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Forecasting and uncertainty in the economic and business world

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Abstract

Forecasts are crucial for practically all economic and business decisions. However, there is a mounting body of empirical evidence showing that accurate forecasting in the economic and business world is usually not possible. In addition, there is huge uncertainty, as practically all economic and business activities are subject to events we are unable to predict. The fact that forecasts can be inaccurate creates a serious dilemma for decision and policy makers. On the one hand, accepting the limits of forecasting accuracy implies being unable to assess the correctness of decisions and the surrounding uncertainty. On the other hand, believing that accurate forecasts are possible means succumbing to the illusion of control and experiencing surprises, often with negative consequences. We believe that the time has come for a new attitude towards dealing with the future. In this article, we discuss the limited predictability in the economic and business environment. We also provide a framework that allows decision and policy makers to face the future — despite the inherent limitations of forecasting and the uncertainty, sometimes huge, surrounding most future-oriented decisions.

Keywords: Forecasting; Accuracy; Uncertainty; Subway uncertainty; Coconut uncertainty; Black swans; Illusion of control; Dealing with uncertainty

1. Introduction

In the 1970s and 1980s, social scientists hoped that computers and sophisticated mathematical models would allow them to emulate the forecasting successes of the hard sciences (see Orrell & McSharry, 2009). Their hopes have proven groundless. Instead, a huge body of empirical evidence has led to the following conclusions.

- The future is never exactly like the past. This means that the extrapolation of past patterns or relationships cannot provide accurate predictions.
- Statistically sophisticated, or complex, models fit past data well but do not necessarily predict the future accurately.

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- "Simple" models do not necessarily fit past data well but predict the future better than complex or sophisticated statistical models.
- Both statistical models and human judgment have been unable to capture the full extent of future uncertainty. People who have relied on these methods have been surprised by large forecasting errors and events they did not consider.
- Expert judgment is typically inferior to simple statistical models.
- Forecasts made by experts are no more accurate than those of knowledgeable individuals.
- Averaging the predictions of several individuals usually improves forecasting accuracy.
- Averaging the forecasts of two or more models improves accuracy while also reducing the variance of forecasting errors.

These conclusions raise important issues for almost all economic and business decisions requiring forecasting. How can managers and policy makers plan, make decisions, and formulate strategies in a complex world characterized by limited predictability, high levels of uncertainty, and future outcomes that they cannot even conceive? These issues are the topic of this paper, which is organized as follows. We first provide several prominent examples of our lack of success in predicting the future. We then discuss an earthquake and storm/hurricane analogy for business and economic activity. These examples and analogies are used to make a distinction between two types of uncertainty that we label "subway" and "coconut" uncertainty, respectively, while asserting that most events in the economic and business world combine elements of both. "Subway" uncertainty refers to what we can model and reasonably incorporate in probabilistic predictions that assume, for example, normally distributed forecasting errors. "Coconut" uncertainty pertains to events that cannot be modeled, and also to rare and unique events that are simply hard to envision.

If we want to be realistic, we must first understand and accept what we can and cannot predict. For example, we know that at some time in the future there will almost certainly be a major earthquake or a Category 5 hurricane somewhere in the world, just as yet another bubble will burst in the financial markets. However, we are unable to predict accurately when and where these events might occur. At the same time, we will continue to face rare and unique events that are completely unexpected, and even outside the realm of our imaginations — what Taleb (2007) has imaginatively labeled "Black Swans". However, we can still make meaningful statements about classes of feasible sets of events in particular domains (such as earthquakes and hurricanes). While not providing precise, accurate forecasts, this activity can have considerable value for planning and strategy. We conclude with suggestions about how to assess levels of future uncertainty realistically, and, in consequence, how to plan in the world of economics and business.

2. The anatomy and unpredictability of a crisis

It all started as a major Wall Street financial innovation. Instead of holding the mortgages they were issuing and assuming the credit risk, banks started selling them to investors by creating Mortgage Backed Securities (MBS) and Collateralized Debt Obligations (CDO), insured through Credit Default Swaps (CDS). The major consequence was that the credit risk, rather than staying with the banks, was passed on to investors, who believed that their securities were of the highest quality (AAA), because they were insured. Through this process, banks relaxed their lending standards in order to attract more customers, thus creating subprime mortgages. Customers, on the other hand, were willing to assume strenuous mortgage payments in the belief that house prices would continue to go up, thus increasing their equity and creating a substantial profit on sale of the property.

The innovation was working well, as house prices were increasing at a fast pace and interest rates remained low. However, towards the end of 2006 interest rates began to rise and house prices began to decline, while, at about the same time, the initial easy terms for repaying the loans were expiring. Bank regulators and executives generally agreed that a potential problem was developing and that there would be losses. However, their prediction was that such losses would be easily absorbed, as they would be widely dispersed and thus have a limited overall impact on the financial markets and the economy. The financial system, they believed, had been made more resilient by deregulation, technological innovation and the globalization of capital flows.

Reality proved otherwise. The innovative "subprime" products turned "toxic". Defaults and foreclosures started to accelerate and eventually triggered a global financial crisis that has pushed the world economy into a major recession, the worst since the 1930s depression. During the week of October 6 to 10, 2008, the Dow Jones Industrial Average (DJIA) share index fell by close to 20%, leaving its value 40% down on that of the same date a year earlier. The banks and financial institutions, the architects of the subprime crisis, found themselves with huge losses and an unprecedented liquidity squeeze. Lehman Brothers went bankrupt, while Bear Stearns and Wachovia, among others, were forced into selling themselves to other banks. The stocks of Wall Street titans plummeted. Morgan Stanley's share price, for example, fell to a low of $6.81 on Friday October 10, 2008, from a high of $88.50 less than a year and a half earlier.

On Friday, October 10, the DJIA had one of the biggest one-day drops in its history (679 points), while bank shares went into free fall. The situation obliged the governments of all major countries to commit trillions of US dollars to avert the collapse of the financial system and pledge the buying of more than a trillion US dollars' worth of bank stocks in the USA and Western Europe in order to boost confidence in the banking system. This was in addition to the $700 billion committed in the USA to buy toxic mortgage loans and the $100 billion-plus paid to avert AIG's bankruptcy. Worse, it is still not clear that these measures will work.

How well did we predict the financial crisis and its consequences? As late as March 16, 2008, Henry Paulson, the US Secretary of the Treasury, made the following statement:

"I have great, great confidence in our capital markets and in our financial institutions. Our financial institutions, banks and investment banks, are strong. Our capital markets are resilient. They're efficient. They're flexible."

Similarly, on July 15, 2008, President Bush stated:

"Our economy has continued growing, consumers are spending, businesses are investing, exports continue increasing and American productivity remains strong. We can have confidence in the long-term foundation of our economy... I think the system basically is sound. I truly do."

Yet, less than three months later, on September 23, 2008, Paulson said:

"The market turmoil we are experiencing today poses great risk to US taxpayers. When the financial system doesn't work as it should, Americans' personal savings, and the ability of consumers and businesses to finance spending, investment and job creation are threatened."

A day later President Bush echoed Paulson by saying, *"our entire economy is in danger"*, when urging Congress to pass the $700 billion bailout.

Perhaps politicians are not good forecasters, but what about the IMF and all the other agencies that specialize in forecasting? They have not done any better. The following are a few quotes from the IMF:

- April 2007: Notwithstanding the recent bout of financial volatility, the world economy still looks well set for continued robust growth in 2007 and 2008. While the US economy has slowed more than was expected earlier, spillovers have been limited, growth around the world looks well sustained, and inflation risks have moderated.
- October 2007: The problems in credit markets have been severe, and while the first phase is now over, we are still waiting to see exactly how the consequences will play out. Still, the situation at present is one with threats rather than actual major negative outcomes on macroeconomic aggregates. At this point, we expect global growth to slow in 2008, but remain at a buoyant pace.
- April, 2008: Global growth is projected to slow to 3.7% in 2008, $\frac{1}{2}$% point lower than at the time of the January World Economic Outlook Update and $1\frac{1}{4}$% points lower than the growth recorded in 2007. Moreover, growth is projected to remain broadly unchanged in 2009. The divergence in growth performance between the advanced and emerging economies is expected to continue, with growth in the advanced economies generally expected to fall well below potential. The US economy will tip into a mild recession in 2008 as the result of mutually reinforcing cycles in the housing and financial markets, before starting a modest recovery in 2009 as balance sheet problems in financial institutions are slowly resolved.
- October, 2008: The world economy is entering a major downturn in the face of the most dangerous

financial shock in mature financial markets since the 1930s. Global growth is projected to slow substantially in 2008, and a modest recovery would only begin later in 2009. [...] The immediate policy challenge is to stabilize financial conditions, while nursing economies through a period of slow activity and keeping inflation under control.

Business experts did not fair better either. *Business Week,* in its annual survey of business forecasters, summarized their predictions as follows:

"The economists project, on average, that the economy will grow 2.1% from the fourth quarter of 2007 to the end of 2008, vs. 2.6% in 2007. Only two of the forecasters (of a total of 34) *expect a recession"* (Business Week, Dec. 20, 2007)

It does not seem that the seriousness of the financial crisis, or the resulting economic recession, was predicted by the great majority of forecasters. The consequences, so far, have been big surprises, huge losses, many bankruptcies and several trillions of dollars of taxpayers' money being spent in an attempt to fix the problem. But is it any easier to make accurate predictions in other areas of the economy and business?

3. The accuracy of past forecasts

This section considers a number of areas in the economic and business environment, demonstrates the colossal errors made by forecasters in the past, and discusses the implications of these errors.

3.1. Forecasting the US economy and stock market

Influenced by the stagflation prevailing in the latter part of the 1980s, several books (e.g., Batra, 1988; Davidson, 1994) predicted a serious economic downturn or even depression for the 1990s. The following is a quote from one of these books.

"I am an economist, trained in scientific analysis, not a sensationalist or a Jeremiah. Yet all the evidence indicates that another great depression is now in the making, and unless we take immediate action the price we will have to pay in the 1990s is catastrophic." (Batra, 1988, p. 17)

Yet the 1990s experienced one of the biggest booms in world history. For instance, the DJIA grew from 2,753 at the beginning of the 1990s to 11,358 at the end, a 313% increase.

Towards the end of 1990s the climate had changed to one of jubilation, with books predicting that the DJIA would reach 36,000 (Glassman & Hassett, 1999), 40,000 (Elias, 1999) or even 100,000 (Kadlec, 1999). As one book said:

"A sensible target date for Dow 36,000 is early 2005, but it could be reached much earlier. After that, stocks will continue to rise, but at a slower pace. This means that stocks, right now, are an extraordinary investment. They are just as safe as bonds over long periods of time, and the returns are significantly higher." (Glassman & Hassett, 1999, p. 140)

On March 9, 2009, four years after early 2005, not only had the DJIA still not reached 36,000, but it had fallen to 6,547 — well below its value in 1999 when the *Dow 36,000* book was published. Will the Dow ever reach 36,000? Perhaps, given enough time, but certainly nobody can predict when.

3.2. Industry forecasts

In 1968, C. Jay Parkinson, the then president of Anaconda, a major producer of copper, said, *"This company will still be going strong 100 and even 500 years from now"*. But in less than a decade, the vast superiority of fiber optics made copper wire virtually obsolete. Demand for the metal collapsed, most copper companies went bankrupt, and employment in the industry fell by 70%. To save itself from liquidation, Anaconda, once the fourth largest company in the world, was sold to ARCO in 1977. But prices continued to fall, and ARCO was obliged to cease all its copper-mining activities in 1983, including those of Anaconda. Parkinson had underestimated the incredible power of the market to drive prices down. And it was this power that wrought revenge on the few companies that, since the 1930s, had formed a copper cartel and controlled the market, setting prices to increase their profits steadily for over 35 years. Clearly, Parkinson was unable to predict the demise of the copper industry and with it his own

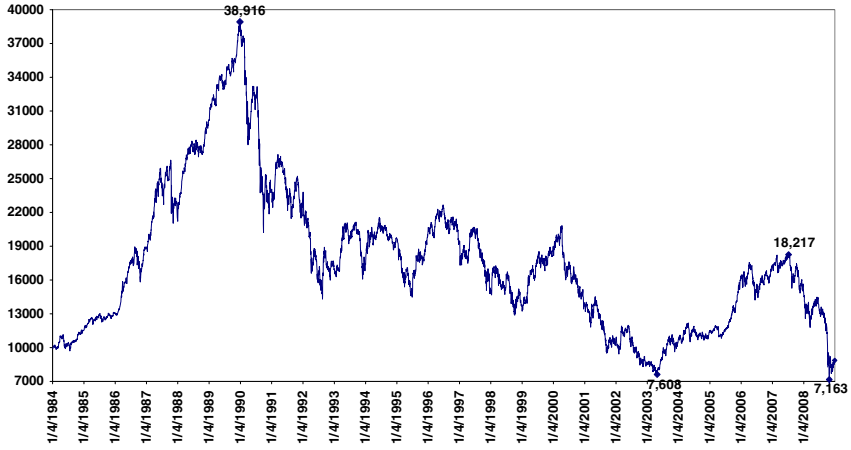

Fig. 1. The Nikkei 225 Index: 1984–2008.

company, which ceased to exist less than 10 years after his 1968 prediction.

3.3. The Japanese miracle

In the 1980s, Japan witnessed unprecedented economic growth, as its companies improved their productivity and the quality of their products, thus achieving huge competitive advantages and outpacing the rest of the world. In the process, they became the envy of the world and contributed to vast trade surpluses for their country. The Nikkei 225 stock index grew from around 6,500 at the beginning of the 1980s to almost 39,000 at the end of the decade, a six-fold increase. The Japanese threat was an important issue in the minds of Western business leaders, who were desperate to understand and imitate their productivity and quality achievements. Needless to say, there were many books and plenty of consultants offering advice on how to emulate Japan's business practices and compete with its high-flying firms. At that time, *nobody* considered that the Japanese miracle would end abruptly and that Japan would enter a prolonged slump starting at the beginning of 1990 and lasting for more than 22 years. Fig. 1 shows the values of the Nikkei 225. This records the Japanese miracle and its unexpected destruction, as it fell from 38,916 on the last day of 1989 to 7,608 on April 28, 2003, a huge 80.5% decline. It then increased to 18,217 on July 10, 2007, but fell to 7,163 on October 27, 2008, the same level as in 1982.

3.4. The stock market's blackest days

On October 19, 1987, known as Black Monday, the DJIA fell by 22.6% and increased its cumulative losses for the last four trading days to 33.4%, a third of its total value. Worse, *nobody* predicted a fall so huge, and so it entailed considerable financial hardship and even triggered suicides and killings (Makridakis, 1990). Nor did anyone ever provide any reasonable explanation after the fact. There have been several similarly black days in the history of the stock market. On October 12 and 13, 1929, known as Black Monday and Tuesday, the DJIA fell 12.8% and 11.7% respectively, wiping out close to a quarter of its value in just two days. Yet only one month earlier, there was euphoria about the market and the incredible wealth it was generating. Similarly, on September 29, 2008, the Dow had its biggest point drop of 777.7, while 10 days later on October 13, 2008, it experienced its biggest one-day gain of 936.4 points.

3.5. The best managed firm

On April 11, 2008, GE's market capitalization was reduced by a staggering $47 billion in a single day as its share price dropped 12.8% — the second worst decline in its history. In December 2007, Jeffrey Immelt, GE's CEO and Chairman of the Board, had assured shareholders that, despite the worsening economic climate, earnings would increase

10% during 2008, and, in a press conference in mid-March, gave no indication of any problems. Yet, on April 10, the updated growth forecast for 2008 was cut to 5%, while the actual first-quarter results were below expectations. But the decline in GE's share price did not end there. Its second- and third-quarter earnings fell further, and 2008 growth was not +10% but an estimated –10%. Immelt moved to shore up GE's cash. On October 1, he raised $12 billion from selling common stock, and an additional $3 billion by selling preferred shares to Buffett Berkshire Hathaway Inc. (six days earlier, he had told investors that no such move was needed, even as he lowered his 2008 profit target a second time). GE's share price declined to $6.66 on March 6, 2009 (the same price as on February 20, 1992), though it had been selling at $60 in October 2000. Even at GE, famous for its sound management practices, accurate forecasting was not possible, and its shareholders paid dearly for the consequences.

3.6. The merger of the century

In May 2007, Chrysler, the US auto manufacturer, was sold, or rather, given away, to Cerberus, a private equity firm. Daimler–Benz, the German car company, had bought Chrysler eight years earlier for $36 billion, to create one of the world's strongest automobile firms — expecting to greatly increase its profits. Yet none of the armies of corporate strategy specialists, nor the highly paid consultants, envisioned the sequence of events that led to huge losses on both sides of the Atlantic, and eventually forced the resignation of Erich Schrempp, CEO of Daimler–Benz and architect of the "merger of the century" (as it was called by the business press in 1998).

The above examples are but a small sample of disastrous errors that have been committed by forecasters pretending to hold crystal balls. Yet it is common sense that no such crystal balls can possibly exist, and that all forecasts should be accompanied by statements specifying their underlying assumptions. Most importantly, forecasters should emphasize the uncertainty surrounding their predictions. For instance, instead of *Dow 36,000*, a more appropriate title might have been *Dow 36,000 if established trends continue*, or even better, *Range of Dow in 2005: 6,000 to 36,000.* But perhaps with such titles the book would not have sold as many copies? On the other hand, incorrect forecasts can affect those who believe in them extremely adversely. What are the responsibilities of those who make such wildly inaccurate predictions?

4. Predicting earthquakes and storms/hurricanes

It is generally accepted in the scientific community that it is impossible to predict the timing and location of earthquakes (see, e.g., Buchanan, 2001). This belief has two bases in fact. One is the lamentable track record that scientists – and others – have had in predicting the location and timing of earthquakes. The second is our scientific knowledge about tectonic plates, and, in particular, the processes by which earthquakes are produced. And yet, as is illustrated in Fig. 2, there is a remarkable degree of consistency worldwide in the occurrence of earthquakes, in terms of intensity and frequency.

Despite this statistical regularity, we still do not know where or when this year's approximately 44 earthquakes between 7.5 and 7.599 on the Richter scale will occur. Will they be in populated or unpopulated zones, or, perhaps, under the sea? Will they result in large numbers of deaths? Will they create a tsunami? All we know is that the frequency of earthquakes follows an almost perfect pattern, and that they are more likely in some parts of the world than others (i.e., in regions with friction between large tectonic plates). As is also clear from Fig. 2, catastrophic earthquakes are less frequent than smaller ones. In addition, seismologists know that large earthquakes tend to be followed by many smaller aftershocks until the region settles into a new equilibrium. How then does the world handle the eventuality of earthquakes, and, in particular, strong ones?

The ability to cope with large earthquakes does not depend on prediction. Instead, the solution focuses on being prepared when they do occur. If you live in a poor part of the world, you just have to take your chances and suffer the consequences — as people have done for millennia (most recently and dramatically in China). If you live in a rich area like California, however, engineers can and do construct buildings capable of withstanding quite strong earthquakes, even though there is still the potential for disaster. The important conclusion is that the smart thing to do, resources permitting, is to make sure that strong earthquakes will

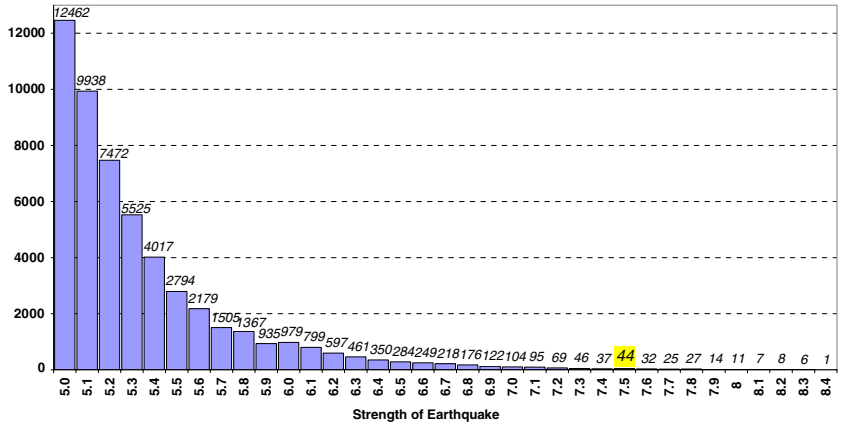

Fig. 2. Total number of earthquakes of various strengths: 1973–2007.

cause the minimum damage, as opposed to focusing your efforts on pinpointing forecasts.

Storms with wind speeds greater than 89 km an hour (10 on the Beaufort scale) strike more regularly and more widely than earthquakes. Hurricanes, with wind speeds that start at 118 km an hour and can exceed 250 km an hour in Category 5, are rarer than ordinary storms. Indeed, like earthquakes, the number of storms/hurricanes decreases exponentially the higher their wind force. However, unlike earthquakes, storms and hurricanes can be predicted a few days in advance — although there are often false alarms and mistakes concerning their exact paths. More importantly, once storms and hurricanes start developing they can be observed and followed closely using satellite photos and supercomputers that allow meteorologists to predict their approximate course and provide the areas likely to be affected with adequate warnings. Storms and hurricanes last much longer than earthquakes, and do not usually catch us by such utter surprise, but their winds can still cause devastation (in particular when they grow beyond Category 1), while occasionally they cause even more extensive damage than major earthquakes – witness the devastation of New Orleans by Katrina in 2005.

4.1. Earthquakes in business and economic activity

As an analogy with earthquakes, think first of the sheer number of small businesses or ventures that start or fail during the course of a year. It is estimated that there are some 40 million new businesses in the world each year, and about the same number of bankruptcies (Bosma, Acs, Autio, Coduras, & Levie, 2008). Although the actual figures vary from year to year, there is a continual process of many small businesses entering and leaving the market. Whereas some of the small businesses go on to be successful, many more just manage to survive or fail completely (see, e.g., Bernardo & Welch, 2001). However, the constant churning out of "births" and "deaths" is consistent year after year, and is reminiscent of the small tremors that occur under the earth all the time. In addition, just as there are earthquake-prone regions of the world, there are also certain countries with many more new and closing businesses.

At the other end of the scale, there are also large "economic earthquakes" that occur with destructive consequences. Consider the following, from recent years.

- The close bankruptcy of the entire Icelandic economy was followed by the collapse, and nationalization, of its three biggest banks.
- Lehman Brothers, one of the victims of the subprime crisis, went bankrupt and helped to cause serious disruption in the world financial system, which is still not entirely resolved several months later. Yet their website clearly stated: *"The effective management of risk is one of the core strengths that has made Lehman Brothers so successful. We rely on it to identify, measure and monitor the issues associated with doing business in the global capital markets"*.

- American International Group (AIG) was practically nationalized, narrowly avoiding bankruptcy, when the US government stepped in with a massive $100 billion bailout (its stock price fell to $1.44 on November 20, 2008, from more than $40 a year earlier).
- LTCM (Long Term Capital Management) had to be rescued some years ago by a consortium of financial organizations because of the fear that the entire Western financial system was endangered (Dunbar, 2000). The fund was run by a team of highly experienced practitioners and Nobel Prize winning academics, experts in managing risk.
- Enron, the company that had been lauded by the business gurus (see, e.g., Hamel, 2000, p. 212) as a perpetual innovator, ended up in a mammoth bankruptcy that caused its employees to lose their savings as well as their jobs.
- Amaranth Advisors, the hedge fund that used an anti-hedging strategy, lost close to $6 billion in a single week in 2006.
- WorldCom surpassed even Enron in the size of its losses.
- The Internet bubble of 2000–2003 resulted in stock market losses that exceeded $13 trillion worldwide (about $2000 for every person on the planet).
- As we mentioned earlier, the subprime and credit crisis that started in 2007 still continues today, having resulted in more than $30 trillion of stock market losses world wide.

The "financial earthquakes" listed above are clearly not the only ones. However, they share a common characteristic: none was predicted in advance, not even by the IMF or other national or international organizations specializing in economic forecasts. In addition, none of the credit agencies paid to warn investors about the health of firms provided the slightest warning before disaster struck. The occurrence of these financial disasters was as unpredictable as that of large earthquakes. For example, had anyone heard of "toxic mortgages" before 2008? Now that we know about this phenomenon, can anyone predict the next financial crash? The answer is clearly "no" — but rest assured, whether we call it the subprime crisis or the credit crunch, this will not be the last financial disaster.

4.2. Storms and hurricanes in economic and business activity

Most of the time the speed of the wind is not extreme. Storms and hurricanes are the exception, and, like financial crises, it is certain that they will be followed by calm. The issue is how to withstand them without deadly damage until the calm returns. Unlike earthquakes, whose duration is measured in seconds, storms and hurricanes can last several days, and their course and intensity can be predicted a few days in advance. However, is this useful? If one is on a boat, the answer is a definite "yes", assuming that a safe harbor can be found before the storm hits. But what about people on land? Clearly, they can stay home, cover their windows, and fasten down whatever can be blown away. There is not much more they can do, apart from waiting for the storm or hurricane to pass and then being prepared to deal with the damage. In some highly threatening cases people can be evacuated, but there are severe limits to such an action when the number of people involved is large. Moreover, there is always the chance of a false alarm, as was the case in August 2008 when 1.8 million people were evacuated from the coastal area of South Louisiana to avoid hurricane Gustav. Perhaps it is the same with financial and business crises? What can firms do to cope with the current credit crunch? They can possibly reduce their costs, adjust their production or service levels, increase their sales efforts and so forth, but whatever measures they take will be defensive in character, in the hope of staying in business until the crisis passes and financial calm returns. Even in this case, the value of forecasting is limited, as the available options are restricted and there is no way of knowing the depth and duration of the crisis or the industries that will be hit the hardest.

Despite our emphasis on disasters so far, it is important to point out that major future success is also hard to predict. One of the most notable recent examples is the rise of Google. At the end of the 1990s, the founders of Google tried to sell the company for $1.6 million (Battelle, 2005). Fortunately for them, they got no takers and went on to become multi-billionaires (their company was worth some $230 billion in mid-2008). Now, we are not claiming a scientific law based on a single observation. We are simply making the point that, in addition to our

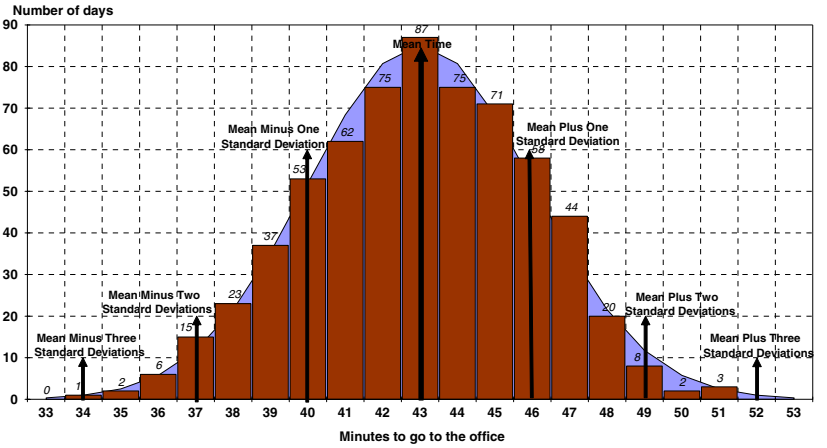

Fig. 3. Variations in travel times to go to the office.

inability to predict big failures, it is not obvious which successes will turn out to be large. To develop the earthquake analogy, this is the equivalent of *not* having a major earthquake in the Bay Area, even though a study released by the United States Geological Survey says that there is a 62% chance of an earthquake greater than 6.7 on the Richter scale occurring at some time during the next 30 years, and that this could strike at any time, including today. Luck, it seems, is of paramount importance, both in start-ups like Google and when catastrophic earthquakes do not occur.

4.3. Two types of uncertainty

Assuming that – as with the location and timing of earthquakes – we cannot predict certain classes of events in the economic and business world, not to mention the Black Swans identified by Taleb, should we just forget about prediction and suffer the consequences? Should we continue living on our fault line and ignore the possibility of earthquakes? In addition, can we ignore storms and hurricanes, even though we know they will occur but have little idea of when and how strong they will be? Even if we can predict them a few days in advance, the alternatives open to us are limited. In this paper, we suggest an approach that recognizes that there are two types of uncertainty in economic and business activity, and that, by acknowledging this fact, we can be better prepared to act.

Suppose you are a meticulous person and keep a record of how long it takes you to reach the office each morning. Over time, your record shows variations in travel times due to a variety of uncontrollable factors that seem to occur at random. For example, your wait at the metro station can vary between almost nothing and three and a half minutes. And on some days, the sidewalks are more crowded, which affects how quickly you walk. Indeed, when you make an empirical graph of your travel times, it resembles the well-known bell-shaped curve of the normal distribution shown in Fig. 3, where almost all observations lie within three standard deviations of the mean travel time, and some 95% lie within two standard deviations of the mean (the smooth curve in Fig. 3 represents the theoretical normal distribution, which fits the empirical one quite well).

This is what we call "subway uncertainty". To all intents and purposes, it successfully models the time taken to reach the office in the morning and the uncertainty of being earlier or later than the average of 43 min. Indeed, you can make probabilistic predictions of how long your journey will last — and, generally speaking, your predictions will be quite accurate. Now, the model does not come without some important assumptions; for example, that future days are drawn from the same distribution as was observed in the past. However, provided that there is no major change (e.g., works associated with a new metro line, a major snow storm, or a blackout), this is typically a safe assumption. If there is continuity between past and

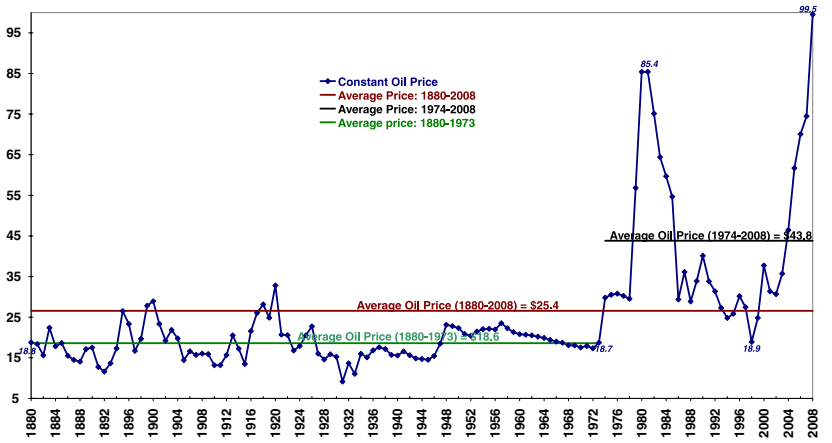

Fig. 4a. Yearly oil prices (per barrel) in constant 2008 dollars.

future, this model is useful, and the ability to quantify uncertainty is beneficial for a range of applications in the economic and business worlds.

Now let's complicate subway uncertainty with something totally unexpected. One day on your way to work, a block of ice slides off the roof of a tall building and hits you on the head. You are rushed to hospital, where you stay for nearly two weeks before being allowed home. Although the chances of this particular rare event occurring are very small (i.e., the ice falling at just the moment you were passing, your precise location on the sidewalk), rare events do happen. Indeed, it is an example of what we call "coconut" uncertainty – in honor of a fictional character who died when a coconut dropped on to his head as he was enjoying the shade of a palm tree in a tropical paradise (Makridakis, Hogarth, & Gaba, 2009). In our language, a "coconut" is the occurrence of a rare event with critical consequences.

The point about coconut uncertainty is that any particular instance – say the ice falling off the roof or the coconut hitting a person's head – is very rare and unexpected, and thus it is no surprise that you never even considered it. However, even though the particular event that affected you was highly unlikely, this does not mean that the *class* of rare events that one typically fails to consider is negligible. Indeed, the disjunction of the probabilities of these events can be significant (i.e., the probability that at least one "coconut" occurs). Indeed, some time ago Tversky and Kahneman (1974) demonstrated that people have a strong tendency to underestimate the probability of the disjunction of events, and that this can lead to serious errors in developing fail-safe systems (i.e., when only one element of a system failing can lead to a disaster). Psychologically, people are aware that rare events can occur and may even be able to imagine a few exemplars, but they are unable to go far enough to consider their impact and consequences. Coconuts are like earthquakes — although unlikely, they can strike at any point with destructive consequences.

Most real-life situations are a mixture of subway and coconut uncertainties. Let's explain with an example that affects us all: oil prices. Specifically, look at Fig. 4, which shows (a) a graph of yearly oil prices since 1880, (b) monthly data since 1946, and (c) daily data since 1986. Now consider the following two interrelated questions.

- First, what is the most appropriate forecast for the long term, for the next month and for each month next year, as well as, on a daily basis, for tomorrow and for the next couple of weeks?
- Second, what is the uncertainty in these forecasts?

For the 94 years between 1880 and 1973, oil prices (in constant 2008 US dollars) fluctuated around $18.6 a barrel (see Fig. 4a). Then the price shot up from $18.7 in 1973 to $85.4 in 1980, an increase of more than 450% (a negative coconut for oil-importing countries, but a positive one for the exporters). At the end of the 1970s and during the early 1980s, there were forecasts that the price of a barrel of oil would jump to the

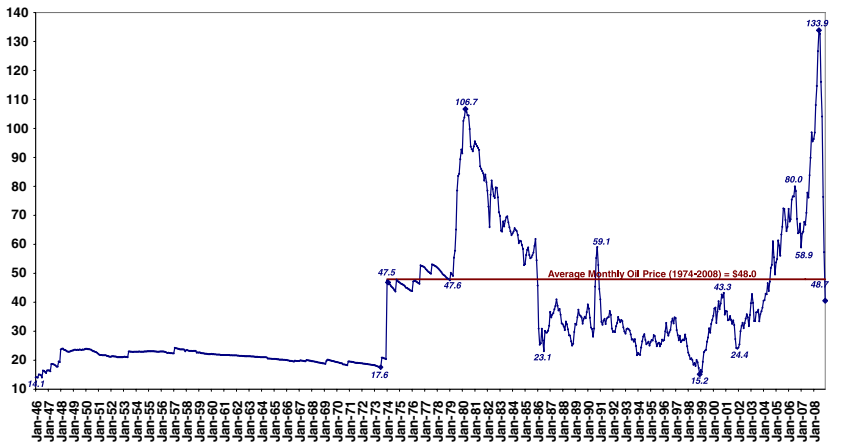

Fig. 4b. Monthly oil prices (in constant 2008 $): Jan. 1946–Dec. 2008.

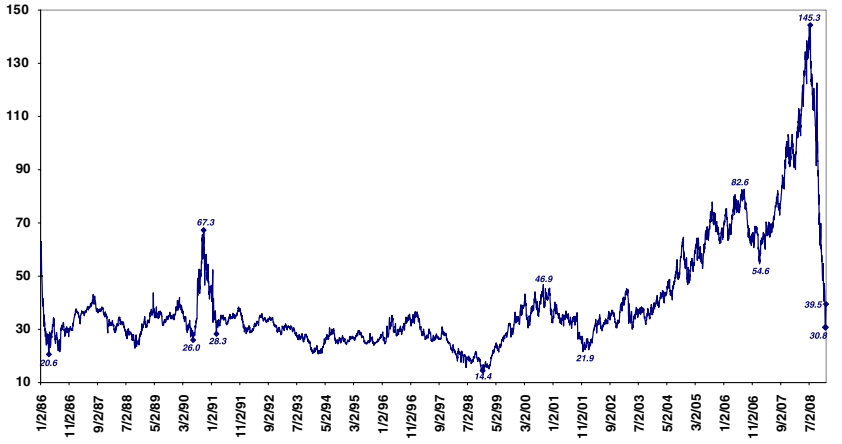

Fig. 4c. Daily oil prices (in 2008 constant $): 1986–2008.

equivalent of 265 constant 2008 dollars. Interestingly, however, oil prices started to drop from their yearly height of $85.4 in 1980 and 1981 to a low of $18.9 in 1998. This was an amazing fall. This time it was a negative coconut for oil-producing countries, as the price of a barrel of oil dropped to practically the same level as in 1880 and 1973. However, low prices encouraged demand, which started increasing at a fast pace and eventually surpassed the normal supply of oil.

Since 1998, oil prices have had another spectacular rise, reaching a yearly level of $99.5 in 2008, practically the same as that in 1980 and 1981. Needless to say, during this period of rising prices, there were new forecasts predicting that a barrel of oil would soon exceed $200. But at the end of 2008, oil prices were again heading south, falling to as low as $30 a barrel. Will the price of a barrel of oil once again descend to the 1973 and 1880 level? We do not think that anyone can tell, but let's also look at Fig. 4b, showing the monthly oil prices.

Monthly prices, like yearly ones, did not fluctuate much before 1974, but then in a single month they shot up from $17.6 in December 1973 to $47.5 in January of 1974 (a 170% increase in a single month). Since then, they have risen to $106.7 in April 1980 and fallen to $15.2 in December 1998, while over the entire

1974 to 2008 period they seem to have fluctuated around $48, the overall average for the period (see Fig. 4b). However, after December 1998, oil prices started another vertical climb, shooting to a high of $133.9 just under ten years later, and then dropping to $48.72 in December, 2008. What will the price of a barrel of oil be next month and over those of 2009?

Daily oil prices, shown in Fig. 4c, fluctuate even more than monthly ones, at times increasing or decreasing by several hundred percent in less than 100 days, as happened between June 20 and October 11, 1990, when the oil price went from $26 to $67.3 (a 160% jump) and then down to $28.3 (a 58% drop) in February 25, 1991. Subsequently, prices continued their decline, reaching a low of $14.4 in December 21, 1998, then starting an increase that reached its peak on July 3, 2008, at $145.3, prompting predictions of prices exceeding $200. Yet, as in 1980, prices subsequently started falling at a fast pace, dropping to $30.8 (a 79% decline) on the last day of December 2008.

Daily oil price fluctuations are the equivalent of random walks, making the task of forecasting future prices impossible and obliging us to assume that the most appropriate prediction for oil prices is that of today's price. Therefore the most appropriate forecast for tomorrow's and next week's daily prices is that of today.

The price mechanism for oil is a highly complex system that is hard to predict, as it is influenced by a host of interdependent factors, including human actions and reactions. OPEC, for instance, wants high oil prices, while oil-importing countries have a great interest in keeping them low. It is left, therefore, to market mechanisms to determine the "equilibrium" price that equates demand and supply, and determines the market price for now and the future. In addition to real market forces, however, speculators attempt to influence prices, and there are also overreactions to both good and bad news. All of these factors affect oil prices and complicate the task of forecasting them in the long, medium and short term.

On the one hand, there are those who argue that reserves are being depleted at a fast pace and that we will soon run out of oil, because the populations of developing countries, in particular China and India, are increasing their consumption at an alarming rate. Under this scenario, it is inevitable, they say, that future oil prices will increase together with consumption. On the other hand, such prophecies have been made many times in the past, and have been proven wrong, as market mechanisms have brought equilibrium in the supply and demand for oil. High prices discourage consumption and encourage new oil exploration. They also contribute to slower economic growth, which puts a brake on consumption. This, for instance, has been the case both in 1974–1980 and the present period, when serious recessions have followed the steep increases in oil prices that contributed to decreases in consumption.

High oil prices encourage R&D expenditure on improving energy efficiency and venture capital for commercializing renewable energy sources. Clearly, there are long lead times between oil-price increases on the one hand, and decreases in demand and increases in supply, on the other. However, the higher the oil prices, the greater the incentives – not only for additional supplies coming into the market but also for investments in alternative sources of energy. The problem at present is that investments in alternative sources of energy are discouraged, because oil is too cheap and the uncertainty about its future price too great. Long-lasting, high oil prices will remove this problem and will encourage the development of new energy sources, reducing our dependence on oil and decreasing its price in the long run. This may take time, but it will be inevitable if prices increase substantially. Thus, the scenario of running out of oil is not consistent with market mechanisms.

But, in the final analysis, we must make long- and medium-term forecasts. We believe that the most logical alternative is to use the average yearly oil price from 1974 to 2008 of $43.8 as the most appropriate prediction for the long run, and the average monthly oil price for 1974–2008 of $48.0 as the most appropriate forecast for the medium term (see Figs. 4a and 4b). The reason for ignoring the pre-1974 data is the change that occurred in the oil pricing mechanism as the power of setting prices shifted from the oil consumers to oil producers. These two forecasts will be utilized below to determine the size of the forecasting errors and to appreciate the uncertainty in predicting long- and medium-term oil prices.

Another important forecast concerns daily oil prices. The best alternative in this short-term case is to assume that today's price is the most appropriate forecast for the near future. The reason is that daily oil

prices behave like a random walk, thereby making it impossible to predict their next turning points, either temporary or permanent. Thus, the most appropriate forecast is:

$$F_{t+i} = X_t;$$

where F_{t+i} is the forecast for $i = 1; 2; 3; m$ periods ahead and X_t is today's oil price.

The majority of forecasters, however, would not use any of the simple alternatives mentioned above. Instead, they prefer highly complex and statistically sophisticated models, even though empirical research has proven (Makridakis & Hibon, 1979, 2000; Makridakis et al., 1982) that the simple models above are at least as accurate, and that averaging the forecasts of such models improves the accuracy of predictions. Other forecasters prefer making judgmental predictions, in the belief that such forecasts are superior to those of models, even though it has also been proven that judgmental biases typically lead to worse forecasts than those of simple models. Most importantly, the major emphasis of practically all forecasters is on making definitive predictions, thereby ignoring or completely downplaying the uncertainty involved. However, as can be seen from Fig. 4 and the following sections, this is substantial, and should be considered together with the forecast itself.

4.4. Handling uncertainty

In dealing with uncertainty, it is important to know whether and to what extent one is dealing with phenomena governed by subway uncertainty, coconut uncertainty, or, as in most cases, a combination of the two. This knowledge can be confirmed from past data (fortunately these days such data are accessible) or inferred from similar situations. Empirical evidence has shown that in the great majority of economic or business situations the distribution of forecasting errors does not behave like that of Fig. 3 (see also the introductory article of this issue). The difficulty for decision and policy makers, however, is to understand and accept the extent of future uncertainty so that appropriate plans, similar to those made for earthquakes or storms and hurricanes, can be formulated.

Makridakis et al. (2009) discuss a systematic way of thinking about subway and coconut uncertainty. In a given situation — borrowing from a quote by Donald Rumsfeld, the former US Secretary of Defense — it is useful to distinguish between *known knowns*, *known unknowns*, and *unknown unknowns*. For example, the return on an insured fixed deposit in a bank is a known known — we know exactly what we will receive in the future. The outcome of a coin toss is an example of a known unknown. We know that the result will be heads or tails, but we do not know which. Similarly, we know that there will be bubbles in financial markets in the future, but we do not know when or where. Then there are the unknown unknowns, rare events that are completely unexpected and unimagined. These are *Black Swans*, so eloquently characterized by Taleb (2004, 2007). They can only be identified after their occurrence, since if we could have anticipated them before, they would not be Black Swans. Looking back at history, the internet was a Black Swan, as was the Great Depression of 1929–1933.

Once we accept that there are known knowns, known unknowns, and unknown unknowns, we can start thinking about the underlying uncertainty in a more systematic manner. There is no uncertainty associated with known knowns, as we know exactly what will happen. In the case of known unknowns, we may be able to quantify and model the uncertainty for some events but not all. Going back to our examples above, we can model the uncertainty of a coin toss, but it is impossible to quantify or model the uncertainty concerning future bubbles in financial markets, even though we can clearly expect these to occur. What this means is that some of the known unknowns involve subway uncertainty (like the coin toss) while others involve coconut uncertainty (like bubbles in the financial markets). The unknown unknowns are necessarily cases of coconut uncertainty. These distinctions are summarized in Fig. 5.

As a discipline, the field of forecasting has done excellent work with models of subway uncertainty that can be assessed precisely and incorporated into all sorts of analyses to determine optimal decisions. However, until now it has ignored coconut uncertainty, as it is difficult if not impossible to model. Even for events like oil prices, where plenty of historical information is available, modeling coconut uncertainty is extremely difficult. Black Swans, which by definition are inconceivable a priori and occur very rarely, are only a small part of the coconut uncertainty. In other words, the world is beset not by Black Swans, but by the entire