Risk and Uncertainty*

BY PABLO A. GUERRON-QUINTANA

Many news reports and economic experts talk about uncertainty. But what does the word mean in an economic context? Specifically, what do economists have in mind when they talk about it? In this article, Pablo Guerron-Quintana discusses the concepts of risk and uncertainty, what the difference is between the two terms, and why their presence in the economy may have widespread effects. He also talks about measuring risk at the aggregate level — that is, risk that affects all participants in the economy — and he reviews the various types of risk measures that economists have proposed.

Many news reports and economic experts talk about uncertainty. Take, for example, the recent discussion about the U.S. budget situation. Although several proposals have been offered that aim to achieve a fiscally sustainable budget, we do not know with certainty which measures will ultimately be adopted or their timeline. According to some economists, this uncertainty seems to have contributed to a slowdown in investment, hiring, and economic activity and has the potential to affect our standard of living. But what does uncertainty mean? More important, what do economists have in mind when they talk about it?

This article will discuss the concepts of risk and uncertainty and why their presence in the economy may have widespread effects. We will also talk about measuring risk at the aggregate level, that is, risk that affects all participants in the economy. Different measures of this aggregate risk have been proposed: (1) disagreement among forecasters, (2) stock market volatility, (3) interest rate volatility, and (4) tax rate volatility. Each of these measures has its pros and cons.

Over the years, the concepts of *risk* and *uncertainty* have often been used interchangeably in the popular press, but economists have long distinguished between the two. Indeed, the concept of uncertainty was probably first introduced to economics by Frank Knight in his 1921 treatise *Risk, Uncertainty, and Profit*.[1] Knight drew the distinction between *risk* – unknown outcomes whose odds of happening can be measured or at least learned about – and *uncertainty* – uncertain events that we do not even know how to describe. Economists often label these ideas *Knightian risk* and *Knightian uncertainty,* although sometimes they are called *objective uncertainty* and *subjective uncertainty*. (See *Uncertainty Is Different from Risk*.)

Risk can affect us at an individual level. In our daily lives, we get hit by unanticipated events such as accidents or diseases or being hired for a dream job or even winning the lottery. While the last two examples are pleasant surprises, the first two events involve physical and mental strain and potential monetary losses. Since most of us dislike facing stressful situations, we modify our behavior when bad luck knocks on our door. For instance, we buy insurance to protect us from the monetary loss we could sustain from car accidents or the cancellation of a vacation trip. Furthermore, the knowledge that we may lose our job can be strong enough to deter us from taking that well-deserved vacation. All of these examples provide powerful reasons why we may want to learn more about risk.

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*The views expressed here are those of the author and do not necessarily represent the views of the Federal Reserve Bank of Philadelphia or the Federal Reserve System.

[1] The interest in uncertainty in economics seems to coincide with a broader wave of interest in the topic in science, as reflected by Heisenberg's 1927 work on uncertainty in physics.

Uncertainty Is Different from Risk

To understand the difference between risk and uncertainty, let's consider the experiment of flipping a fair coin (Case A). In this experiment, the unknown is whether the coin will land heads or tails. Since we are dealing with a fair coin, we know that the odds of heads after each flip are 50-50. That is, if we were to flip the coin let's say 100 times, the coin would land, on average, 50 times heads and 50 times tails. The crucial insight from this experiment is the observation that we *know* exactly the odds of each of the possible events: 50 percent heads and 50 percent tails. Furthermore, we have this knowledge before starting the experiment. This is precisely the essence of risk: We can describe the odds of the unknowns.

Now let's consider an alternative experiment (Case B). As before, we are interested in learning the result of flipping a coin. The key difference is that we know the coin is no longer fair, but we do not know the odds of obtaining heads. Furthermore, the coin is replaced by a new (and unfair) coin after each flip.[a] Under this scenario, the only thing we know is that the coin will land either heads or tails. If we were thinking about flipping the coin 100 times, we could not (before we start the experiment) tell how many times the coin will land on heads. This is an example of Knight's *uncertainty*.

Another way to see the difference between risk and uncertainty is as follows. Suppose 100 people are asked to place odds on the coin landing on heads in experiments A and B. In Case A, people would agree that the odds are 50-50, but in Case B, their assessment would range from 0 to 100 percent. Furthermore, those people would prefer to bet on getting heads in experiment A than on getting heads in experiment B.[b]

The concept of uncertainty goes beyond those situations in which we cannot establish the likelihood of events. It also includes cases when we do not even know the outcomes. An extreme example is as follows. Imagine that a person from the Midwest decides to vacation in Volcanoland, a fictitious country buffeted by constant volcanic and seismic activity. If a sudden volcanic eruption surprises our friendly Midwesterner, his lack of knowledge and experience with volcanoes makes his immediate future quite uncertain. How long is the eruption going to last? Does he have enough food and water? Is his shelter safe? Our friend is asking himself these questions because he is uncertain about the possible outcomes from an eruption. In this example, we are aware that something has happened (an eruption), but we do not know its potential consequences.

Assessing the impact of uncertainty is trickier. The reason, as explained in the introduction, is that one cannot assign probabilities to the possible outcomes or one does not know all the possible outcomes. This lack of knowledge means that the consequences of uncertainty can range from nothing to vast monetary losses.[c] To see this point, let's reconsider the case of tossing an unfair coin 100 times. Suppose that we get $1 each time the coin lands on heads and pay $1 otherwise. What we know before flipping the coin is that we may make as much as $100 (all trials land on heads) or we may lose $100 (all trials land on tails). Furthermore, any payment in between is possible. The unfair nature of the coin makes it impossible for us to determine the expected payoff from entering into this contest.

Now consider the case of the Midwesterner facing a volcanic eruption in Volcanoland. What are the potential consequences for this person? On the one hand, the only annoyance our friend may face is ashes falling from the sky. The uniqueness of this event also implies that if the eruption turns out to be violent, our friend may be risking a lot more than a spoiled vacation. As with the case of the coin tossing exercise, we cannot determine beforehand the potential losses from being exposed to a geologic contingency.

[a] This assumption is needed to ensure that we cannot learn the odds of getting heads by repeatedly flipping the coin. If this were the case, after the learning stage, we would be in a case essentially the same as that of flipping a fair coin, whose odds of landing on heads are a known constant, although different from 50-50.

[b] This preference to act on known rather than unknown probabilities is called the Ellsberg paradox (Ellsberg, 1961).

[c] Larry Epstein and Tan Wang provide a comprehensive analysis of uncertainty.

The idea that risk can affect not only our daily lives but also the overall economy is not new. Indeed, in the 1930s, the English economist John Maynard Keynes indicated that investors' mood could lead to economic downturns. He reasoned that investment was in part driven by investors' view of the economy. If they are uncertain about the economy's prospects, they reduce investment, triggering a downturn.

ASSESSING THE IMPACT OF RISK

Risk can affect the economy in at least two ways: through investment and/or through savings. The current "risky" scenario about where house

prices are heading (up, down, or stable) and whether interest rates are going up makes the investment decision nontrivial. The optimal response to risky situations may be to wait and see. In other words, households choose to delay investment (buying a house) until things calm down. The reason is that individuals may face an adverse scenario with high interest rates and a contraction in house prices. This possibility makes investment quite risky, inducing households to wait for better times. Put differently, when facing uncertain scenarios, investors must decide on the timing of their investment decisions.[2]

But risk can affect savings as well. Imagine that you owe credit card debt and that your monthly payment is $200. Suddenly, your credit card company announces that interest rates may go up next month. Moreover, the company announces that if interest rates go up, interest payments will most likely double for some customers. Under these circumstances, you may find it desirable to consume less today and use that extra cash to repay part of your debt. The additional cash should be used to repay part or all of your debt. If you choose otherwise, you may face credit card payments as high as $400 next month. Even more worrisome, because of those large payments, you may have to cut your consumption by a large amount tomorrow.

The previous example can be extended to the case of countries. Imagine that a country issues debt to cover part of its investment and other expenses. If the country's creditors disclose that interest rates may change next month, the country may want to repay part of its debt to reduce the future burden of interest rate payments. In order to pay more today, the country needs to produce more. But increasing production takes time (hiring more workers, building factories, and so on). This means that the only way the country can repay its obligations is by cutting its expenses, that is, reducing consumption and investment. In other words, the country needs to sell more goods abroad (increase exports) and buy fewer goods from abroad (decrease imports). Since not all goods can be exported (for example, haircuts, legal and medical services, and houses), some industries will be forced to produce less. This decline in production will result in higher unemployment for a segment of the population.

Obviously, how our decisions change when we face risky situations depends on our attitudes toward risk. For instance, a gambler (a person who loves taking additional risk) may well opt to purchase a home with the hope that prices will eventually recover. The gambler understands there is a big chance that prices may not recover for a while. Yet the mere fact of taking a chance gives him satisfaction and hence drives him to bet on the housing market. In contrast, a cautious person may choose not to gamble on the housing market and may refrain from buying a house these days. For the cautious person, the potential losses far outweigh the benefits from buying a house in a depressed market and hoping it will recover.[3]

Since the presence of risk can entail monetary losses, people try to protect themselves by buying insurance. In simple terms, an insurance contract transfers the risk of loss from the policy holder to the insurer, usually a large company. The contract typically sets a small and regular payment to be made by the insured person. In exchange, the insurer promises to pay the policy holder a given monetary amount if certain events happen, as defined in the contract. Some examples include having a car accident, having a vacation trip cancelled, or being laid off from a job. In this last case, the insured person is a worker and the insurer is the federal government and/or the state.

How our decisions change when we face risky situations depends on our attitudes toward risk.

But accidents happen; people get sick; workers get laid off. More important, these unpleasant events happen more frequently than we would like. So why do insurance companies exist? One reason is that the insurer and the policy holder may have different views about the odds that an event will occur. To illustrate my point, imagine a person who is afraid of flying. His pessimistic view about air transportation leads him to look for insurance. In contrast, an insurance company knows that flying is the safest medium of transportation. The odds of an incident are very small, so the insurer is more than willing to extend a policy to the concerned flyer.[4]

Even if the insurer and the policy holder have the same assessment of

[2] Committing to early investment brings in extra returns, while waiting is beneficial because of access to additional information. See the article by Ben Bernanke.

[3] In the context of an economic model, whereas a gambler would correspond to a person whose preferences are described by a linear utility function, a risk-averse person — a cautious person — has a concave utility function. If the two persons were to invest in a risky project, such as buying stocks, the gambler would care only about the project's payoff, since he considers only his total consumption. He would take on whatever project offers large rewards, even though it may also entail large losses. In contrast, the cautious person would also factor in the odds that the project could fail. Even if the promised payoff is large, a risk-averse person may opt out of the project because the odds that it will fail are too big. In other words, he would rather have fewer swings in his income even if that means a lower average income.

[4] Indeed, the odds of dying in a plane crash for the average American is about 1 in 11 million.

the odds that an event will occur, the insurer may still be willing to extend a policy to the insured person. For example, this is the case with car insurance. For instance, a car owner who lives in a crowded city has a greater probability of being involved in an accident, a situation that requires payments from the insurer to the policy holder.[5] To reduce their exposure to this type of event, insurance companies offer policies to a large number of drivers. Since car accidents tend to be isolated events, the likelihood of an insurance company facing accident claims from all its insured customers at the same time is very low. Hence, although the insurer may need to make frequent payments, the insurer is also receiving payments (premiums) from those policy holders who have not been involved in an accident or the deductibles from those who have been. In this way, the insurance company has enough funds to pay its insured customers who have car accidents.

MEASURING RISK: SOME BASICS

From the discussion in the previous sections, it should be clear that risk can influence our lives. Obviously, the influence of risk depends on the circumstances under which it affects us. For example, consider the risk associated with the weather. Under normal circumstances, a day with bad weather means that we may be late getting to work; that is, the expected loss — the risk — is low. But in some cases, the risk can be high. Imagine if you missed an interview for your dream job because of bad weather. The stakes are even higher when we think of the risk associated with buying a house or a government that is considering issuing bonds. In the first case, risk arises from fluctuations in the price of houses, and in the second case, the variability of interest rates (and hence the cost of issuing bonds) matters. The bottom line in these examples is that understanding the consequences of risk requires measuring it. Once we have a measurement, we can then take actions such as postponing the purchase of a house or buying insurance.

Economists have proposed different measures of risk: (1) disagreement among forecasters, (2) stock market volatility, (3) fluctuations in interest rates, and (4) fluctuations in tax rates.[6]

Disagreement Among Forecasters. Imagine that today is a bright and sunny day. If you were asked to forecast the weather for the afternoon, assuming that you don't have access to a weather forecast service, you would most likely answer "a sunny afternoon." In fact, everyone would agree with you. Now imagine that today is sunny, but a few clouds lurk on the horizon. The presence of those clouds makes forecasting the weather for this afternoon more difficult. Some people may forecast a sunny afternoon; others may guess a cloudy but dry afternoon, while a third group may forecast a rainy afternoon.

The idea behind the last example is that periods of elevated risk are associated with very imprecise forecasts about future events. In other words, the more risky the event, the harder it is to forecast and, therefore, the larger the disagreement among forecasters. In our example, the risky situation arises from those clouds on the horizon. Rather than the weather, economists are frequently interested in the total number of goods that an economy produces, that is, a country's gross domestic product (GDP). Hence, our first measure of risk comes from the forecasters' disagreement about what the growth rate of GDP is going to be a year from now. This measure is published quarterly by the Federal Reserve Bank of Philadelphia in the *Survey of Professional Forecasters*. It is the percent difference between the 75th and 25th percentiles of the one-year-ahead projections for U.S. real gross domestic product.

Figure 1 shows that the degree of riskiness (measured by forecast dispersion) was large in the 1970s, in particular, during the oil embargo of 1974 and at the beginning of the Fed's disinflationary era around 1979. The figure also suggests that disagreement has diminished during the 1990s and the first half of the 2000s. This decline coincides with what economists call the Great Moderation, that is, the period between 1984 and 2007 characterized by two relatively mild recessions and, in general, moderate fluctuations in the economy. During this period, the increasing agreement among forecasters resulted from the more stable, and thus more predictable, economy. This reasoning has led some observers to argue that the prolonged boom prior to the recent crisis arose from a stable economy.[7] This stability stimulated consumption and investment. To meet higher demand, firms increased their production by expanding their facilities (additional investment) and increasing employment.

Another look at Figure 1 reveals a rise in risk since the start of the 2007 financial crisis. The highest level of risk happens by the end of 2008, which coincides with the collapse of Lehman Brothers. What makes the 2007-2010 episode different from other periods over the last 20 years is that risk remained heightened for more than a year. With so much risk around, it is not surprising that firms and house-

[5] Eric Smith and Randall Wright analyze the interesting issue of why car insurance is so expensive in certain metropolitan areas.

[6] Economists have proposed other ways to measure risk. The interested reader is invited to consult the article by Nicholas Bloom, Max Floetotto, and Nir Jaimovich.

[7] See the study by James Stock and Mark Watson.

holds postponed their purchasing and investing decisions. Interestingly, the improvement in the economy of recent months seems to coincide with a decline in risk. Note how the measure at the end of 2010 is getting close to its pre-crisis levels. [8]

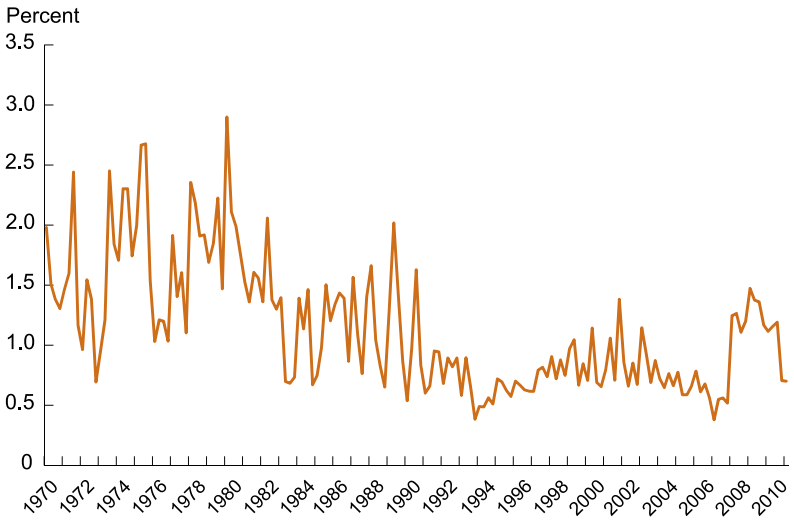
A simple way to make sense of the numbers in Figure 1 is as follows. You and I own an apple tree, and we are interested in forecasting our tree's annual production. Furthermore, let's suppose that our disagreement over the years is represented by Figure 1. In the first quarter of 1980, our forecast disagreement reached an all-time high of almost three. This means that at that moment, if I had forecasted that our tree would produce 100 apples in 1981, your forecast would have been 103.[9] Now, let us move forward to March 2007 when our disagreement was the lowest (0.4). At that point, if my forecast was 100 apples, you would have forecasted 100.4 apples. We were essentially making the same forecast. After the turbulent financial events of 2008, our disagreement rose to 1.5 apples and remained at that level for most of 2009.

Stock Market Fluctuations. During times of high risk, new information about the state of a company (for instance, its profits and prospects for future projects) tends to arrive frequently. In response to the arrival of information, investors buy and sell stocks in the company quite frequently. As a result, the stock price of the company fluctuates substantially in the short run. The more uncertain investors are about a company, the more they bet up or down on that company's stock. Hence, our second measure of risk comes from the variability (volatility) in the stock prices of companies publicly traded on the New York stock exchange. This indicator (displayed in Figure 2) is closely tracked by financial practitioners, since it is considered a measure of investor sentiment: The higher stock market volatility is, the more pessimistic investors are, that is, the greater the expectation that the market will fall. But recall that worried investors tend to wait and see. Hence, a sudden and persistent increase in stock market volatility may be signaling weak demand down the road and a potential contraction in the overall economy. It is this linkage between stock market volatility and economic activity that has made our second measure of risk popular both in academia and in policy circles. (See the studies by Nicholas Bloom.)

Based on Figure 2, it is clear that periods of economic and financial turmoil are associated with strong fluctuations in the stock market.[10] For example, the market was more volatile during the oil embargo of 1974 or the Asian financial crisis and the collapse of dot-com companies in the late 1990s. Similarly, the stock market crash of October 1987 resulted in a large spike, albeit temporary, of our measure of risk.[11] Figure 2 also shows that the U.S. economy enjoyed a period of tranquility and low risk starting around 1988 and extending into 1997. More recently, the onset of the mortgage crisis (2007) and the demise of Bear Stearns (March 2008) and

FIGURE 1

U.S. Real GDP Growth Forecast Dispersion



Source: *Survey of Professional Forecasters* from the Federal Reserve Bank of Philadelphia, quarterly data 1970:Q1 - 2010:Q3

[8] Of course, the causality could go the other way around: Periods of high growth promote tranquil times and hence low risk. In a recent paper, Scott Baker and Nicholas Bloom use stock market information from several countries to argue that the causality runs from risk to economic growth.

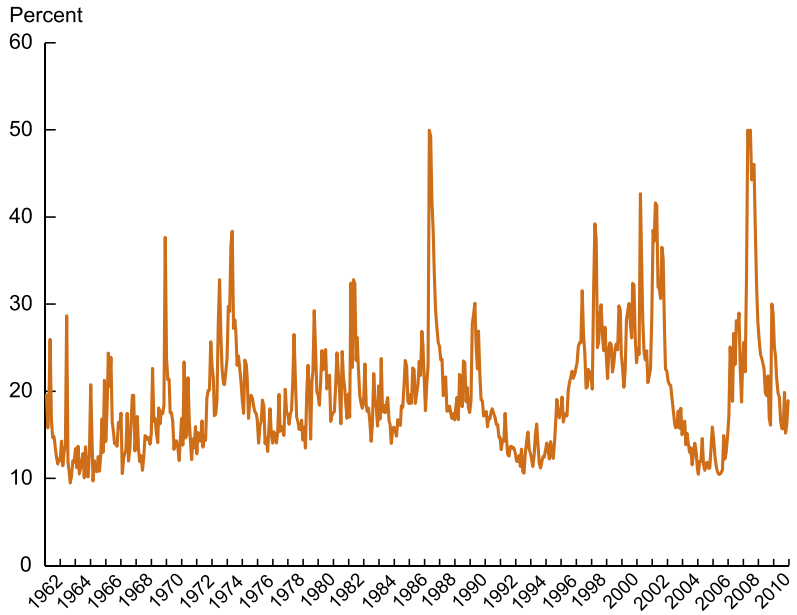
[9] For simplicity, I assume in this example that I am the person making the conservative forecast.

[10] The U.S. stock market volatility is taken from the article by Nicholas Bloom. The measure corresponds to the Chicago Board of Options Exchange VXO index of implied volatility from 1986 onward. Prior to 1986, actual volatility in monthly returns is calculated as the monthly standard deviation of the daily S&P 500 index.

[11] Some economic observers attributed this quick reversal in risk to the Federal Reserve System's (and its then-Chairman Alan Greenspan's) swift actions to support financial markets. See the paper by Mark Carlson.

FIGURE 2

Stock Market Volatility: 1963 - 2011



Source: Nicholas Bloom. Monthly data 1963:M1 - 2011:M1

Lehman Brothers (September 2008) shook financial markets. Figure 2 reveals that our measure of risk rose in response to those events. In fact, risk reached its all-time high in October 2008 and remained elevated for most of 2009.

An advantage of the stock market volatility measure is that it goes back to the 1960s and therefore allows us to illustrate how risk responds to political events. For example, the spike in risk at the beginning of 1964 coincides with President Kennedy's assassination. Moving forward, the Cambodian campaign and the Kent State shooting in 1970 pushed risk up.[12] Finally, the attacks on the World Trade Center and the Pentagon in September 2001 are also associated with more risk in the market.

To make sense of the numbers in Figure 2, let's consider the following example. You own stock in a large group of leading companies in diverse industries in the U.S.[13] You are interested in learning the odds that the return on your portfolio will move up or down by 10 percent next month. If you were wondering this in October 2008 and asking about your return in November 2008, the results in Figure 2 imply that the odds are roughly 50 percent that the return on your portfolio will move up or down by 10 percent. In contrast, if you were asking the same question in December 2006, you would conclude that the chances that your returns would go up or down by 10 percent is practically 100 percent. This means that you are almost certain that the returns to your portfolio would not exceed +/–10 percent in January 2007.[14] This is because stock market volatility was so low in December 2006 that sudden changes in stock prices and hence abrupt movements in stock returns were very unlikely.

I must stress that when stock market volatility is high, it does not necessarily mean that the market expects a sharp decline in stock prices. It only means that the market expects that sudden price movements in either direction (up or down) are more likely. Since most people tend to be concerned about losses, investors seem to dislike high stock market volatility (high risk) because it signals that a sharp collapse in stock prices is more likely.

Interest Rate Volatility. An alternative description of risk results from direct measures of fluctuations in interest rates. Such measures have been used recently in papers that try to assess the impact of risk on the economy. (See my paper with Jesus Fernandez-Villaverde, Juan Rubio-Ramirez, and Martin Uribe.)

The idea behind the measure of interest-rate volatility is that people tend to trade (sell or buy) bonds very frequently during periods of high risk. This frequent exchange of bonds makes their price fluctuate substantially, which results in large swings in interest rates.[15] Hence, periods of large

[12] The shooting at Kent State University (Kent, Ohio) resulted in four people being killed and nine others wounded. Students were protesting the Vietnam War. The shooting happened just days after President Nixon announced the launch of the Cambodian incursion. This military action was intended to defeat North Vietnam's troops using the eastern part of Cambodia to stage attacks on South Vietnam.

[13] More precisely, you own stock in each of the 500 companies that are part of the S&P 500 index.

[14] These numbers were computed following the interpretation outlined in the study by Robert Whaley. Succinctly, the probability is computed by asking ourselves what is the probability that a random normal variable falls within σ standard deviations from 0. Here, $\sigma = \frac{Er}{VIX}\sqrt{12}$, Er is the anticipated movement in the asset return, and VIX is the stock market volatility in Figure 2. In our first example, the values are Er = 10 percent and VIX = 50 percent, which implies $\sigma = 0.69$ or a probability of 50 percent. If the VIX drops to 10 percent, then $\sigma = 3.46$, which, based on a normal distribution, implies a probability of 1.

[15] The price and interest rate of a bond are inversely related, so any movement in prices translates directly to fluctuations in interest rates.

fluctuations (volatility) in interest rates are interpreted as episodes in which risk is high. As an example, Figure 3 illustrates the evolution of our interest-rate risk measure for Argentina. A quick look at this figure reveals that risk in Argentina was high in early 1998 and again during the period 2001 to 2004.[16]

To understand these changes in risk, some background information about Argentina is necessary. The 1990s were mostly a boom period for Argentineans (presumably due to economic reforms introduced early in that decade). The country experienced sustained economic growth and stable prices. In the eyes of investors, Argentina was an example for other countries to follow. However, this stability started to collapse around 1998 when several East Asian countries experienced financial difficulties, forcing them to stop payments on their debt obligations to international lenders. Although Argentina was in better economic health than the defaulting countries, nervous lenders worldwide feared that Argentina (and other countries in South America) would follow suit. Investors could not assess how much the Argentinean economy would be affected by the collapse of Asian economies. Ultimately, Argentinean debt was heavily traded during this period, which resulted in sudden fluctuations in interest rates and hence a spike in risk.[17] As time went by, it was clear that Argentina would be able to meet its obligations, so the country became less risky. This is reflected by the drop in our measure of risk between 1999 and 2000.

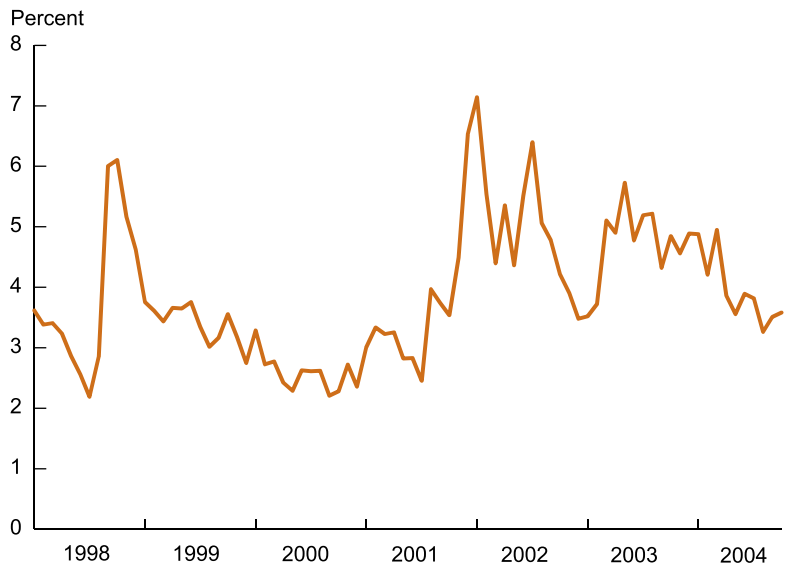
After almost a decade of boom, the Argentinean economy slowed down in 2000 and contracted in 2001. At the same time, the Argentinean currency (the peso) was greatly overvalued, which made Argentina's products more expensive than those imported from abroad and hence reduced its exports. This decline in production and lack of exports meant that fewer resources were available to repay debt. In response, investors demanded higher interest rates for loans extended to Argentina. These tough economic conditions led the country to default (stop paying principal and interest on its debt), which triggered the spike in our measure of risk by the end of 2001. Risk remained heightened for the next two years as the country continued to miss payments on its obligations.

Figure 3 shows that risk started to decline around 2003. This improvement seems to coincide with the beginning of Nestor Kirchner's presidency. To some observers, the economic policies implemented by Kirchner and his predecessor (Eduardo Duhalde) paved the way to an orderly recovery. By the end of our sample period (August 2004), risk had reached its lowest level in three years, since international investors anticipated that Argentina would eventually try to meet or renegotiate its debt obligations. Indeed, in 2005, the country restructured its obligations with roughly 75 percent of its debt holders.[18]

A simple way to make sense of the numbers in Figure 3 is as follows. Imagine that you are living in Argentina in August 2000. You just bought a new car with an adjustable interest rate loan. The prevailing annual interest rate at that point was about 8 percent.

FIGURE 3

Interest Rate Volatility in Argentina



Source: Jesus Fernandez-Villaverde et al. (2011). Monthly data 1997:M12 - 2004:M9

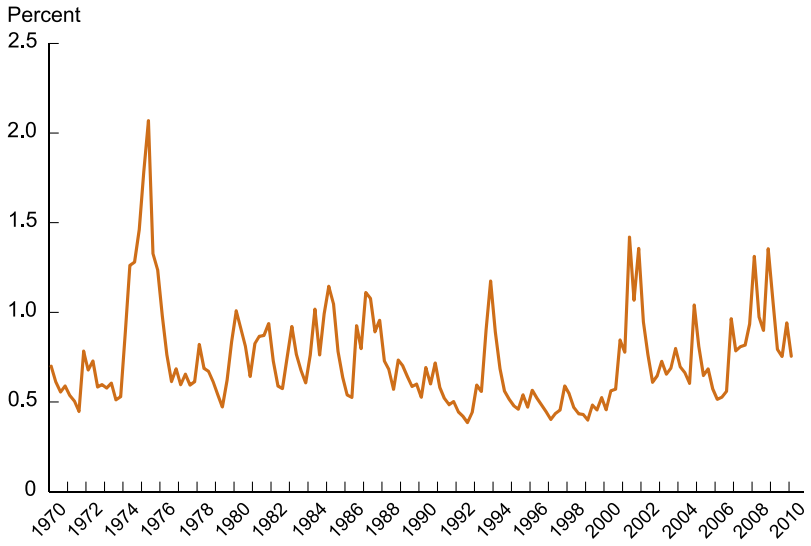
[16] The Argentinean interest rate is the sum of the real rate on the three-month U.S. Treasury bill plus Argentina's Emerging Markets Bond Index+ (EMBI+). The T-bill rate is taken from the St. Louis Fed's FRED database. The EMBI+ index is published monthly by J.P. Morgan. The risk measure in Figure 3 is constructed using the econometric approach described in my paper with Jesus Fernandez-Villaverde, Juan Rubio-Ramirez, and Martin Uribe.

[17] Interestingly, risk in the U.S. was also elevated in the late 1990s, as shown in Figure 2.

[18] Old bonds were replaced by new debt with longer maturity and nominal value of between 25 and 35 percent of the original debt.

FIGURE 4

Capital Tax Rate Volatility



Source: Jesus Fernandez-Villaverde et al. (2012). Quarterly data 1970:Q1 - 2010:Q1

By construction, Figure 3 tells us that there was a 68 percent chance that the interest rate would go up or down by 2 percentage points. This means that in August 2000 you believed that your interest rate could be as high as 10 percent or as low as 6 percent in September 2000. Let's move forward to December 2001. Our risk measure indicates that with a probability of 68 percent, your interest rate could jump up or down by 7 percentage points! This means that, all other things equal, you could have faced interest rates as high as 15 percent on your car loan. For a principal of $10,000, these numbers imply that whereas your monthly payment in September 2001 could have been as high as $800, your payment in December 2001 could have been $1,170.[19] Clearly, there is a non-trivial increase in your payments when the economy gets riskier.

The Argentinean example teaches us two important lessons about risk. First, risk can be contagious. Even though Argentina was a well-positioned economy in the late 1990s, it suffered from substantial fluctuations in its risk index. In this case, risk was imported from financial turmoil abroad. The second lesson is that risk can arise from domestic factors. The economic instability of Argentina and its subsequent inability to meet its obligations at the end of 2001 resulted in the massive spike in Argentina's risk. Here, there were no foreign elements triggering the sudden change in interest rate fluctuations.

Tax Rate Volatility. A final description of risk comes from fluctuations in tax rates. This notion was recently proposed in my paper with Jesus Fernandez-Villaverde, Keith Kuester, and Juan Rubio-Ramirez. The idea is that governments tend to overhaul tax systems during periods of fiscal strain (such as the current one), which results in substantial fluctuations in tax rates. The worse the fiscal situation, the more volatile the taxes are.

Figure 4 presents our new risk measure based on the volatility of the capital tax rate in the United States.[20] The measure shows that risk associated with fiscal policy was high during President Clinton's first term. Indeed, the Omnibus Budget Reconciliation Act, which was signed into law in 1993, raised tax rates, affecting both individuals and businesses. Similarly, our risk measure rises during President George W. Bush's tax cuts in the early 2000s.

It is also apparent from Figure 4 that the recent financial crisis has heightened the fiscal-related risk. Risk was high between 2007 and 2009; only in early 2010 does risk linked to fiscal policy go back to pre-crisis levels.

In our paper we show that risk associated with fiscal policy can slow down the economy. The reason is that volatility makes it difficult to forecast future tax rates on capital. As a consequence, investors considering investing in new projects may opt to wait or completely skip those projects. This is because investors fear that large volatility may ultimately translate into large future taxes, thus reducing the profitability of their investments. If the capital tax rate volatility is sufficiently high, the decline in investment can induce a general contraction in economic activity (lower production and higher unemployment).

Imagine that you are back in the fourth quarter of 1995. You just invested in a new project whose payoffs are taxed at 35 percent. By construc-

[19] An annual interest rate of 10 percent is roughly equivalent to 0.8 percent on a monthly basis. Similarly, a 15 percent annual interest rate translates into a monthly rate of 11.7 percent.

[20] The tax rate on capital corresponds to aggregate effective rates on capital income. The risk measure in Figure 4 is constructed using the econometric approach described in my paper with Fernandez-Villaverde, Kuester, and Rubio-Ramirez.

tion, Figure 4 tells us that there was a 68 percent chance that the capital tax rate would go up or down by 0.5 percentage point. This means that in December 1995, you believed that the tax rate on capital income could be as high as 35.5 percent or as low as 34.5 percent in March 1996. Let's move forward to December 2001. Our risk measure indicates that with a probability of 68 percent, your tax rate could jump up or down by 1.4 percentage points! This means that, all other things equal, you could have faced a tax rate on capital as high as 36.4 percent. This sudden change in the tax rate is sufficient to deter investment, at least temporarily, and induce a contraction in economic activity.

SUMMARY

This article introduced the economic concepts of risk and uncertainty. It provides clear and simple definitions and examples of risk and uncertainty. Furthermore, this article shows that risk can have important consequences for economic activity. For example, an increase in the volatility of interest rates at which countries borrow can induce a contraction in consumption and investment.

Economists have proposed alternative measures of risk: (1) disagreement among forecasters, (2) stock market volatility, (3) interest rate volatility, and (4) tax rate volatility. All of these measures indicate that risk increases during periods of political and economic turmoil, such as President Kennedy's assassination, the 1987 stock market crash, and the recent financial crisis. Furthermore, these measures show that risk in the U.S. was low during the late 1980s and the first half of the 1990s.

REFERENCES

Baker, Scott, and Nicholas Bloom. "Does Uncertainty Drive Business Cycles? Using Disasters as a Natural Experiment," mimeo, Stanford University.

Bernanke, Ben. "Irreversibility, Uncertainty, and Cyclical Investment," *Quarterly Journal of Economics* 97:1 (1983).

Bloom, Nicholas. "The Impact of Uncertainty Shocks," *Econometrica*, 77:3 (May 2009), pp. 623-85.

Bloom, Nicholas, Max Floetotto, and Nir Jaimovich. "Really Uncertain Business Cycles," mimeo, Stanford University (2009).

Carlson, Mark. "A Brief History of the 1987 Stock Market Crash," Board of Governors of the Federal Reserve System, Finance and Economics Discussion Series 2007-13 (2007).

Ellsberg, Daniel. "Risk, Ambiguity, and the Savage Axioms," *Quarterly Journal of Economics* 75:4 (1961).

Epstein, Larry, and Tan Wang. "Intertemporal Asset Pricing under Knightian Uncertainty," *Econometrica*, 63 (1994).

Fernandez-Villaverde, Jesus, Pablo Guerron-Quintana, Juan Rubio-Ramirez, and Martin Uribe. "Risk Matters: The Real Effects of Volatility Shocks," *American Economic Review*, 10:6 (2011), pp. 2530-61.

Fernandez-Villaverde, Jesus, Pablo Guerron-Quintana, Keith Kuester, and Juan Rubio-Ramirez. "Fiscal Volatility Shocks and Economic Activity," Federal Reserve Bank of Philadelphia Working Paper 11-32/R (January 2012).

Heisenberg, Werner. "Quantum Theory and Measurement," *Zeitschrift für Physik* 43 (1927), pp. 172–98.

Knight, Frank H. *Risk, Uncertainty, and Profit*. Boston: Houghton Mifflin, 1921.

LeRoy, Stephen, and Larry Singell. "Knight on Risk and Uncertainty," *Journal of Political Economy* 95:2 (1987), pp. 394-406.

Santomero, Anthony. "Monetary Policy in the Post 9/11 Environment: Stability Through Change," speech for the Global Interdependence Center's 22nd Annual International and Monetary Trade Conference, held at the Federal Reserve Bank of Philadelphia, October 2, 2003.

Smith, Eric, and Randall Wright. "Why Is Automobile Insurance in Philadelphia So Damn Expensive?" *American Economic Review*, 82 (1992), pp. 756-72.

Stock, James and Mark Watson. "Has the Business Cycle Changed and Why?," NBER *Macroeconomics Annual* (2002).

Whaley, Robert. "Understanding the VIX," *Journal of Portfolio Management*, 35 (Spring 2009), pp. 98-105.