players to an important case of central bank activity that influenced Slovenia's stock market. This incident, we argue, induced herding among traders who recognized an increase in Big Player influence beginning in 1994. Section 4 contains statistical methods and results. Finally, Section 5 contains a few concluding remarks.

## 1. Persistent Dependence

The concept of persistent dependence and tests for its existence were developed originally by H.E. Hurst, the great hydrologist known as "the Father of the Nile" (Mandelbrot 1972:282). Together with the use of rescaled-range analysis as a test, it was developed not only by the hydrologist H. E. Hurst (Hurst et al. 1965), but also by Benoit Mandelbrot (1971, 1972, 1997), Mandelbrot and Wallis (1968, 1969a, 1969b) and Wallis and Matalas (1970).

Persistent dependence or memory in a stationary time series is simply the failure of the autocorrelations to die off quickly, i.e., at least exponentially. The influence of each innovation "persists" indefinitely. Such a time series is not ergodic. Persistent dependence in time-series data creates "aperiodic cycles," irregular ups and downs in the data that cannot be attributed to "short-period" autocorrelation. When a time series has a long memory, it will swing up and down about its long-term expected value in irregular waves or "aperiodic cycles." If a present innovation in one direction tends to produce future innovations in the same direction, there is "postive persistence." In this case, the waves will be longer, on average, than the pseudo-cycles of an ergodic process such as white noise. Graphs of the time series will undulate too much to have been generated by an ergodic process. If there is "negative persistence," the aperiodic cycles will be shorter on average than the pseudo-cycles of a white-noise process. In this case, the graph of the time series will be too spiky to have been generated by white noise. The aperiodic cycles created by persistent dependence are just these too-undulant or too-spiky pseudo-cycles in the graph of the time series.

Hurst performed an experiment with playing cards that nicely illustrates the nature of positive persistence—the case of interest to us. He relabeled the 52 cards with the numbers $+1$, $-1$, $+3$, $-3$, $+5$, $-5$, $+7$, and $-7$ in proportions designed to approximate a normal distribution. He then shuffled the deck and picked a card at random by cutting the deck. After writing down the number of the card turned over, $+5$ for example, he shuffled the deck again and dealt out two hands of 26 cards each. He then biased one of the hands by replacing some of its cards according to the number written down earlier. In our example the number was $+5$, so Hurst would have created the biased hand by removing the five lowest cards and replacing them with the five highest cards of the other hand. The final step in preparing the biased hand was adding a joker. Hurst would repeatedly shuffle the biased hand, cut it, and record the number of the card turned over. This shuffling and cutting would go on until the joker came up, at which point a new biased hand would be created and the process repeated. The sequence of values generated through this experiment exhibited persistent dependence and aperiodic cycles.

Note that the joker introduces two sources of uncertainty, namely, timing and content. We do not know when the joker will be drawn. Thus, we do not know at what time the current the trend will change. This is uncertainty in timing. When the joker is drawn, a new bias is determined randomly. The size and direction of the bias, +5 for example, is unknown. This is uncertainty in content. In this sense, the joker may be said to create uncertainty about both timing and content.

Persistent dependence has been found in foreign exchange markets (Booth, Kaen, and Koveos 1981, 1982, Koppl and Yeager 1996), the New York Stock Exchange (Greene and Fielitz 1977, Peters 1989), the commodity futures market (Helms, Kaen, and Rosenman 1984), gold and silver spot markets (Booth and Kaen 1979), Treasury-bond returns (Peters 1989), money-demand residuals (Gilanshah and Koppl 2001) and sports scores (Hurst et al. 1965). The phenomenon of memory in asset-market time series conflicts with martingale models. Thus, it is important to develop and test models of this phenomenon.

As far as we know, before Koppl and Yeager (1996) there was only one explanation of persistent behavior in asset prices, namely, that of Kaen and Rosenman (1986) who were building on Heiner (1983). Heiner had suggested that his theory of choice, outlined below, might be used to explain "switching between buying and selling strategies in financial markets, resulting in sudden movement in stock prices" (1983:582). Kaen and Rosenman extended Heiner's suggestion to argue that his model predicts herding under certain circumstances. The news indicating a change in asset value may come in a flow over time with the early signals harder to read than the later signals. (For on thing, late signals are accompanied by many other confirming bits of news; early signals are not.) If some traders are better at reading the signals than others, then asset prices may move up and down in aperiodic cycles. They point out that "Part of the news flow, of course, could be that other traders are buying [or selling] the asset" (1986:216). Citing many of the studies mentioned in the last paragraph, Kaen and Rosenman note that the persistent dependence measured by R/S analysis is indeed present in many financial markets. Heiner's theory, they conclude, "provides an explanation for the observed statistical persistence and switching behavior in financial markets .... Highly perceptive individuals react to news early, the less perceptive wait for more news. The flow of movement causes a *series* of partial adjustments towards the new equilibrium asset price" [p. 218].

Kaen and Rosenman do not offer any testable hypotheses about when the degree of persistence should be greater and when less. Nor do they develop the connection between herding and persistence. Koppl and Yeager address both issues. Their use of R/S analysis may be viewed as something of an extension or development of the ideas of Kaen and Rosenman. In this study, we follow the logic of Koppl and Yeager as well as their statistical technique. The next section develops that logic. After examining the historical facts in Slovenia, we apply the statistical technique used by Koppl and Yeager to our Slovenian data. Our results are consistent with theirs.

## 2. The Theory of the Big Player[4]

A Big Player as defined by Koppl and Yeager (1996) and Butos and Koppl (1993) must satisfy three criteria:

1. He must be big in the sense that his actions influence the course of economic events.
2. He must be relatively insensitive to profit and loss.
3. He must use discretion in his exercise of market power.

Koppl and Yeager (1996) and Butos and Koppl (1993) argue that when a Big Player is present, not only will his actions directly affect economic variables, but they will lower the informational content of many market signals, including prices. This has several implications. First, "small players" will have increased difficulty extracting useful knowledge about economic fundamentals, thereby reducing the reliability and usefulness of their expectations. Second, success now becomes more closely tied to anticipating the behavior of the Big Player, resulting in a reallocation of entrepreneurial alertness toward this task and away from fundamentals.[5] Finally, discretionary policies on the part of the Big Player will create "Keynesian beauty contests" (Butos and Koppl 1999). That is, the decisions of policy makers will be based on their expectations of how private actors will behave, while the decisions of private actors will be based on their expectations of how policy makers will behave. This, at least in part, divorces the process of expectations formation from underlying economic fundamentals. The theory maintains, then, that the Big Player's discretionary policies increase the uncertainty of the market, and contribute to greater volatility or market instabilities.

An independent central bank may become the quintessential Big Player. The policy actions of a central bank clearly affect the course of economic events. The bank's policy-making committee may exercise any desired degree of discretion in setting and pursuing various targets, and it is free of profit and loss constraints with respect to its policy actions. Whether a central bank is a Big Player depends on its choice between rules and discretion. If it chooses rules, it is not a Big Player. But if it chooses discretion, it becomes a Big Player. One of the many variables that may be affected by the discretionary actions of a central bank is the behavior of traders on the stock market. Since, through its policies, the central bank directly affects the opportunity cost of holding money, it also affects the opportunity cost of holding other assets, including stocks.

In asset markets, the presence of Big Players can induce "herding" or "bandwagon effects" and therefore "irrational bubbles." The size and duration of such bubbles depend on many particulars, including how active the Big Players are. The greater their activity and influence, the stronger the bandwagon effects. We develop this argument by using Ronald Heiner's model of choice among routines.

If you are buying and selling assets on financial markets, you must respond to signals. Some say "buy" and some say "sell." All of these signals are more or less unreliable. Your job is to decide which to respond to and which to ignore. Heiner's "reliability condition" (1983) suggests a criterion. You respond to those signals for which the expected value of responding is positive. In Heiner's notation,

$$r/w > (l/g) * [(1-\pi)/\pi] \tag{1}$$

where

$r =$ the probability of getting a true signal to act (buy or sell as the case may be),
$w =$ the probability of getting a false signal to act,
$l =$ the loss from acting when you should not,
$g =$ the gain from acting when you should, and
$\pi =$ the relative frequency or *ex ante* probability of there being a favorable occasion to act.

(Heiner merely restates the condition that expected gain be positive: $r * g * \pi - w * l * (1 - \pi) > 0$.)

Discretionary interventions of a Big Player, threatening to override the fundamentals, weaken the reliability of the old signals about wise buy and sell decisions. In Heiner's notation, $r/w$ falls below $(l/g) * [(1 - \pi)/\pi]$ for many of the signals.

So far, we have not shown that herd behavior results. We have only argued that discretionary intervention dilutes the influence of fundamentals on trading. But why should *more* trading occur on the basis of herd behavior? Koppl and Yeager provide an answer.

Following Scharfstein and Stein (1990), we must look a little more closely at what the people actually making buy and sell decisions stand to gain and lose. Many of the real decisionmakers are managers trading with other people's money. Accordingly, an important part of the gains and losses from good and bad trades is the effect on one's reputation as a hired hand. Reputation typically hinges on relative performance. If most banks are failing, including yours, you are not considered a bad banker, just the unlucky victim of an industry crisis. On the other hand, if you defy prevailing wisdom and lose, your reputation is shot and you must look for a new line of work. This is the sharing-the-blame effect (Scharfstein and Stein 1990:466). When you go along with the common wisdom and things work out, your wisdom is proved. When you go along with the common wisdom and things go bad, you can share the blame with everyone else. Your relative performance is still pretty good. The really dangerous thing is to defy common wisdom.

The share-the-blame effect can lead to herding (Scharfstein and Stein 1990). If the penalty for a bad idiosyncratic decision is high compared with the penalty for the same bad decision made along with everyone else, then one has an incentive to ignore buy and sell signals *except* those that indicate what other traders are doing. If signals about the fundamentals are "reliable" in Heiner's sense, however, then they provide a powerful counterweight to this incentive, namely, the large gains to be expected from making good idiosyncratic decisions with some regularity. But when most of the signals about fundamentals have been rendered unreliable by a Big Player's discretionary interventions, this counterweight no longer exists. The prospective gain from idiosyncratic decisions then becomes too small to discourage herd behavior. Herd behavior is encouraged by discretionary interventions because of the role of reputation in the market for the labor of portfolio managers.

If herding begins, movement in an asset's price conveys information about how other traders are acting, information that will lead traders to amplify the movement. If the price of a stock should start to rise, then some traders will buy it on this sign of bullishness by other traders. The further price rise now strengthens the common wisdom that the stock is on its way up. And so on. The less reliable signals about the fundamentals are, the longer such self-reinforcing movements can go unchecked. The stronger the actual or conjectured influence of Big Players, the more frequent and persistent such bubbles are likely to be.

The bubbles created by herding will increase the persistence of asset prices.[6] Hurst's card experiment, described in Section II, provides a metaphor for the bubbles created by herding in asset markets. In this metaphor, the Big Player may play the role of joker, but so to may other factors including extraneous, chance events. Something causes an asset's price to rise. Herding transforms this price hike into an upward trend. Though the asset's price is going up and down, movements up tend to be larger and more frequent. The trend has no internal tendency to weaken and will thus continue indefinitely. Finally, some chance event such as a rumor about the plans of the Big Player will, like the drawing of the joker, remove the bias and a new trend in the same or the opposite direction will kick in. Note that the length of time a bubble may be expected to continue does not depend on how old the bubble is, so it is hard to know when to jump off the bandwagon. Since the autocorrelations die off slowly, the trend is your friend even on rather long views. If the market's tendency toward herding is strong enough, even traders who prefer to analyze the fundamentals have good reason to ride the bandwagon.

The joker in this story need not always be the Big Player. While some specific action of his may cause a change in the trend of asset price movements, other events too can play this role. The Big Player creates an atmosphere in which it is sensible to follow trends and dangerous to buck them. This will create herding and aperiodic cycles. Some changes in trend will be directly attributable to actions (or inactions) of the Big Player, others will not.

This story about how asset markets work in the presence of Big Players bears some similarity to Keynes's description of the stock market. In our story, as with Keynes, waves of optimism and pessimism "which are unreasoning and yet in a sense legitimate" (1936:154) create fluctuations of price unrelated to changes in the fundamentals. In our story too, such movements are possible only because of the market participants' necessary ignorance of the future. But there is an important difference. The extent of the market participants' ignorance of the future is a function of Big Player influence. Keynes thought of market pathologies as necessary features of modern financial markets as such and did not imagine that discretionary interventions could influence the degree of herding. Our view is somewhat different. While it seems unlikely that herding should ever disappear completely, we expect more of it when Big Players exert their influence and less of it when they are absent.

## 3. Big Players in Slovenia

### *3.1. Slovenian Monetary Policy*

Slovenia gained its independence from Yugoslavia in 1991. Slovenia's war of independence cost her five lives and lasted ten days. In the necessary confusion after independence, Slovenia acted quickly to establish a modern central bank to regulate the new nation's fiat currency. (See Minniti and Polutnik (1999) for an interesting account of how Slovenia launched its new national currency.) In the first few years of its operation, the bank abstained from strong interventions in money and credit markets. By 1994, however, the bank felt that an unexpectedly great influx of foreign-exchange balances had pushed the domestic money supply dangerously high. The bank decided for action in the form of a substantial issue of notes. The bank exchanged these notes for money. Their issue, therefore, reduced the domestic money supply. These central-bank notes may be compared to the Treasury bills traded by the Federal Open Market Committee in the US.

In 1994, Bank of Slovenia issued high yield bank notes with warrants. The warrants were an inflation protection. They gave the holder the right to buy more notes in the future.

The price at which one might exercise this right was a function of the inflation rate and the exchange rate. The Appendix describes these notes in greater detail. The purpose of this issue was to neutralize the effect of a foreign-exchange influx on the local money supply. High-yield, low-risk notes with warrants attracted the majority of security investors. They left the capital market and switched to the money market. Besides the important reduction of liquidity, there was an important decrease of securities prices on the capital market.

The actions of 1994 did more than depress securities prices. They sent a very important signal to participants in Slovenia's stock market. The message sent was that a Big Player had entered the market. By taking the unprecedented action it did, the Slovenian authorities showed their willingness to respond to ongoing events with acts based on discretion rather than pre-established rules. We believe the bank acted properly given the necessarily irregular and difficult circumstances of the emerging transition economy of a nation not yet three years old. Nevertheless, the actions constituted an increase in Big Player influence on the Ljubljana stock exchange. Thus, they should have had the effects implied by the Big Player theory. That is, the data should show an increase of herding and thus and increase in "persistent dependence" after 1994. As we document presently, this is precisely what happened.

At the introduction of the Slovenian tolar (SIT) on the 8th October 1991, the newly estabilished Bank of Slovenia, the nation's central bank, had no foreign currency reserves, while total foreign currency reserves of Slovenia were a negligible 170.1 million USD.[7] Since October 8, 1991, Slovenia experienced a massive capital inflow, mainly due to extremely high interest rates. Real, inflation-adjusted rates on short term credits sometimes exceeded 40%. Real rates on deposits of 365 days or more reached 11.5%. The highest rates were recorded in 1992 and 1993.[8] This period also saw a considerable repatriation of capital.[9] These large capital flows greatly influenced Slovenia's current account. The Bank of Slovenia had to sterilize the foreign currency inflows to stabilize the Slovenian tolar. As a consequence, by January 1, 1994 the foreign exchange reserves of the Bank of Slovenia had increased to 770.1 million USD and the total reserves of Slovenia to 1,569.6 million USD.[10] In spite of these attempts at sterilization, net inflow was still increasing in 1994. The Bank of Slovenia was bound to react with a more vigorous sterilization policy. The main sterilization instruments were Bank of Slovenia Notes with Warrants.

Draško Veselinovič, CEO of Ljubljana Stock Exchange, Inc. carried out unstructured interviews with the main actors on Ljubljana Stock Exchange (listed companies, brokers, investment fund managers and others) concerning their views on the appropriateness of the Bank of Slovenia sterilization policy. He combined their views with his own views and wrote an unpublished manuscript (1994). Reading this rather long manuscript it is clear, that the views of the author and main actors at Ljubljana Stock Exchange did not differ—the Bank of Slovenia had entered the market as a Big Player and would stay for quite a while. Veselinovič's report makes it clear that most traders believed that the offerings of Notes with Warrants by the Bank of Slovenia had a strong depressive effect on the stock market. At the time of the big issues of Bank of Slovenia Notes in 1994 it was also believed that the Bank of Slovenia had emerged as an active, significant, and long-term player on Slovenian capital markets. It had become a Big Player.

Veselinovič's report clearly expresses the belief that the Bank of Slovenia would stay involved with events over the long run. The reports notes that "sterilization as such is controversial on a scientific-theoretical level and must be short-term oriented (Slovenia's will be more than obviously long-term) with the intent of gaining time" (p. 3). The report notes further that "A problem of Slovenian 'sterilization' is also that it will be difficult to end it, because at expiration of one issue of financial innovations [Notes with Warrants], another issue will have to be offered—new ones. The total value of offerings is scary" (p. 12).

Veselinovič's report shows that market participants did not think it possible to predict the size and the timing of the future issues. It says that "the size of issue was not set in advance . . . according to latest data already 38 (bil. SIT)—numbers have changed so many times that it is difficult even to follow them"(p. 5).

The expected big impact of Bank of Slovenia Notes on the short term rate of return on financial investments is well described by the impact on the business sector. "Producing goods, a company would earn less than had it invested its equity capital in attractive 'speculative' and at the same time safe short-term instruments of our central bank. This has been understood by a number of companies who—conditionally speaking—had temporarily suspended their basic activity" (p. 4).

The report describes the market's perception of the amount of money invested in securities of the Bank of Slovenia. "And, that all financial savings (i.e. demand) in Slovenia, which have been previously seeking returns in long-term securities (governmental, communal, and corporate, bonds and those few shares listed at the stock exchange), had almost entirely flown to the famous central bank innovations and totally crashed stock-exchange trading, probably does not need to be emphasized" (p. 6).

It can be empirically demonstrated in at least three ways that the effect of trading Bank of Slovenia with notes and warrants was significant enough to have caused a major instability of the capital market in general. The first approach is to compare the volume of trading with notes and warrants to all long-term securities (common stock, preferred stock, and bonds). The second approach may is to calculate the return to early investors. The notes themselves conveyed a high return, but adding the additional return from warrants boosted returns to unprecedented heights. The third approach compares the market capitalization of Ljubljana Stock Exchange to the capitalization of notes and warrants.

### *3.2. Trade Volume of Notes and Warrants and for Long-Term Instrument*

Warrants, and, separately, notes of the Bank of Slovenia were first traded on the 21st of July 1994, 51 days after the first notes were sold together with warrants. The notes issued up to June 23rd were issued with 5 warrants. Those issued from June 24th to July 21st were issued with 4 warrants. According to internal data provided by the Bank of Slovenia, 2,188 Notes amounting to a nominal value of 1,094,000,000 SIT were sold together with 5 Warrants, and an additional 4,244 Notes amounting to a nominal value of 2,122,000,000 SIT were sold together with 4 Warrants (Internal data of Bank of Slovenia). Therefore, the total nominal value of notes outstanding before the trading began, was 3.216 billion SIT. A total of 27,910 warrants were issued. Before the appearance of these short-term securities on

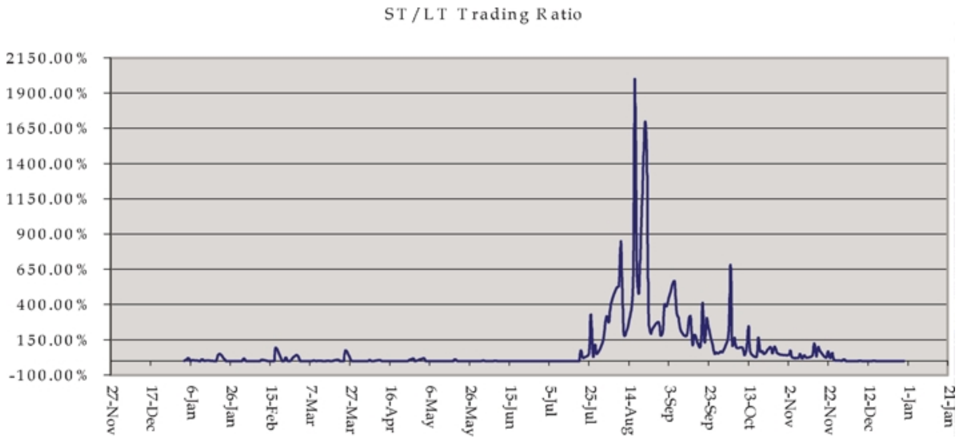


*Figure 1.* The total value of short-term instruments traded over the total value of long-term instruments traded, expressed as a percent. Source: Data tapes from Ljubljana Stock Exchange, 1994.

the stock exchange, there were only a few issues of short-term paper traded. The volume of long-term equity and debt traded was low. The situation changed drastically after the Notes and Warrants were introduced on the stock exchange. The ratio of short-term to long-term trading is depicted in Figure 1.

Figure 1 shows that the value of short-term instruments traded never exceeded the value of long-term instruments traded before July 21, 1994. Indeed, the ratio was often zero or close to zero. The ratio then jumped dramatically. It reached its peak August 17th. On that day, the value of short-term instruments traded reached 1,998.87% the value of long-term instruments traded. A ratio close to zero was not reestablished until December.

The impact can also be seeen by comparing average turnover of long-term securities before the 21st of July and afterwards, and the same with average daily turnover of short-term instruments. In the 139 trading days from the January 1, 1994 to July 20, 1994, the average daily turnover with long term securities was 370,944,355 SIT, while with short-term instruments it was only 11,513,272 SIT. From July 21st to December 31st, average trading volume with long-term instruments fell to 257,211,597, a decline of 31% from the average of the previous 139 trading days. Average daily trading with short-term securities, almost exclusively Notes and Warrants, soared by 1,807% to reach 219,551,154 SIT.

### 3.3. *An Example of a Total Holding Period Return*

A trader who bought Bank of Slovenia Notes and Warrants could have enjoyed an annual equivalent yield of 386%. In devising the following example we have used both internal data from the Bank of Slovenia and data from the Ljubljana Stock Exchange. Suppose an investor bought a Note on the 1st of June 1994, when the Bank of Slovenia first issued these securities. The note could be bought at a discount. The Note brought a nominal annual interest rate of 17%. The Bank of Slovenia, however, shows figures that provide an interest rate of 19.44% and we will use this value to calculate the return. An investor buying a note at discount together with the 5 warrants attached to it would have paid 457,384 SIT.

Suppose the investor decided to sell the Note and the Warrant on the first day of trading with these securities. Therefore, she held the initial investment of 457,384 SIT for 51 days. The price quoted on the stock exchange was 27,000 SIT for a single Warrant and the note was quoted at a minimum of 87.1% of nominal value up to 88.4% on the 21st of July. We use the more conservative (i.e. lower) price. Therefore an investor realized the following return:

$$r = \frac{435{,}500 + 5 \times 27{,}000 - 457{,}384}{457{,}384} = 24.731\%. \tag{2}$$

Our hypothetical investor would have earned almost 25% in only 51 days! Assuming 51-day compounding, which is a rather conservative assumption, the annualized return would be:

$$EAR = (1 + 0.24731)^{\frac{365}{51}} - 1 = 386.3\% \text{ p.a.} \tag{3}$$

This annualized return came with very little risk. The average Slovenian investor probably viewed the Bank of Slovenia Notes as riskless.

### *3.4. Long-Term Market Capitalization Compared vs. Size of Notes*

The total market capitalization of Ljubljana Stock Exchange at the end of 1994 was around 75 billion SIT. According to the data available from the Bank of Slovenia, the last new issue of Notes with Warrants was sold on 23rd of September 1994. At that time, a total of 66,233 Notes had been issued together with a total of 200,698 Warrants.[11] Notes were priced on the exchange at 93.65% of nominal value, and a single Warrant (a coupon) was trading at around 35,000 SIT. Total market capitalization of both Notes and Warrant was therefore around 38 billion SIT. That sum is just about half of market capitalization of all shares of stock and bonds three months later[12] and represented more than a half of primary money and about a third of M1 (Bulletin of Bank of Slovenia 1998:21). For the small capital market this undoubtedly represents an enormous shock.

## 4. Rescaled-Range Analysis

The central bank of Slovenia acted as a Big Player in 1994. Thus, there should have been more herding or follow-the-leader or "mimetic contagion" (Topol 1991) after the bank acted in 1994 than before. To test this conjecture statistically, we use R/S analysis to measure the "persistence," or "memory" in stock prices under the two regimes.

Today's most popular techniques of times-series analysis assume that the series under study has a "short memory." They assume, that is, that the autocorrelation between $X_t$ and $X_{t+k}$, $\rho(k)$, declines rapidly as $k$ goes to infinity. The decline in the covariance is rapid when

$$|\rho(k)| \leq Cr^{-k}, \tag{4}$$

where $C$ is positive and $r$ is between zero and 1 (Brockwell and Davis 1991:520). When this condition fails, the series is characterized by "memory," "persistence," "persistent dependence" or, as Mandelbrot and Wallis put it, the Joseph Effect (Genesis 41:29). The presence of persistence is consistent with both short-term autocorrelation and its absence. We do not assume any particular functional form for $\rho(k)$.

Rescaled-range analysis tests for persistence assuming the series is "stationary" in the sense that the expected value of any function of $\{X_t\}$ is the same for $\{X_{t-k}\}$. Let us consider such a series $\{X_t\}$ for which we have a sample of size T. The cumulative sum of the series, $X^*(t)$, is just the sum of the values up to $t$:

$$X^*(t) = \sum_{u=1}^{t} X(u) \tag{5}$$

where $t \geq 1$. For $t = 0$ we define $X^*(t) = 0$. For any interval of length $s$ beginning at $t$, the range of the interval is

$$\begin{aligned} R(t,s) = &\max_{0 \leq u \leq s} \{X^*(t+u) - X^*(t) - (u/s)[X^*(t+s) - X^*(t)]\} \\ &- \min_{0 \leq u \leq s} \{X^*(t+u) - X^*(t) - (u/s)[X^*(t+s) - X^*(t)]\} \end{aligned} \tag{6}$$

To rescale the range, divide through by the sample standard deviation, $S(t, s)$, of the original series $\{X_t\}$, where

$$S(t,s) = \surd S^2(t,s). \tag{7}$$

and

$$\begin{aligned} S^2(t,s) &= s^{-1} \sum_{u=1}^{s} \{X(t+u) - s^{-1}[X^*(t+s) - X^*(t)]\}^2 \\ &= \left[ s^{-1} \sum_{u=1}^{s} X^2(t+u) \right] - \left[ s^{-1} \sum_{u=1}^{s} X(t+u) \right]^2. \end{aligned} \tag{8}$$

The rescaled range, $R/S$, is just the ratio $R(t,s)/S(t,s)$. The expected value of the rescaled range is independent of t because the series $\{X_t\}$ is stationary. It is not, however, independent of $s$. The rescaled range tends to grow with the length of the sample. Its asymptotic rate of growth, moreover, is a measure of the degree of persistent dependence.

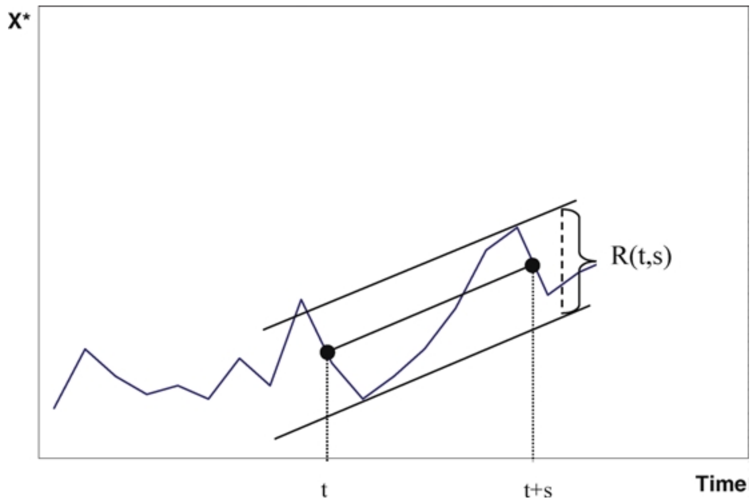


*Figure 2.* A graph illustrating $R/S$ analysis.

Mandelbrot and Wallis (1969a, 1969b, 1970) report that $R/S$ is asymptotically proportional to a fractional power of interval length. That is,

$$R(t, s)/S(t, s) \sim Cs^h \tag{9}$$

where $C > 0$ and $0 < h < 1$. The Hurst coefficient, $h$, is a measure of persistence. If $h = 0.5$, there is no persistence. If $h > 0.5$ there is positive persistence and if $h < 0.5$, there is negative persistence.

Figure 2 illustrates the $R/S$ analysis. The range, $R(t, s)$, of an interval is the vertical distance between two straight lines tangent to the cumulative series and parallel to the straight line connecting $X^*(t)$ and $X^*(t + s)$. The range just measures how much the cumulative series deviates from trend over an interval. (The trend is calculated by connecting the end points of the interval.) Rescaling adjusts this figure to correct for the size of the variance of the original series over the interval.

The Hurst coefficient, h, measures the rate at which the rescaled range of the cumulative series grows with interval length. If the original series is white noise, this growth rate is 0.5. Even if there is autocorrelation, the asymptotic rate of growth is still 0.5 as long as the correlellogram dies off "quickly." If there is positive persistence, then deviations from trend tend to persist. In this case, the rate at which the rescaled range grows with interval length will exceed the rate given by chance: $h > 0.5$. Similarly, if there is negative persistence, then deviations from trend tend to be reversed more promptly than the rate chance alone would have produced. In this case the rescaled range of the cumulative series will grow more slowly than the rate given by chance: $h < 0.5$.

If an asset's price is subject to bubbles because of herding occasioned by Big Players, then there should by positive persistence in the time series of its returns. The measured value of the Hurst coefficient should exceed 0.5. The greater the influence of Big Players, the larger the Hurst coefficient will be, *ceteris paribus*. Big Players are not the only reason for herding, and thus persistence, to exist. But their presence should increase the degree of persistence.

As we have seen, Wallis and Matalas report that

$$R(t, s)/S(t, s) \sim Cs^h. \tag{9}$$

Taking the natural logarithm of each side of this equation gives us

$$\ln(R/S) = \ln(C) + h\ln(s). \tag{10}$$

The coefficients of this equation can be estimated by ordinary least squares regression if the value of $R/S$ is calculated for at least two intervals of different length. The more intervals for which the value of R/S is known, the more precise the coefficient estimates will be. But trying to use too many intervals can impose high costs of calculation. Thus, there is a tradeoff in deciding how to pick intervals.

Wallis and Matalas recommend an “F Hurst” and a “G Hurst” technique for picking intervals. They found that, for the computer-generated series they used in their simulation study, other procedures “led to larger biases and variances than F Hurst and G Hurst” (Wallis and Matalas 1970:1590).

F Hurst uses all possible intervals except those of length five and below. As Wallis and Matalas note, for big data sets “an enormous amount of computation is involved” (1970:1586). G Hurst selects a large, but not prohibitively large, set of intervals ranging in length from 10 to 1,000 (or the length on one’s data set if it is less than 1,000). Our data sets were small enough to permit the use of F hurst.

Using F hurst, we computed the hurst coefficients for an index of stocks traded on the Ljubljana exchange and for two stocks, Dadas and SKB banka. We calculated the Hurst coefficient for the period before the central bank issued its neutralizing notes and again for the period just after the notes were issued. Our results are reported in Table 1. In each case the Hurst coefficient rose. This is the result predicted by the Big Players theory.

*Table 1.* The results of a rescaled-range analysis for two stocks and an index of stocks traded on the Ljubjlana stock exchange.

| | Dadas | SKB | Stock index |
|---|---|---|---|
| Before note issue | 0.650 | 0.374 | 0.529 |
| | (0.0087) | (0.0149) | (0.0115) |
| After note issue | 0.769 | 0.677 | 0.734 |
| | (0.0083) | (0.0062) | (0.0080) |

The numbers reported are Hurst coefficients. The numbers in parentheses are standard errors. In each case the degree of “persistent dependence” increased after the issue of central-bank notes. This is evidence that the note issue produced herding.

## 5. Conclusion

In this paper, we have subjected the Big Players theory to a possibly falsifying test. The theory passed. The theory has passed similar tests with other data sets and with other techniques. We encourage other researchers to find more test cases.

We can look at our results from quite another angle, however. Let us grant that the theory is basically right. Our investigations into the Slovenian stock market, together with other studies, show that Big Player effects are significant enough to be measurable. It seems reasonable, then, to consider the policy implications of Big Player effects. In the old debate on "rules vs. discretion," the advocates of rules were right to contrast rules with discretion. They may also have been right to prefer the former in most cases. Transition economies such as Slovenia present special problems. In the case at hand, the Bank of Slovenia probably improved matters in spite of its role as Big Player. But governments should apply caution. Any benefits of Big Player activism must be balanced against the costs of increased herding and increased uncertainty in financial markets. We should recall Adam Smith's warning against "system." In striving to influence events, governments must recognize that "in the great chess-board of human society, every single piece has a principle of motion of its own, altogether different from that which the legislature might choose to impress upon it" (1976:381).

## Appendix

Bank of Slovenia notes with warrants are short-term (6 month), bearers' securities with a nominal value of 500.000 SIT each. They are sold with a discount to the face value when issued. Each note brings five detachable warrants. The five warrants provide entitlement to a discount when buying specific short-term notes of Bank of Slovenia. The discount brought by warrants is an additional discount over the discount price at which the note itself is sold. Warrants can be exercised at any time in the 12 months after they were issued. The two common groups of notes that the bearer of a coupon can buy (with discount) are Notes of the Bank of Slovenia denominated in tolars (6 month) and Notes of the Bank of Slovenia denominated in Deutschmarks (180, 270, or 360 days). Discounts that the warrants bring are calculated each month for the current month. This could imply that warrants provide only short-term hedge against inflation. The Protection is therefore not cumulative.

The computation of the discount differs according to the type of notes bought. The discount for notes denominated in tolars is calculated as

$$\textit{discount percentage} = \textit{CPI in previous month} - \textit{anticipated monthly inflation (a constant)}$$

and the discount for notes denominated in Deutschmarks as

$$\begin{aligned}\textit{discount percentage} &= \textit{anticipated monthly inflation (a constant)}\\ &\quad - \textit{percentage SIT/DEM E.R. growth in previous month}.\end{aligned}$$

Discount percentages are rounded to one decimal point. Therefore, the higher the growth of inflation in the past month, the higher the discount percentage received from exercising a warrant. When buying the foreign-currency denominated notes, the calculation of discount is a means of ensuring that the exchange rate follows inflation. It is often the case that the exchange rate does not follow inflation. If, for example, the exchange rate fell (appreciation of tolar) then the discount percentage would rise, providing the bearer with additional hedge against inflation.

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## Notes

1. Following Lo (1991), some researchers have concluded that the evidence for persistence in asset prices is weak. We are less skeptical. Our view is based in part upon our preference for the "classical Hurst" test for persistence. The classical Hurst has been criticized by Lo (1991). We prefer it to Lo's technique, however, for the reasons given in Ahmed et al. (1997:30–31). Mandelbrot (1997) continues to defend the assumption of "global dependence," i.e., persistent dependence. It is widely accepted that persistent dependence exists in the volatility of asset prices. See, e.g., Parke (1999).
2. Koppl (2002) places the theory of Big Players in the context of a larger theory of expectations. This theory, in turn, is set in the context the work of Ludwig von Mises, Alfred Schutz, F.A. Hayek, and Fritz Machlup. Koppl identifies himself as an "Austrian" economist; Mramor does not.
3. One referee has questioned our claim that our analysis constitutes a "possibly falsifying test." Our use of the word "falsifying" did suggest that such a test could be definitive. We did not wish to give that impression. This mistaken idea of definitive falsification seems to have been the target of his or her objection. Philosophers of science and economic methodologists have generally abandoned falsificationism. (See, e.g., Hands, 1993.) We believe, however, that empirical testing remains a vital part of the scientific process. Facts matter even if they are hard to interpret.
4. Some of the theoretical and methodological issues surrounding Big Players are discussed in Butos and Koppl (1993), Koppl and Langlois (1994), and Koppl (1996, 1998). Koppl (2002) is meant to give a relatively complete statement of the theory and its methodological foundations; it also discusses some, but not all of the case studies mentioned in the introduction.
5. We presume the acts of the Big Player are not a part of the fundamentals. If one prefers to count them among the fundamentals, the substance of the argument is not changed. We would merely be obliged to say things such as "Big Players distract attention from *other* fundamentals." The implications for ignorance, uncertainty, and herding are unchanged.
6. Our prediction is that persistence is increased. A price series may exhibit persistent dependence without the influence of a Big Player. Introducing a Big Player, however, will strengthen such dependence, raising the Hurst coefficient (explained in Section V).
7. Bulletin of Bank of Slovenia (January 1995:42).
8. Bulletin of Bank of Slovenia (June–July 1994:28).
9. Foreign-currency deposited by households and companies abroad and foreign-currency held by households at their homes.
10. *ibid.*
11. We have considered that at different dates a different number of notes were issued.
12. According to the data from Securities Market Agency of Slovenia, after 23rd of September 1994 (and up to 31st Dec.) 4 more companies were quoted, but 7 bonds have been removed from the stock market listing. (Source: Poročevalec št 36, 1994)

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