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# Anomalies
# The Law of One Price in Financial Markets

Owen A. Lamont and Richard H. Thaler

Economics can be distinguished from other social sciences by the belief that most (all?) behavior can be explained by assuming that rational agents with stable, well-defined preferences interact in markets that (eventually) clear. An empirical result qualifies as an anomaly if it is difficult to rationalize or if implausible assumptions are necessary to explain it within the paradigm. Suggestions for future topics should be sent to Richard Thaler, c/o *Journal of Economic Perspectives,* Graduate School of Business, University of Chicago, Chicago, IL 60637, or ⟨richard.thaler@gsb.uchicago.edu⟩.

## Introduction

It is good for a scientific enterprise, as well as for a society, to have well-established laws. Physics has excellent laws, such as the law of gravity. What does economics have? The first law of economics is clearly the law of supply and demand, and a fine law it is. We would nominate as the second law "the law of one price," hereafter simply the Law. The Law states that identical goods must have identical prices. For example, an ounce of gold should have the same price (expressed in U.S. dollars) in London as it does in Zurich, otherwise gold would flow from one city to the other. Economic theory teaches us to expect the Law to hold exactly in competitive markets with no transactions costs and no barriers to trade, but in practice, details about market institutions are important in determining whether violations of the Law can occur.

■ *Owen A. Lamont is Visiting Professor of Finance at Yale School of Management, New Haven, Connecticut. Richard H. Thaler is Robert P. Gwinn Professor of Behavioral Science and Economics, Graduate School of Business, University of Chicago, Chicago, Illinois.*

Consider the case of aspirin. Suppose, for the sake of argument, that Bayer aspirin and store brand aspirin are identical products, but that Bayer costs twice as much because some consumers believe (falsely, in this example) that Bayer is better. Would we expect markets to eradicate this price difference? Since the Bayer brand name is trademarked, it is not (legally) possible to go into the business of buying the store brand aspirin and repackaging it in Bayer bottles. This inability to transform the store brand into Bayer prevents one method arbitrageurs might use to drive the two prices to equality. Another possibility for arbitrageurs would be to try to sell the more expensive Bayer aspirin short today, betting that the price discrepancy will narrow once the buyers of Bayer "come to their senses." Short selling works like this: an arbitrageur would borrow some bottles from a cooperative owner, sell the bottles today and promise the owner to replace the borrowed bottles with equivalent Bayer bottles in the future. Notice that two problems impede this strategy. First, there is no practical way to sell a consumer product short, and second, there is no way to predict when consumers will see the error in their ways. These problems create limits to the forces of arbitrage, and in most consumer goods markets, the Law may be violated quite dramatically.[1]

The aspirin example illustrates the essential ingredients to violations of the law of one price. First, some agents have to believe falsely that there are real differences between two identical goods, and second, there have to be some impediments to prevent rational arbitrageurs from restoring the equality of prices that rationality predicts. Can these conditions hold in financial markets, where transactions costs are small, short selling is permitted and competition is fierce?

Traditionally, economists thought that the Law could be applied almost exactly in financial markets because of the workings of arbitrage. Arbitrage, defined as the simultaneous buying and selling of the same security for two different prices, is perhaps the most crucial concept of modern finance. The absence of arbitrage opportunities is the basis of almost all modern financial theory, including option pricing and corporate capital structure. In capital markets, the Law says that identical securities (that is, securities with identical state-specific payoffs) must have identical prices; otherwise, smart investors could make unlimited profits by buying the cheap one and selling the expensive one. It does not require that all investors be rational or sophisticated, only that enough investors (dollar weighted) are able to recognize arbitrage opportunities. According to the standard assumptions, the Law should hold in financial markets because if some investors mistakenly think that odd-numbered shares of some stock are better than even-numbered shares, rational arbitrageurs will prevent these investors from driving up the price of odd-numbered shares (unlike the aspirin market discussed above). Moreover, unlike international trade where it may take some time to move gold physically from London to Zurich, one would expect the Law to hold not only in the long run, but almost instantaneously, since one can quickly buy and sell securities.

[1] See Russell and Thaler (1985) for a discussion of when markets eliminate the effects of irrationality.

Unlike government-enforced laws prohibiting litter on the sidewalk, the Law does not require hired law enforcement agents any more than one need enforce a law prohibiting the littering of $100 bills. Rather, the Law is enforced by arbitrageurs as a byproduct of following their selfish profit motives, that is, picking up the $100 bills. In this sense, the law of one price, while not quite as automatic as the law of gravity, seems like a law that should never be broken in a well-functioning capital market. For this reason, theorists have used it as an uncontroversial minimal condition, a starting point that leads to other implications. Upon the Law, they have built the mighty edifice of modern financial theory, including the Modigliani-Miller capital structure propositions, the Black-Scholes option pricing formula and the arbitrage pricing theory. But it turns out that the application of the Law in financial markets is not as uncontroversial as was originally thought. Over the past decade or so, numerous violations have been detected. We survey some of the more interesting ones here and then consider the implications for how we should think about financial markets.

## Closed-End Country Funds

Closed-end funds are a special sort of mutual fund that are interesting from the perspective of the law of one price. Traditional mutual funds stand ready to buy and sell shares to investors at the underlying value of the assets they own (the net asset value, or NAV). In contrast, closed-end funds issue shares in the fund that trade in markets. (See the Anomalies article on this topic by Lee, Shleifer and Thaler, 1990, for details.) The relationship between closed-end fund prices and net asset values can vary across funds and across times with both discounts and premia of greater than 30 percent commonly observed.

While closed-end fund discounts and premiums appear to be a violation of the law of one price, they might not be considered pure examples, since the two assets (the underlying securities owned by the fund and the fund itself) are not precisely identical. One difference is that the portfolio manager of the fund charges a fee for his services and incurs other expenses, and thus the cash flows going to the holders of the fund are different from the cash flows going to the holders of the underlying assets. This could, in principle, justify moderate discounts. Even premia could be rational if the closed-end fund manager had superior stock picking ability, though in practice, there is little relation between discounts/premia and future asset returns. Nevertheless, these rational justifications for discounts and premia can at best justify small deviations between price of the fund's shares and the value of the assets the fund owns.

The late 1980s saw a proliferation of a special type of closed-end fund called country funds, which trade on U.S. exchanges, but hold equities in a specific foreign country (Klibanoff, Lamont and Wizman, 1998). These country funds often had much larger deviations between price and value than those observed in the domestic funds, and the deviations were much too large to be consistent with any

rational story. An extreme example is the Taiwan Fund trading on the New York Stock Exchange. During early 1987 (shortly after its start), it had a 205 percent premium, meaning that the price was more than three times the asset value (the premium stayed above 100 percent for ten weeks and above 50 percent for 30 weeks). This mispricing can persist due to legal barriers preventing U.S. investors from freely buying Taiwanese stocks. Still, the question remains why U.S. investors were willing to pay a dollar to buy less than 33 cents worth of assets.

Another extreme example is the behavior of the Germany Fund when the Berlin Wall fell in late 1989. At the beginning of 1989, the Germany Fund had a small discount of about 9 percent. As political developments in 1989 made the fall of the Communist regime and the eventual reunification of Germany more likely, German stocks went up. The value of the Germany Fund, traded on the New York Stock Exchange, went up even more, and by September 1989, the fund had a premium instead of a discount. By January 1990, the premium was 100 percent. After that, the euphoria in the United States wore off, the price of Germany Fund shares fell and the premium returned to about zero in April 1990. This example is even more of a puzzle since U.S. investors were free to invest directly in Germany. (A similar "bubble" occurred in the Spain Fund at about the same time.) One explanation, which we discuss further below, is short-sale constraints. Some evidence indicates it was difficult for arbitrageurs to short the Germany and Spain Funds.

## American Depositary Receipts: Coming to America

Another situation involving international equity markets is the pricing of American Depositary Receipts, or ADRs. ADRs are shares of specific foreign securities held in trust by U.S. financial institutions. Claims to these shares trade in U.S. markets, such as the New York Stock Exchange, and are created to make it easier for U.S. investors to own shares in foreign companies. Like closed-end funds, ADRs can have prices different from the value of the underlying assets, although in most cases, they do not have significant deviations, since arbitrage is possible. For example, if an ADR were selling at a premium to the underlying security, a financial intermediary could buy shares of the original stock in the home market and create new ADRs, making an instant profit.

Occasionally, however, price discrepancies do exist in this market. A particularly remarkable example is Infosys, an Indian information technologies company trading in Bombay, and the first Indian company to list on an American exchange (Nasdaq). As of March 7, 2000, Infosys had experienced a huge increase in value, and its ADR was trading at $335, up from $17, the (split-adjusted) price at which it had been introduced to the U.S. market just a year earlier. However, as with the Germany Fund in 1989, the enthusiasm of American investors appeared to be much greater than that of local investors. The ADR was trading at a 136 percent premium to the Bombay shares.

In this case, official barriers prevented Americans from buying the shares trading in Bombay, and so there was no way for American arbitrageurs to create new ADRs and thus instantly profit from this relative valuation. While it certainly appears that American investors were acting irrationally in buying Infosys, this is hard to prove. In segmented markets, it can be rational for the same asset to have different prices in different markets, reflecting differences in supply and demand. In the case of Infosys, the interpretation would be that American investors value Infosys because its returns are uncorrelated with other assets held by Americans, so Infosys offers valuable diversification. Indian investors, on the other hand, correctly place a lower value on Infosys since it confers no diversification benefit to them. It is dubious, however, that such an argument can ever justify as large a discrepancy as was seen here. And since the deviation has now (summer 2003) fallen to 41 percent, or about a third of what it was at the peak, one would also have to argue that the hedging premium is highly volatile.

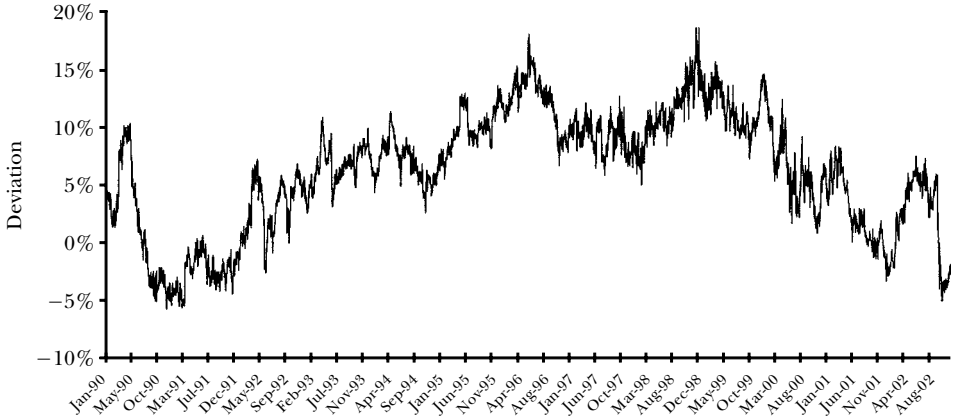
## Twin Shares: Can the Stock Market Multiply by 1.5?

A third situation from international equity markets is Siamese Twins. Siamese Twins, as discussed in Rosenthal and Young (1990) and Froot and Dabora (1999), are firms that for historical reasons have two types of shares with fixed claims on the cash flows and assets of the firm. An example is Royal Dutch/Shell, which has both Royal Dutch shares (traded in Amsterdam) and Shell (traded in London). There is only one firm, the Royal Dutch/Shell Group, but based on the 1907 merger agreement, all cash flows are split so that Royal Dutch shares receive 60 percent and Shell shares receive 40 percent. Given this setup, the ratio of the market value of the Royal Dutch to the market value of Shell should be 1.5. However, this ratio has varied considerably from its theoretical value, from 30 percent too low in 1981 to more than 15 percent too high in 1996. After trading at a premium of greater than 10 percent for most the decade of the 1990s, Royal Dutch shares are now trading at roughly par with the Shell shares (see Figure 1).

The substantial deviations that have been observed are somewhat surprising since both Royal Dutch and Shell trade in highly liquid and open markets in Europe and, additionally, have ADRs trading in the United States. Thus, to profit from the mispricing, a U.S. investor doesn't even need to trade in international markets. All that is necessary is to short the overpriced shares, buy the underpriced shares and hold forever. Still, forever is a long time, and, in the near term, the price disparity can widen, producing losses to this strategy. (More on this below.)

Even if there are not enough arbitrageurs taking the strategy of buying the cheap version and shorting the dear one, there is an even simpler strategy that one might think would be enough to keep the prices lined up. Why don't investors simply buy whichever version of the stock is cheaper? Why, during the 1990s, when Royal Dutch was selling for a premium over Shell, did U.S. mutual funds own billions of dollars of Royal Dutch? One partial answer to this question is that Royal

*Figure 1*
**Pricing of Royal Dutch Relative to Shell**
(*deviation from parity*)



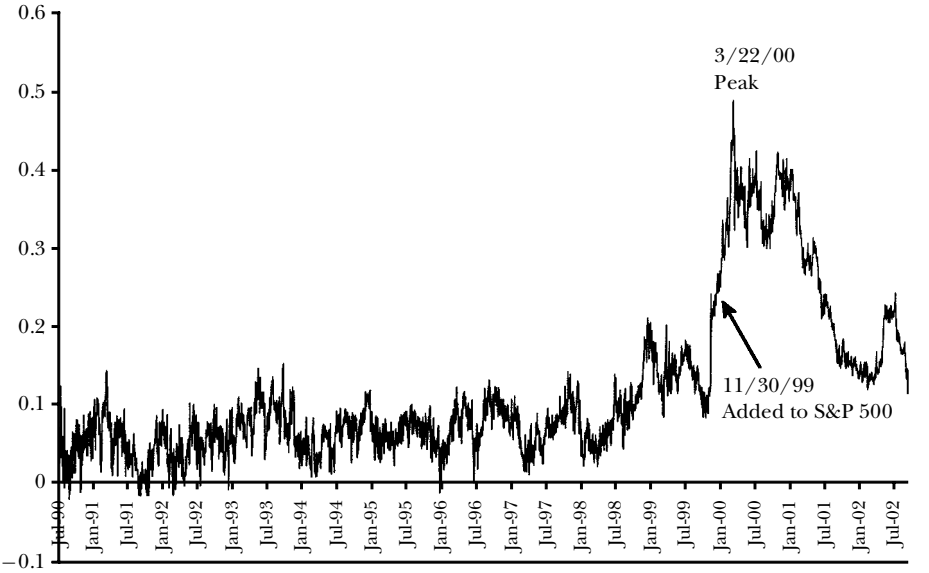

Dutch was, until recently, a member of the S&P 500 index. This fact meant that index funds tracking the S&P 500 index were forced to buy the more expensive version of the stock, and even active large cap U.S. mutual fund managers whose performance was compared to the S&P 500 index might be inclined to own Royal Dutch rather than is cheaper identical twin. One bit of evidence for this factor being important is that on July 10, 2002, S&P announced it was dropping all foreign stocks, including Royal Dutch, from the index. The premium had been 6 percent the previous day, but fell to 1 percent on the announcement. Although the premium had been fluctuating around zero in the previous year, the fact that it dropped sharply on the announcement adds support to the index inclusion hypothesis.[2] Still, whatever the reason, this example is a blatant violation of the Law, and one that is surprising since there are no impediments to short selling or other restrictions on the actions of arbitrageurs.

## Dual Share Classes

Another way in which companies can sometimes have two different types of shares of stock in their company is when they have two classes of stock with different voting rights. Usually these two classes trade at about the same price, except at times when there is some battle for corporate control, in which case voting stock is more

[2] It is a well-known puzzle that when the S&P 500 adds a stock to its index, the price of this stock jumps. This is a puzzle because S&P does not claim that the addition has information content; additions usually occur because other stocks have been dropped (often because of mergers), and stocks are selected mostly on the basis of size and industry. See Shleifer (1986), who argues that the effect shows that the demand curve for stocks is downward sloping.

*Figure 2*
**Premium of Molex common over Molex Class A, 1990–2002**




valuable. An example with evidence of Law violations is the case of Molex, a manufacturing company. Molex has two classes of stock with claims to identical dividends and cash flows, but different voting rights. In August 1999, the voting stock was trading at a 15 percent premium. At the time, 15 percent was seen as inexplicably high (the premium had tended to range between zero to ten percent in previous years), and a Molex official said, "I can see no rational reason for such a big discrepancy" (Rublin, 1999). Then in November 1999, S&P announced it was adding Molex to the S&P 500 index. S&P chose to include the common stock (with voting rights), but not the class A nonvoting shares in the index. On the announcement, the premium rose from 12 percent to 24 percent and subsequently rose as high as 49 percent in March 2000 (see Figure 2). Whatever the value of the voting rights in Molex, it is hard to see why these rights would become more valuable because the firm was included in the S&P 500.[3]

## Corporate Spinoffs: Can the Stock Market Multiply by 1.5? (Part II)

A situation where the relationship between the price of two stocks is bounded by some common ratio can arise in the case of a corporate spinoff. One example occurred in 1999 when a Silicon Valley technology company called 3Com felt that

[3] In an even more bizarre Law violation involving voting rights in May 2001, McData had shares with superior voting rights trading at a 22 percent discount.

the stock market was not giving their shares proper respect, in spite of the fact that 3Com owned the Palm division, maker of the hot new handheld computers. 3Com decided to spin off its Palm division, presumably to "unleash" its true value. Notice that this action in and of itself is suspicious from a Law abiding perspective—if the same cash flows always have the same price, why should bundling or unbundling securities change value?

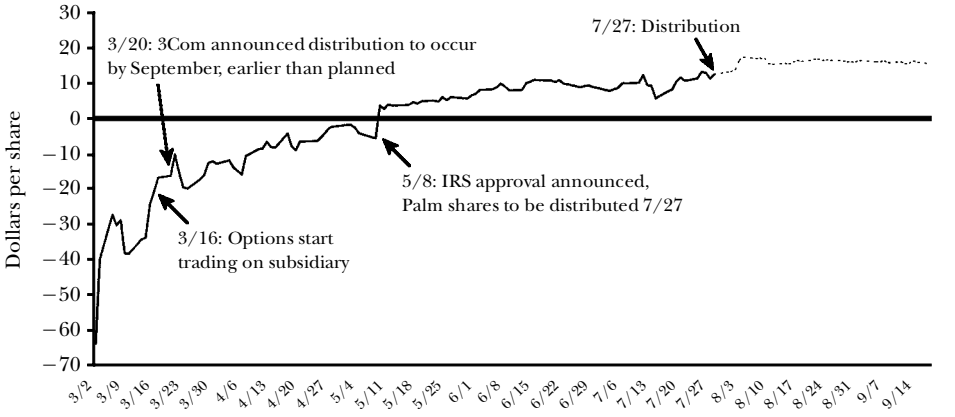
To initiate this divorce, 3Com adopted a two-step process. The first step was an "equity carve-out," in which 3Com sold a small portion of the value of Palm in an initial public offering (IPO). Specifically, 4 percent of the shares of Palm were sold in the IPO and another 1 percent was sold to a consortium of institutional investors. The second step, called the "spinoff," would take place in about six months. At this point, the remaining 95 percent of the shares would be distributed to 3Com shareholders. When the spinoff took place, each 3Com shareholder would receive 1.5 shares of Palm. In this case, the Law requires that investors obey an inequality, namely, that once Palm shares start trading, shares of 3Com must sell for at a price equal or greater than 1.5 times the price of Palm.

On the day before the IPO, 3Com was selling for $104. The Palm shares were sold to the public at $38 a share, but ended the day selling for $95 (after trading as high as $165!). During this same day, the stock price of 3Com actually *fell* 21 percent during the day to $82. To see how ludicrous this price is, consider the so-called "stub value" of 3Com, which is the implied value of 3Com's non-Palm assets and businesses. To compute the stub value, one just has to multiply the Palm share price by 1.5 to get $145 and then subtract this from the value of 3Com, obtaining the novel result of a negative $63 per share (using the precise ratio of 1.525). Indeed, the market was valuing the remaining (profitable) 3Com business at minus $22 billion. To add insult to injury, 3Com had about $10 a share in cash! Investors were willing to pay over $2.5 billion dollars (based on the number of Palm shares issued) to buy expensive shares of Palm rather than buy the cheap Palm shares embedded in 3Com and get 3Com thrown in.

This example is even more puzzling than that of closed-end funds or twin stocks, because there is a clear termination date. To profit from the mispricing, an arbitrageur would need only to buy one share of 3Com, short 1.5 shares of Palm and wait six months or so. In essence, the arbitrageur would be buying a security worth at worst worth zero for −$63 and would not need to wait very long to realize the profits. The spinoff did depend on a favorable IRS ruling, but this appeared highly likely. Figure 3 shows the actual time pattern of the stub value of 3Com, that is, its non-Palm assets. As can be seen, the stub returned to a more rational level after several months.

This mispricing was not in an obscure corner of capital markets, but rather took place in a widely publicized initial public offering that attracted frenzied attention. The nature of the mispricing was so simple that even the dimmest of market participants was able to grasp it. On the day after the issue, the mispricing was widely discussed, including in two articles in the *Wall Street Journal*, one in the *New York Times*, and it even made *USAToday*!

*Figure 3*
**3Com/Palm Stub, 3/2/00–9/18/00**




Why would anyone ever buy one share of Palm for $95 instead of buying one share of 3Com (embedding 1.5 shares of Palm) for $82? One superficially appealing explanation for the mispricing is when only a small portion of the subsidiary firm is sold in an equity carve-out, the demand for these shares outstrips supply. Once 3Com sells the remaining 95 percent of Palm, this argument goes, supply of Palm stock will rise and thus the price will fall. While this argument must be true at some level, it is inconsistent with market efficiency, with rationality and with the Law.

What prevented arbitrageurs from enforcing the Law in this case? The primary problem was the inability of investors to sell Palm short. To be able to sell short a stock, one must borrow it, and this borrowing is typically done through financial institutions, such as mutual funds, trusts or asset managers who lend their securities. In the case of Palm, retail investors rather than institutions held most of the shares, thus making Palm hard to borrow. At one point, 148 percent of the floating shares had been borrowed.[4]

The Palm/3Com episode is not unique. Lamont and Thaler (2003) provide other examples during the 1998–2000 stock market bubble. These mispricings often involved technology and Internet stocks, with the more exciting Internet stock being overpriced and the more traditional stock underpriced. A somewhat older example comes from the 1920s. In 1923, a young man named Benjamin Graham, later to coauthor a classic book on security analysis, was managing money. Graham noticed that although Du Pont owned a substantial number of GM shares,

[4] A relation in finance called put-call parity is another application of the Law, and it says one should not be able to construct a security using options that has the same payoff as Palm but a different price. Lamont and Thaler (2003) look at options prices on Palm. While this is not the place to provide details, we found massive violations of put-call parity due to the difficulty of shorting Palm. Given time, the shorting market can continue to expand the shares available to sell, but this process is far from instantaneous.

Du Pont's market capitalization was about the same as the value of its stake in GM. Du Pont had a stub value of about zero, despite the fact that Du Pont was one of America's leading industrial firms with other hugely valuable assets. Graham bought Du Pont, shorted GM and profited when Du Pont subsequently rose (Lowe, 1994).

As the Benjamin Graham episode shows, despite enormous changes in capital markets and information technology, it is not clear that financial markets have gotten more Law abiding since 1923. The tech stock mania period of 1998–2000 supplies many of the examples discussed here. In this period, companies large and small appeared to be flagrantly mispriced, where "mispriced" has a clear and provable meaning. The weight of the evidence is overwhelming. Beyond a reasonable doubt, U.S. equity markets are violating the Law.

## Long-Term Capital in a Short-Term World

What prevents arbitrageurs from enforcing the Law? In the case of Palm and 3Com, short-sale constraints limited the amount of money that could be made and the amount of price pressure arbitrageurs could bring to bear. In some of the examples of closed-end country funds, limits on foreign investments prevented some kinds of attractive trades. But these cases are special. For many of the examples we have discussed, markets were free and open, and selling short was not particularly costly. So, why aren't the arbs doing their job? The answer is that violations of the Law do not generally create arbitrage opportunities (meaning sure profits with no risk), they just create good but risky bets.

The risks to arbitrageurs are particularly large in situations without a specified terminal date. One risk is that after taking a position, the valuation disparity widens, causing the net wealth of the arbitrageurs to fall. De Long, Shleifer, Summers and Waldmann (1990) dub this risk "noise trader risk." The idea is whatever the irrational opinion was that caused noise traders to get excited (or depressed) about some security and create a mispricing, it could get worse before it gets better! In extreme cases, this widening spread can cause the arbitrageur to approach bankruptcy, as his net worth becomes negative and he no longer has the collateral to hold his positions. A prominent example is Long-Term Capital Management (LTCM), which had several "convergence trades" in place during the summer of 1998. These are bets that mispricings would narrow. Most of LTCM's bets involved mispriced bonds and derivative securities, but LTCM had equity positions as well, including some of the examples discussed here. For example, LTCM had a $2.3 billion pairs trade on Royal Dutch/Shell (Spiro and Laderman, 1998). When spreads widened in 1998, diverging instead of converging, LTCM entered financial distress. LTCM attempted to raise new money, but found no takers, despite the fact that the convergence strategy had presumably become *more* attractive as the value disparity increased. LTCM was forced to enter into an agreement with its creditors, leading to an eventual liquidation of its positions. This scenario had been

anticipated one year earlier by Shleifer and Vishny (1997) in their article on limits to arbitrage. They discussed the possibility that arbitrage opportunities may fail to be eliminated, and mispricings may widen, if arbitrageurs are driven out of business (or experience withdrawals by scared investors) by adverse market movements (see also Edwards, 1999).

## Commentary

The law of one price is the basic building block of most of financial economic theorizing. The logic of why it should hold is simple: if the same asset is selling for two different prices simultaneously, then arbitrageurs will step in, correct the situation and make themselves a tidy profit at the same time. The concept is so basic that Steve Ross (1987) has written that "to make a parrot into a learned financial economist, he only needs to learn the single word 'arbitrage.'" As the examples we have discussed illustrate, it may be necessary to teach the parrot at least a few new words: "limits" and "risk" immediately come to mind and, for the very talented parrot, perhaps "short-sale constraints."

Cynical financial economists, and parrots with only one-word vocabularies, may complain that we have merely picked out a series of peculiar examples. Surely, they would claim, the Law holds for the vast majority of securities. For example, most ADRs are not mispriced relative to the underlying security because arbitrage is mechanically possible. While this claim is correct (true riskless arbitrage opportunities are both rare and fleeting), it is not clear how useful it is. The reason is that for most securities that the market needs to price, there are not good substitutes. There are no close substitutes for GE or for the whole stock market, so arbitrage cannot be relied upon to set their prices correctly.

What can we learn from these special cases about the big picture question: are asset markets sending the "right" signals? What economists should really care about is whether financial markets are sending approximately correct signals to market participants in order to direct capital to its most productive uses. Our view is that these special cases are interesting because they should be situations in which it is particularly easy for the market to get things right. To price Royal Dutch correctly versus Shell requires investors merely to multiply by 1.5. The same is true for Palm and 3Com. If the market is flunking these no-brainers, what else is it getting wrong?

During the Nasdaq bubble of the late 1990s, approximately $7 trillion of wealth was created and then destroyed. Was this a rational process of forecasting the future cash flows of new technology or an investing frenzy based on mob psychology? No one knows the answer to this question, but the fact that some investors were willing to pay more to have one share of Palm than 1.5 imbedded shares of Palm tells us that the frenzy hypothesis is not altogether implausible.

■ *The authors thank Ken Froot for supplying some of the data used to make Figure 1.*

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