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Fluctuations in Uncertainty[†]

Nicholas Bloom

Uncertainty is an amorphous concept. It reflects uncertainty in the minds of consumers, managers, and policymakers about possible futures. It is also a broad concept, including uncertainty over the path of macro phenomena like GDP growth, micro phenomena like the growth rate of firms, and noneconomic events like war and climate change. In this essay, I address four questions about uncertainty.

First, what are some facts and patterns about economic uncertainty? Both macro and micro uncertainty appear to rise sharply in recessions and fall in booms. Uncertainty also varies heavily across countries—developing countries appear to have about one-third more macro uncertainty than developed countries.

Second, why does uncertainty vary during business cycles? The types of exogenous shocks that can cause recessions—like wars, oil price jumps, and financial panics—typically also increase uncertainty. Uncertainty also appears to endogenously increase during recessions, as lower economic growth induces greater micro and macro uncertainty.

Third, do fluctuations in uncertainty affect behavior? Greater uncertainty appears to reduce the willingness of firms to hire and invest, and consumers to spend. However, there is also some evidence that uncertainty can stimulate research and development—faced with a more uncertain future, some firms appear more willing to innovate.

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[†] To access the Appendix and disclosure statement, visit
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Fourth, has higher uncertainty worsened the Great Recession and slowed the recovery? A 2008 jump in uncertainty was likely an important factor exacerbating the size of the economic contraction, accounting for maybe one-third of the drop in the US GDP.

Much of this discussion is based on research on uncertainty from the last five years, reflecting the recent growth of the literature. This surge in research interest in uncertainty has been driven by several factors. First, the jump in uncertainty in 2008 and its likely role in shaping the Great Recession has focused policy attention onto the topic. Second, the increased availability of empirical proxies for uncertainty, such as panels of firm-level outcomes, online news databases, and surveys, has facilitated empirical work. Third, the increase in computing power has made it possible to include uncertainty shocks directly in a wide range of models, allowing economists to abandon assumptions built on "certainty equivalence," which refers to the amount of money that would be required as compensation for risk. While there has been substantial progress, a range of questions remain open around the measurement, cause, and effect of uncertainty, making this a fertile area for continued research.

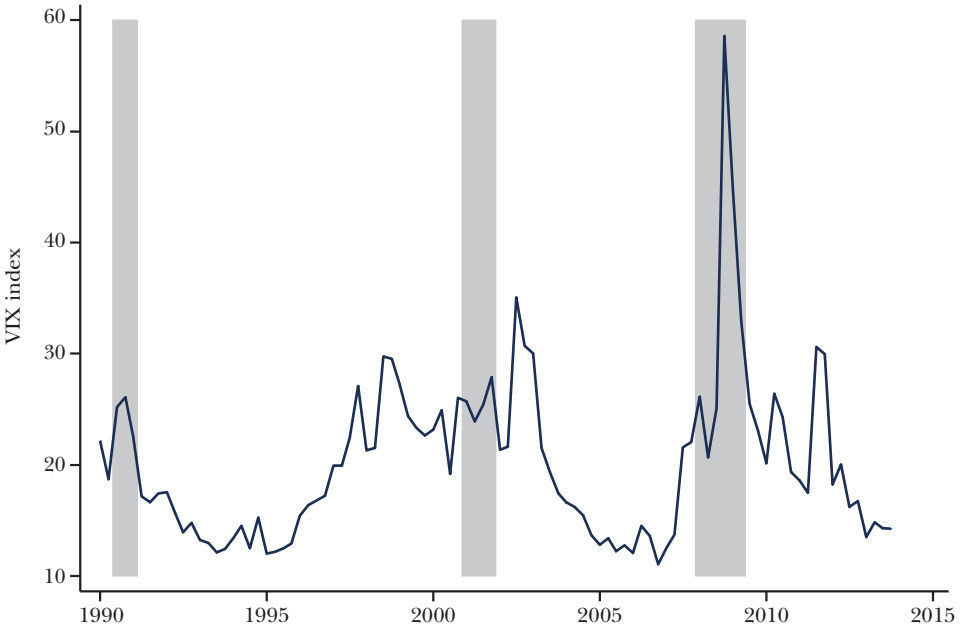
The Facts of Uncertainty

Frank Knight (1921), the famous Chicago economist, created the modern definition of *uncertainty*. Knight started by defining the related concept of *risk*, which he argued describes a known probability distribution over a set of events. In his terminology, flipping a coin is risky—for a fair toss there is a 50 percent chance of heads and a 50 percent chance of tails. In contrast, Knight defined *uncertainty* as peoples' inability to forecast the likelihood of events happening. For example, the number of coins ever produced by mankind is uncertain. To calculate this would require estimating the distribution of coins minted across the hundreds of countries that exist today and throughout history, a task where most people would have no idea even how to begin.

In this article, I'll refer to a single concept of uncertainty, but it will typically be a stand-in for a mixture of risk and uncertainty. Given this broad definition of uncertainty, it should be unsurprising that there is no perfect measure but instead a broad range of proxies. The volatility of the stock market or GDP is often used as a measure of uncertainty because when a data series becomes more volatile it is harder to forecast. Other common measures of uncertainty include forecaster disagreement, mentions of "uncertainty" in news, and the dispersion of productivity shocks to firms. I start by highlighting four key facts about uncertainty based on these proxies.[1]

[1] All the data used in this paper is available in an online Appendix available with this paper at http://e-jep.org, and also at my website in this zip file: http://www.stanford.edu/~nbloom/JEPdata.zip.

Figure 1
Stock-Market Implied Volatility is Higher in Recessions



Source: Author using data from the Chicago Board of Options and Exchange.
Notes: Figure 1 shows the VIX index of 30-day implied volatility on the Standard & Poor's 500 stock market index. The VIX index is traded on the Chicago Board Options Exchange. It is constructed from the values of a range of call and put options on the Standard & Poor's 500 index, and represents the market's expectation of volatility over the next 30 days. Gray bars are NBER recessions.

Fact 1: Macro Uncertainty Rises in Recessions

The volatility of stock markets, bond markets, exchange rates, and GDP growth all rise steeply in recessions. In fact, almost every macroeconomic indicator of uncertainty I know of—from disagreement amongst professional forecasters to the frequency of the word "uncertain" in the *New York Times* (Alexopolous and Cohen 2009)—appears to be countercyclical.

As one example, Figure 1 shows the VIX index of 30-day implied volatility on the Standard & Poor's 500 stock market index. The VIX index is traded on the Chicago Board Options Exchange. It is constructed based on the values of a range of call and put options on the Standard & Poor's 500 index and represents the market's expectation of volatility over the next 30 days. The VIX index is clearly countercyclical, rising by 58 percent on average in recessions (the shaded areas in the figure) as dated by the National Bureau of Economic Research.

One explanation for this surge in stock market volatility in recessions is the effect of leverage. In recessions, firms usually take on more debt, which increases their stock-returns volatility. However, Schwert (1989) calculates that the leverage effect can explain at most 10 percent of this rise in uncertainty during recessions.

Another explanation is that increased risk aversion during recessions will tend to increase the prices of options (because options provide insurance against large price movements), biasing up this measure of uncertainty. However, these fluctuations in the VIX are too large to be explained by plausible movements in risk aversion (Bekaert, Hoerova, and Lo Duca 2013). Moreover, it is not just stock markets that become more volatile in recessions. Other financial prices like exchange rates and bond yields also experience surging volatility in recessions.

An alternative proxy of uncertainty is disagreement amongst professional forecasters. Periods when banks, industry, and professional forecasters hold more diverse opinions are likely to reflect greater uncertainty. Examining data from the Philadelphia Federal Reserve panel of about 50 forecasters shows that between 1968 and 2012 the standard deviation across forecasts of US industrial production growth was 64 percent higher during recessions, similar to results from European countries (Bachmann, Elstner, and Sims 2010). So forecaster disagreement is sharply higher in downturns.

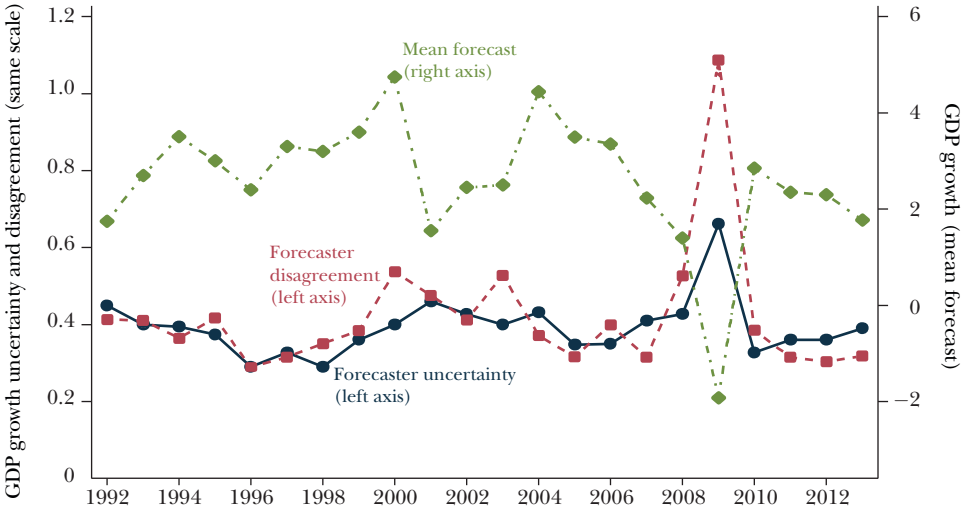
A related proxy is how uncertain forecasters are about their own forecasts, which is called subjective uncertainty. The Philadelphia Federal Reserve has since 1992 asked forecasters to provide probabilities for GDP growth (in percent) falling into ten different bins: "<-2," "-2 to -1.1," "-1 to -0.1," and so forth up to ">6." Figure 2 plots the mean of forecasters' subjective uncertainty calculated using these probabilities (solid line) alongside the forecast mean (dot-dash line), plus for comparison the disagreement across forecasters (dash line). We see that both uncertainty and disagreement rose sharply during the Great Recession.

Yet another proxy for uncertainty is the frequency of newspaper articles about economic uncertainty. Figure 3 shows the Baker, Bloom, and Davis (2012) measure of economic policy uncertainty, which counts the frequency of articles containing the words "uncertain or uncertainty" and "economy or economics" and one of six policy words across ten leading US newspapers. Again, this measure is clearly countercyclical, with its level 51 percent higher on average during recessions. A related proxy is the count of the word "uncertain" in the Federal Reserve's Beige Book. The Beige Book is a 15,000 word overview of the US economy published after each meeting of the Federal Reserves Open Market Committee. Even here we see evidence for higher uncertainty in recessions: the word "uncertainty" is used 52 percent more often during recessions (Baker, Bloom, and Davis 2012).

An eclectic mix of other indicators of macro uncertainty also rises in recessions. Scotti (2013) measures the size of the surprise when economic data is released: that is, she compares the pre-release date expectations (from Bloomberg's median forecast) for categories like nonfarm payroll and quarterly GDP with their release values. She finds these surprises are 36 percent larger in recessions, suggesting forecasts are less reliable in downturns. Jurado, Ludvigson, and Ng (2013) use data on hundreds of monthly economic data series in a system of forecasting equations and look at the implied forecast errors. By their calculations, forecast errors rise dramatically in large recessions, most notably during

Figure 2

GDP Growth Forecaster Uncertainty and Disagreement Both Rose Significantly during the Great Recession

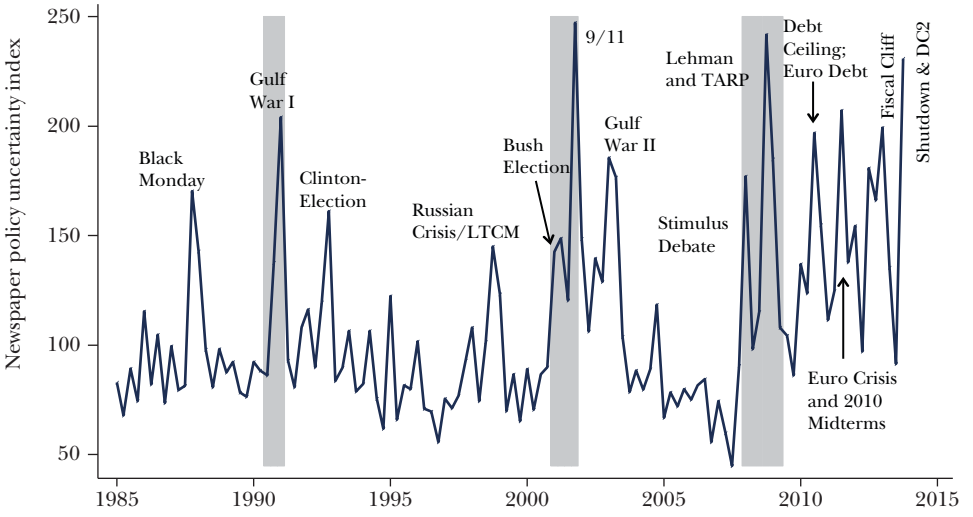


Source: Author using data on the forecaster probability distributions of GDP growth rates from the Philadelphia Survey of Professional Forecasters.

Notes: "Mean forecast" is the average forecaster's expected GDP growth rate, "Forecaster disagreement" is the cross-sectional standard deviation of forecasts, and "Forecaster uncertainty" is the median within forecaster subjective variance. Data are only available on a consistent basis since 1992Q1, with an average of 48 forecasters per quarter.

Figure 3

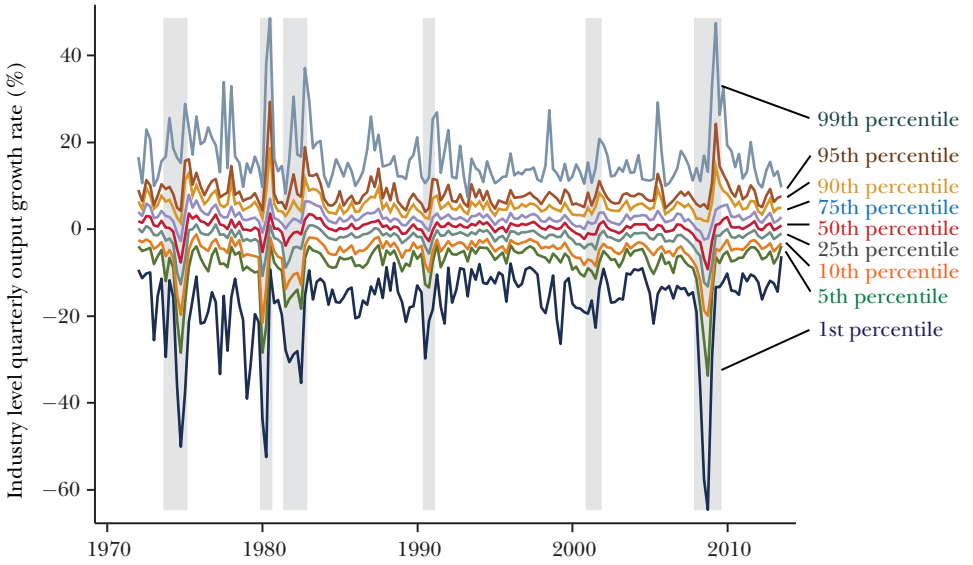
Newspaper Policy Uncertainty Index is 51 percent Higher in Recessions



Source: Data is from Baker, Bloom, and Davis (2012).

Notes: The figure shows the Baker, Bloom, and Davis (2012) measure of economic policy uncertainty, which counts the frequency of articles containing the words "uncertain or uncertainty" and "economy or economics" and one of six policy words in ten leading US newspapers. Data from 1985Q1 to 2013Q4, normalized to 100 for the period 1985 to 2009. Gray bars are NBER recessions.

Figure 4
Industry Growth Rate Spreads Increase in Recessions



Notes: The figure shows the 1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th and 99th percentiles of three-month percentage growth rates of industrial production for all 196 manufacturing NAICS sectors in the Federal Reserve Boards' industry database. Data spans 1972Q1–2013Q3. Gray bars are NBER recessions.

the OPEC I recession (1973–1974), the early 1980s rust-belt recession (1982), and the Great Recession (2007–2009). Nakamura, Sergeyev, and Steinsson (2012) used over 100 years of consumption data from 16 OECD countries to estimate short- and long-run fluctuations in volatility, again finding that this volatility rises strikingly in periods of lower growth.

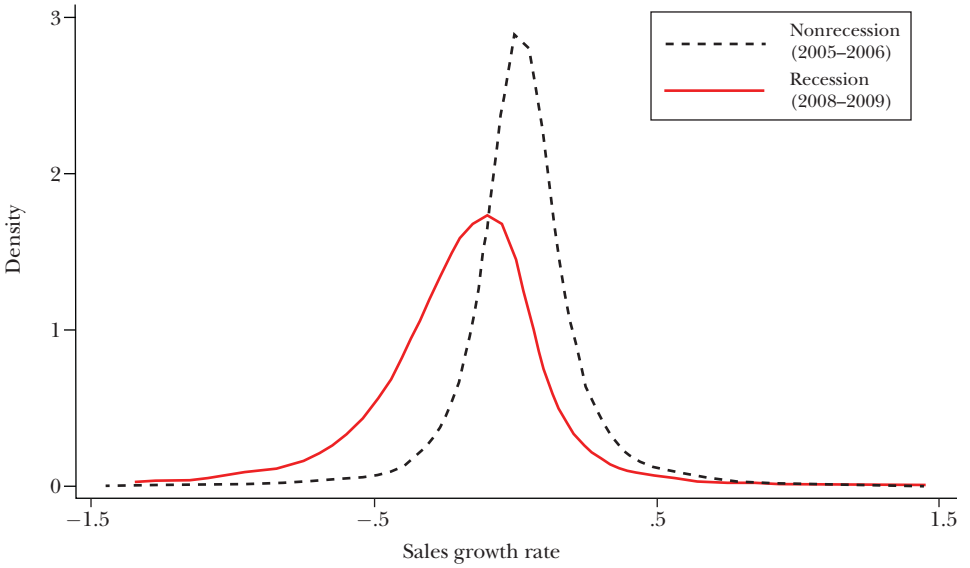
Fact 2: Micro Uncertainty Rises in Recessions

We can drop down a level of aggregation from looking at macro data to looking at micro data on individual industries, firms, and plants. At every level, uncertainty appears to rise during recessions. This result is in some senses "fractal"—that is, uncertainty rises in recession at each level of disaggregation.

For example, Figure 4 is based on a panel of about 200 manufacturing industries. The lines are based on the rate of industry output growth, and they show how different percentiles perform across these industries. During recessions, these percentiles widen out as some industries do well while others are hit hard. This increased dispersion is a proxy for industry-level uncertainty because it suggests that industries are getting larger industry-level shocks during recessions.

Uncertainty as proxied by dispersion at the firm and plant level also surges in recessions. For example, Campbell, Lettau, Malkiel, and Xu (2001) report that

Figure 5
Plant Uncertainty—Sales Growth Dispersion

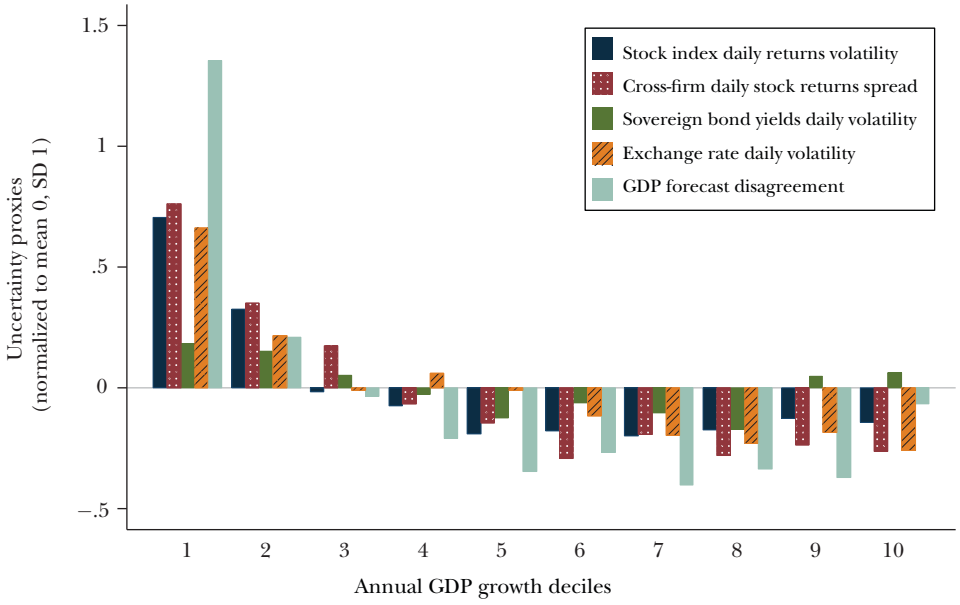


Source: Bloom, Floetotto, Jaimovich, Saporta-Eksten, and Terry (2012).
Notes: Figure 5 plots the dispersion of sales growth rates for a panel of plants within the US manufacturing for Great Recession of 2008–2009 (the solid line) against their values for the pre-recession period of 2005–2006 (the dashed line). Constructed from the Census of Manufactures and the Annual Survey of Manufactures using a balanced panel of 15,752 establishments active in 2005–2006 and 2008–2009. Moments of the distribution for nonrecession (recession) years are mean 0.026 (−0.191), variance 0.052 (0.131), coefficient of skewness 0.164 (−0.330), and kurtosis 13.07 (7.66). The year 2007 is omitted because according to the NBER the recession began in December 2007, so 2007 is not a clean "before" or "during" recession year.

cross-firm stock-return variation is almost 50 percent higher in recession than booms. Likewise, the dispersion of plant-level shocks to total factor productivity rises sharply in recessions (Kehrig, 2011; Bloom, Floetotto, Jaimovich, Saporta-Eksten, and Terry 2012). For example, Figure 5 plots the dispersion of sales growth rates for a balanced panel of about 16,000 plants within the US manufacturing sector for the Great Recession of 2008–2009 (the solid line) against their values for the pre-recession period of 2005–2006 (the dashed line). The variance of plants' sales growth rates rose by a massive 152 percent during the Great Recession, a striking jump in sales dispersion.

Digging down even further to individual product prices, yet again we find a similar story. Vavra (2013) analyzed price changes from the Bureau of Labor Statistics on tens of thousands of products, such as a one-liter bottle of Coca-Cola or a pack of four Duracell AAA batteries. They find price changes for even these kinds of items were about 50 percent more volatile during recessions.

Figure 6
Uncertainty Measures Are Countercyclical Across Countries



Source: Baker and Bloom (2013).
Notes: Figure 6 is based on annual data for 60 developing and developing countries over the period 1970 to 2012. Each country-year is placed into a bin based on the decile of their annual growth rates, with bins from 1 to 10, where 1 is the lowest decile of growth and 10 is the highest decile. So, for example, for the United States, bin 1 is growth rates of below −0.3 percent, bin 2 is growth rates of −0.3 percent to 1.2 percent, bin 3 are growth rates of 1.2 percent to 1.9 percent, and so on, while for the United Kingdom bin 1 is growth rates of below −0.8 percent, bin 2 is growth rates of −0.8 percent to 0.6 percent, and so on. The uncertainty measures plotted for each bin are averages for each country-year in the bin. Each decile shows five different measures of uncertainty: stock market volatility, firm stock-returns dispersion, bond-yield volatility, exchange rate volatility, and macro forecaster disagreement—with each measure normalized to a mean 0 and standard deviation 1.

This increase in both macro and micro uncertainty during recessions is also true on the global scale. Figure 6 is based on annual data for 60 developed and developing countries over the period 1970 to 2012. Each country-year is placed into a bin based on the deciles of a country's annual growth rates, with bins from 1 to 10 where 1 is the lowest decile of growth and 10 is the highest decile. So, for example, for the United States, bin 1 is for growth rates of below −0.3 percent, bin 2 is for growth rates of −0.3 percent to 1.2 percent, bin 3 is for growth rates of 1.2 percent to 1.9 percent, and so on, while for the United Kingdom, bin 1 is for growth rates of below −0.8 percent, bin 2 is for growth rates of −0.8 percent to 0.6 percent, and so on. The uncertainty measures plotted for each bin are averages over each country-year in the bin. Each decile shows five different measures of uncertainty: stock market volatility, firm stock-returns dispersion, bond-yield volatility, exchange rate volatility, and macro forecaster disagreement—with each measure normalized to a mean 0 and standard deviation 1.

All five of these measures of uncertainty are higher when country growth is lower, particularly when growth is in its lowest decile, which is typically during a recession. This highlights the global robustness of the link between recessions and uncertainty.

Fact 3: Wages and Income Volatility Appear to Be Countercyclical

Unemployment rises during a recession, so the volatility of household incomes will rise as well. But perhaps less expected is that wages for even those who are employed also become more volatile during recessions (Meghir and Pistaferri 2004; Storesletten, Telmer, and Yaron 2004; Heathcote, Perri, and Violante 2010). This is particularly true for lower-wage workers, whom Guvenen, Ozkan, and Song (forthcoming) show face a particularly large surge in income volatility during recession. Thus, the increasing volatility of macro, industry, firm, and plant outcomes in recessions translates into higher volatility of wages for employees.

Fact 4: Uncertainty Is Higher in Developing Countries

Low-income countries in regions like Africa and South America tend to have the most volatile GDP growth rates, stock markets, and exchange rates. In fact, the World Bank's *World Development Report 2014*, themed "Risk and Opportunity," focused on how households and firms in developing countries face a huge variety of macro and micro risks (World Bank 2013). In the panel of 60 countries with available growth and financial data I examined, those with low incomes (less than $10,000 GDP per capita) had 50 percent higher volatility of growth rates, 12 percent higher stock-market volatility, and 35 percent higher bond-market volatility, so overall developing countries experience about one-third higher macro uncertainty.

Why Does Uncertainty Vary?

What factors might be causing these variations in uncertainty? I will first focus on factors that might cause uncertainty to fluctuate over time. I'll then turn to some reasons for the higher uncertainty in low-income and emerging economies. Of course, identifying possible causes of uncertainty is only one step; the later discussion will consider evidence on the effects of uncertainty.

Bad events often seem to increase uncertainty, events like oil-price shocks, terrorist attacks, and wars. For example, in Bloom (2009), I defined 17 uncertainty shocks from 1962 to 2008 on the basis of jumps in stock market volatility and found that all but one was bad news (in that they lowered expected growth). These uncertainty shocks included the assassination of President Kennedy, the Cuban missile crisis, the OPEC oil price shocks, the 9/11 attack, and the Gulf Wars. All these dramatic shocks seemed to shake people's confidence in their forecasts of economic growth, raising macro and micro uncertainty. The only uncertainty shock in this series associated with good news was the October 1982 business cycle turning point, a relatively minor uncertainty shock.

Why does good news so rarely cause an uncertainty shock? Perhaps good news often develops more gradually—like the fall of the Berlin Wall or the development of the Internet. These change beliefs more smoothly over time instead of causing large jumps in uncertainty. Indeed, it is hard to come up with any large good news shocks in recent US history. Or alternatively, perhaps bad news itself may induce uncertainty. We know from the previous section that recessions are associated with increased uncertainty. Maybe this is because slower growth increases uncertainty.

The theory literature highlights four mechanisms through which recessions might increase uncertainty. First, when business is good, firms are trading actively, which helps to generate and spread information (Van Nieuwerburgh and Veldkamp 2006; Fajgelbaum, Schaal, and Tashereau-Dumouchel 2013). But when business is bad, this activity slows down, reducing the flow of new information and thereby raising uncertainty. Second, individuals are more confident in predicting the future when "business as usual" prevails in a growing economy. Forecasting is harder during recessions (Orlik and Veldkamp 2014). This arises from the fact that recessions are rare events, so that people are unfamiliar with them. Third, public policy that is unclear, hyperactive, or both, may raise uncertainty. Pastor and Veronesi (2011) argue that when the economy is doing well, politicians prefer to stay largely with their current policies, following the old adage "if it isn't broke, don't fix it." But when the economy turns down, politicians are tempted to experiment, elevating economic policy uncertainty. Indeed, Baker, Bloom, and Davis (2012) find that policy uncertainty rises during recessions, particularly during the Great Recession. Fourth, when business is slack, it is cheap to try out new ideas and to divert unused resources to research and development (Bachman and Moscarini 2011; D'Erasmo and Moscoso-Boedo 2011). This dynamic leads to heightened micro uncertainty, potentially feeding into higher macro uncertainty.

When considering the reasons for higher uncertainty in lower-income countries, three mechanisms are typically mentioned (Koren and Tenereyo 2007; World Bank Development Report 2013). First, developing countries tend to have less-diversified economies—for example, they may export only a small number of products—so their entire economy is more exposed to fluctuations in the output and price of those goods. Second, many of the goods on which developing countries focus also have quite volatile prices: commodities like rubber, sugar, oil, and copper. Finally, developing countries appear to have more domestic political shocks like coups, revolutions, and wars; are more susceptible to natural disasters like epidemics and floods; and have less-effective fiscal and monetary stabilization policies.

Why Might Fluctuations in Uncertainty Matter: Theory

Having established that uncertainty fluctuates over time, to what extent does this matter? I will start by discussing the theory concerning the impact of shocks to uncertainty and then turn to the empirical evidence. The theoretical literature

emphasizes two negative channels for uncertainty to influence growth, but also highlights two positive channels of influence.

Real Options

The largest body of theoretical literature about the effects of uncertainty focuses on "real options" (Bernanke 1983; Brennan and Schwartz 1985; McDonald and Siegel 1986). The idea is that firms can look at their investment choices as a series of options: for example, a supermarket chain that owns an empty plot of land has the option to build a new store on the plot. If the supermarket becomes uncertain about the future—for example, because it is unsure if a local housing development will go ahead—it may prefer to wait. If the housing development proceeds, the supermarket can develop the site, and if not, it can continue to wait and avoid (for now) a costly mistake. In the language of real options, the option value of delay for the supermarket chain is high when uncertainty is high. As a result, uncertainty makes firms cautious about actions like investment and hiring, which adjustment costs can make expensive to reverse.

Investment adjustment costs have both a physical element (equipment may get damaged in installation and removal) and a financial element (the used-good discount on resale). Ramey and Shapiro (2001) and Cooper and Haltiwanger (2006) estimate these investment adjustment costs are extremely large at roughly 50 percent of the value of capital.[2] Hiring adjustment costs include recruitment, training, and severance pay, which in Nickell (1986) and Bloom (2009) are estimated at about 10 to 20 percent of annual wages. Schaal (2010) also emphasizes search frictions, showing how uncertainty can interact with search costs to impede labor markets in recessions.

However, real options effects are not universal. They arise only when decisions cannot be easily reversed; after all, reversible actions do not lead to the loss of an option. Thus, firms may be happy to hire part-time employees even when uncertainty is extremely high, because if conditions deteriorate, they can easily lay off these employees. In fact, because part-time employees are so flexible, firms may switch from hiring full-time to part-time employees during periods of high uncertainty, as indeed happens in recessions (Valetta and Bengali 2013).

Real options effects also rely on firms having the ability to wait. But if firms are racing, perhaps to be the first to patent a new idea or launch a new product, this option disappears. If delay would be extremely costly, then the option to delay is not valuable, breaking the negative real options effect of uncertainty on investment.

[2] The literature distinguishes two families of adjustment costs. There are lumpy "nonconvex" adjustment costs, which are fixed costs (a one-off cost to buy/sell capital) and partial irreversibility (a cost per unit of capital sold). These "nonconvex" adjustment costs generate real options effects. There are also smooth "convex" adjustment costs like quadratic adjustment costs (a cost that increases in the squared rate of investment), which do not generate real options. For details, see Dixit and Pindyck (1994) and Abel and Eberly (1996).

Finally, real options require that actions that are taken now influence the returns to actions taken later. But in some situations—like firms producing with a constant-returns-to-scale technology and selling into a perfectly competitive market—the choice of investment this period will have no effect on the profitability of investment next period, leading to no option value from waiting. Thus, another requirement of the real options literature is that firms are selling into imperfectly competitive markets and/or operating with a decreasing-returns-to-scale technology.

Turning from investment to consumption, an analogous channel arises for uncertainty to cause postponed consumption. When consumers are making decisions on buying durables like housing, cars, and furniture, they can usually delay purchases relatively easily (see, for instance, Eberly 1994). For example, people may be thinking about moving to another house, but they could either move this year or wait until next year. This option value of waiting will be much more valuable when income uncertainty is higher—if, for example, you are unsure about whether a major promotion will arrive by the end of this year, it makes sense to wait until this is decided before undertaking an expensive house move. Delaying purchases of nondurables like food and entertainment is harder, so the real options effects of uncertainty on nondurable consumption will be lower.

The real option argument not only suggests that uncertainty reduces *levels* of investment, hiring, and consumption, but it also makes economic actors *less sensitive* to changes in business conditions. This can make countercyclical economic policy less effective. For example, in low-uncertainty periods, the elasticity of investment with respect to interest rates might be -1, but when uncertainty is very high, this elasticity could fall to -0.25. Similarly, higher uncertainty should also make consumers' durables expenditures less sensitive to demand and prices signals, something Foote, Hurst, and Leahy (2000) and Bertola, Guiso, and Pistaferri (2005) report in studies of US and Italian consumers.

In other words, just as the economy is heading into recession, higher uncertainty can make monetary and fiscal stabilization tools less effective. Firms and consumers are likely to respond more cautiously to interest-rate and tax cuts when they are particularly uncertain about the future, dampening the impact of any potential stimulus policy. Because of this shift, stimulus policy may need to be more aggressive during periods of higher uncertainty. A related argument is that aggressive stimulus policies are helpful for reducing uncertainty by providing reassurance that the government is taking action to stabilize the economy.

This channel whereby uncertainty reduces firms' sensitivity also provides an explanation for procyclical productivity, an empirical regularity found in many modern studies of business cycles (King and Rebelo 1999). When uncertainty is high, productive firms are less aggressive in expanding and unproductive firms are less aggressive in contracting. The high uncertainty makes both of them more cautious. This caution produces a chilling effect on the productivity-enhancing reallocation of resources across firms. Because reallocation appears to drive the majority of aggregate productivity growth (for example, Foster, Haltiwanger, and Krizan 2000, 2006), higher uncertainty can stall productivity growth. This productivity impact

of uncertainty shocks underlies the theories of uncertainty-driven business cycles, which emphasize how uncertainty shocks reduce investment, hiring, and productivity (Bloom et al. 2012). The difference with more-traditional real business cycle models (for example, Kydland and Prescott 1982) is that in the uncertainty-driven theory, the fall in productivity growth is an outcome of the uncertainty shock, rather than the shock itself.

Risk Aversion and Risk Premia

Investors want to be compensated for higher risk, and because greater uncertainty leads to *increasing risk premia*, this should raise the cost of finance. Furthermore, uncertainty also increases the probability of default, by expanding the size of the left-tail default outcomes, raising the default premium and the aggregate deadweight cost of bankruptcy. This role of uncertainty in raising borrowing costs can reduce micro and macro growth, as emphasized in papers on the impact of uncertainty in the presence of financial constraints (Arellano, Bai, and Kehoe 2010; Christiano, Motto, and Rostagno 2014; Gilchrist, Sim, and Zakrasjek 2011).

Another mechanism related to risk premia is the *confidence* effect of uncertainty in models where consumers have pessimistic beliefs (for example, Hansen, Sargent, and Tallarini 1999; Ilut and Schneider 2011). In these models, agents are so uncertain about the future they cannot form a probability distribution. Instead they have a range of possible outcomes and act as if the worst outcomes will occur, displaying a behavior known as "ambiguity aversion." As the range of possible outcomes (uncertainty) expands, the worst possible outcome gets worse, so agents cut back on investment and hiring. Of course this assumes agents are pessimistic, but if instead agents are optimistic (that is, they assume the best case) as Malmendier and Tate (2005) hint at for CEOs, then uncertainty can actually have a positive impact.

A rise in uncertainty risk should also lead consumers to increase their *precautionary saving*, which reduces consumption expenditure (for example, Bansal and Yaron 2004). This effect is likely contractionary for an economy in the short run, but the long-run effects are less clear. After all, at least in theory, lower consumption and greater saving may allow a rise in investment, which could then benefit long-term growth. However, in most open economies some of this increased saving will flow abroad, reducing domestic demand. For this reason, Fernández-Villaverde, Guerrón-Quintana, Rubio-Ramirez, and Uribe (2011) argue that rising uncertainty can be crippling for growth in smaller highly open countries, as domestic money flees the country.

What about the effect of a rise in precautionary saving in larger and more closed countries like the United States? At first, it would seem that uncertainty may have potentially positive effects—by encouraging consumers to save, this will increase investment (because savings equals investment in closed economies). But as several recent papers have noted, if prices are sticky (as New Keynesian models commonly assume), uncertainty shocks can lead to recessions even in closed economies because prices do not fall enough to clear markets (for example, Leduc and Liu 2012; Basu and Bundick 2011; Fernández-Villaverde, Guerrón-Quintana,

Kuester, and Rubio-Ramirez 2011). The intuition is that uncertainty increases the desire of consumers to save, which should cut interest rates and output prices, stimulating an offsetting rise in investment; but if prices are sticky, this effect does not happen—prices and interest rates do not fall enough to encourage the offsetting rise in investment—so that output falls. This effect of uncertainty can be particularly damaging if interest rates are constrained at zero by the lower bound, as has been the case during much of the last five years.

Another precautionary effect of uncertainty may affect firms through the incentives of their chief executive officers. Most top corporate executives are not well diversified: both their personal financial assets and their human capital are disproportionately tied up in their firm. Hence, when uncertainty is high, these executives may become more cautious in making long-run investments. For example, the chief executive officer of an oil exploration company may become increasingly nervous when the price of oil becomes volatile, leading that firm to take a more cautious position on oil exploration. Panousi and Pananikolaou (2012) have shown in a panel of US firms that when uncertainty is higher, investment drops, particularly in firms where the chief executive officers hold extensive equity in the firm and so are highly exposed to firm-level risk.

Growth Options

There are two mechanisms through which uncertainty can potentially have a positive effect on long-run growth. The "growth options" argument is based on the insight that uncertainty can encourage investment if it increases the size of the potential prize. For example, Bar-Ilan and Strange (1996) note that if firms have long delays in completing projects—perhaps because of time-to-build or time-to-develop—then uncertainty can have a positive effect on investment. As an illustration, consider a pharmaceutical company developing a new drug that notices that a mean-preserving increase in demand uncertainty has occurred. The costs of bad draws (for example, the drug turns out to be ineffective or unsafe) have a limited lower bound because the firm can cancel the product losing only its sunk research and development costs. But good draws (the product turns out to be even more useful and profitable than expected) are not constrained in this way. In this situation, a rise in mean-preserving risk means higher expected profit when the product goes to market.[3]

Growth options were often invoked to explain the dot-com boom of the late 1990s. Firms were unsure about the Internet but that uncertainty encouraged investment. The worst outcome for firms starting new websites was losing their development costs, while the best outcome looked ever more profitable as the range

[3] This is sometimes called the "good news principle" that only good news matters in growth options because bad news is capped by closing down the project. This phrase originates from Bernanke (1983), who discussed the reverse "bad news principle" in terms of the classic real-options negative effects of uncertainty on investment. In a recent working paper, Segal, Shaliastovich and Yaron (2013) find interesting evidence for both these good news (growth option) and bad news (real option) effects of uncertainty in aggregate investment.

of uncertainty about the Internet expanded. Because developing websites took time, building one was seen as investing in a "call-option" on the future success of the Internet. Likewise, a literature on the value of oil drilling leases shows how these are call options on possible future extraction, so oil price uncertainty increases their value (Paddock, Siegel, and Smith 1988). More recently Kraft, Schwartz, and Weiss (2013) have shown how growth options are particularly important for research and development–intensive firms, so much so that higher uncertainty can raise their stock value.

Oi–Hartman–Abel Effects

The other channel I examine through which uncertainty can potentially increase growth is known as the Oi–Hartman–Abel effect (after Oi 1961; Hartman 1972; Abel 1983). This effect highlights the possibility that if firms can expand to exploit good outcomes and contract to insure against bad outcomes, they may be risk loving. For example, if a factory can easily halve production volumes if the price of its products falls and double production volumes if the price rises, it should desire a mean-preserving increase in uncertainty, because the firm gets 50 percent during bad outcomes and 200 percent during good outcomes. In effect, the factory is partly insured against bad outcomes by being able to contract and has the option to increase its advantage from good outcomes by being able to expand. (Formally, if profits are convex in demand or costs, then demand or cost uncertainty increases expected profits.) However, for this mechanism to work, firms need to be able to easily expand or contract in response to good or bad news, so while the Oi–Hartman–Abel effects are typically not very strong in the short run (because of adjustment costs), they can be more powerful in the medium and long run.

How Much Might Fluctuations in Uncertainty Matter: Empirics

The evidence on the impact of uncertainty is limited because of the difficulties in stripping out cause and effect. A central challenge in the uncertainty literature (as in macroeconomics as a whole) is to distinguish the impact of uncertainty from the impact of recessions. We know that uncertainty moves with the business cycle, which raises the question of how to distinguish the separate causal effects of higher uncertainty.

To identify the causal impact of uncertainty on firms and consumers, the literature has taken three approaches. One approach relies on timing: that is, estimating the movements in output, hiring, and investment that follow jumps in uncertainty. This approach works reasonably well for unexpected shocks to uncertainty but is more problematic if changes in uncertainty are predicted in advance or are correlated with other unobserved factors. A second approach uses structural models calibrated from macro and micro moments to quantify the potential effect of uncertainty shocks. This approach is conceptually well grounded, but like many

structural models, it is sensitive to somewhat debatable modelling assumptions. A third approach exploits natural experiments like disasters, political coups, trade changes, or movements in energy and exchange rates. The challenge here is over the generalizability of these results, and the extent to which these events influence firms and consumers beyond just changes in uncertainty.

My overall view is that this literature provides suggestive but not conclusive evidence that uncertainty damages short-run (quarterly and annual) growth, by reducing output, investment, hiring, consumption, and trade. The longer-run evidence of the effect of uncertainty on output is far more limited, and while my personal view is that uncertainty is damaging for growth, it is extremely hard to show this definitively. One reason is that while uncertainty appears to reduce short-run hiring and investment, it may also stimulate research and development, as some recent empirical work suggests. This may be because of the "growth options effect"—the idea that uncertainty increases the upside from innovative new products. As such, more empirical work on the effects of uncertainty would be valuable, particularly work which can identify clear causal relationships.

Timing Approaches to Estimating the Effect of Uncertainty Shocks

A standard approach in macroeconomic analysis has been to look at short-term economic fluctuations separately from long-term trends in economic growth. The classic macro study of uncertainty by Ramey and Ramey (1995) challenged this separation. They looked both at a broad sample of 92 countries from 1960 to 1985 and also at a narrower sample of high-income countries from 1950 to 1988. They considered an equation for forecasting GDP by country, and find that economies which depart most strongly from that forecast equation—an idea that they equate with a rise in uncertainty—experience lower growth rates. This negative volatility link with growth has been confirmed in a number of subsequent studies using more advanced estimations techniques (Engel and Rangel 2008) or different measures of uncertainty (Bloom 2009).

Other studies have considered how rising uncertainty might affect other macroeconomic outcomes. For example, Romer (1990) argues that the uncertainty created by the stock market crash of 1929 led to a drop in consumer spending on durable goods. Indeed, she finds a negative correlation between stock market volatility and purchases of consumer durables throughout the prewar period. Handley and Limão (2012) model the role of uncertainty in how firms make investment choices related to export markets. When they apply the model to the example of Portugal joining the European Community in 1986, they find that the removal of uncertainty accounted for a substantial rise in firm investment spending. Finally, Novy and Taylor (2014) use US data since the 1960s to examine the differential impact of uncertainty shocks across sectors to show that uncertainty significantly depresses trade flows and that this effect may explain about half of the collapse of global trade in 2008–2009.

A corresponding micro literature focuses on how uncertainty affects individual firms and households, again typically finding that higher uncertainty has

a negative impact. For example, Leahy and Whited (1996) examined a panel of several hundred US publicly listed manufacturing firms and found a strong relationship between uncertainty, proxied by the stock-price volatility for that firm, and investment, which they argue is consistent with theories of firms looking at investment as an irreversible choice. In Bloom, Bond, and Van Reenen (2007), we confirmed this result in data for 672 UK manufacturing firms from 1972–1991, using lagged firm accounting and financial data outcomes as instruments. Guiso and Parigi (1999) used a survey of Italian firms in 1993 in which the firms themselves reported the distribution of their expectations of future demand, and using this measure of uncertainty, they find a large negative relationship between uncertainty and investment.

Structural Models Estimating the Effect of Uncertainty Shocks

One structural approach is to build micro-to-macro general equilibrium models of firms and the economy, calibrating the key parameters against micro and macro data moments. For example, in Bloom et al. (2012) we build a general equilibrium model with heterogeneous firms with labor and capital adjustment costs and countercyclical micro and macro uncertainty. We find that the average increase in uncertainty that happens during recessions reduces output by about 3 percent during the first year, but with a rapid recovery in the second year. The reason for this rapid drop in output is that higher uncertainty leads firms to pause hiring and investment, cutting aggregate capital and labor through depreciation and attrition. Productivity growth also drops as reallocation freezes (productive plants do not expand and unproductive plants do not contract). However, once uncertainty starts to drop, pent-up demand for hiring and investment leads to a rapid rebound. Hence, uncertainty shocks generate short, sharp drops and rebounds in output.

These results, however, appear sensitive to assumptions on some of the parameter values in the model. For example, Bachmann and Bayer (2012, 2013) model general equilibrium models with heterogeneous agents and capital adjustment, finding much smaller impacts of uncertainty on growth. Their models differ from ours in that they exclude labor adjustment costs, place more weight on micro compared to macro uncertainty shocks, and have smaller fluctuations in uncertainty. Which set of assumptions is right is not obvious, and this highlights the need for richer micro and macro models to pin down these types of questions.

Another structural approach models individual firms' behavior, such as Kellogg's (forthcoming) study of drilling oil wells in Texas. He finds that jumps in oil price uncertainty lead firms to pause new drilling activity, with this response to uncertainty increasing their expected value from drilling new oil wells by up to 25 percent. Hence, for oil firms, it is extremely important to consider both the level and the uncertainty of future oil prices before drilling wells. Intriguingly, Kellogg also shows firms appear to use oil futures and derivatives from the New York Mercantile Exchange to predict future oil prices and volatility (rather than simply

extrapolating from historic prices), suggesting sophisticated forward-looking behavior on the part of drilling firms.

Using Natural Experiments to Estimate the Effect of Uncertainty

A recent approach to estimating the impact of uncertainty shocks has tried to exploit various macro and micro natural experiments. For example, in Baker and Bloom (2013), we sought to use natural disasters, terrorist events, and political shocks as instruments for uncertainty. We defined these events in terms of a minimum share of the population killed, a minimum share of GDP lost, or as resulting in a political regime change and considered data from 60 countries from 1970–2012. Stock market and news data shows that these events were not anticipated. We use the events to predict stock market volatility, and then use the stock market volatility that can be predicted from these shocks to forecast GDP growth. Across countries, the rise in volatility from these events explains about half of the variation in growth.

In another approach along these lines, Stein and Stone (2012) used the exposure of US firms to exogenous variations in energy and currency volatility as an instrument for the uncertainty that they face. They find that those firms exposed to greater uncertainty have lower investment, hiring, and advertising. Indeed, they estimate that uncertainty accounts for roughly a third of the fall in capital investment and hiring that occurred in 2008–2010, a subject taken up in greater detail in the next section. Interestingly, they also find that uncertainty seems to increase research and development spending, something that the growth options mechanism—the idea the more uncertainty yields a larger upside for long-run growth—can explain.

Has Higher Uncertainty Worsened the Great Recession and Slowed the Recovery?

Finally, I turn to the question of the importance of uncertainty in driving the recent Great Recession and sluggish recovery. Certainly, policymakers believe uncertainty has played an important role. For example, the Federal Reserve Open Market Committee (2008) noted that "participants reported that uncertainty about the economic outlook was leading firms to defer spending projects until prospects for economic activity became clearer." In 2009, Chief Economist of the International Monetary Fund (IMF) Olivier Blanchard wrote in *The Economist:* "Uncertainty is largely behind the dramatic collapse in demand. Given the uncertainty, why build a new plant, or introduce a new product? Better to pause until the smoke clears." The Chair of the Council of Economic Advisers, Christina Romer, noted in her 2009 testimony to the US Congress Joint Economic Committee: "Volatility, according to some measures, has been over five times as high over the past six months as it was in the first half of 2007. The resulting uncertainty has almost surely contributed to a decline in spending."

Such claims about the damaging impact of uncertainty have continued, with policymakers arguing it has also been responsible for the slow recovery. For

example, in 2012 the IMF Managing Director, Christine Lagarde, argued: "There is a level of uncertainty which is hampering decision makers from investing and from creating jobs" (IMF 2012). A joint European Union and OECD article in 2013 similarly noted that "high uncertainty is all the more damaging for growth as it magnifies the effect of credit constraints and weak balance sheets, forcing banks to rein in credit further and companies to hold back investment" (Buti and Padoan 2013). The International Labor Organization (ILO 2013) argued that "indecision of policy makers in several countries has led to uncertainty about future conditions and reinforced corporate tendencies to increase cash holdings or pay dividends rather than expand capacity and hire new workers."

But while policymakers clearly think uncertainty has played a central role in driving the Great Recession and slow recovery, the econometric evidence is really no more than suggestive. It is certainly true that every measure of economic uncertainty rose sharply in 2008. As one might guess from Figures 1 to 4, the level of uncertainty around 2008–2009 was more than triple the size of an average uncertainty shock and about twice as persistent as during an average recession. This jump in uncertainty reflects its role as both an impulse and a propagation mechanism for recessions. The shocks initiating the Great Recession—the financial crisis and the housing collapse—increased uncertainty. In particular, it was unclear how serious the financial and housing problems were, or what their impact would be nationally and globally, or what the appropriate policy responses should be. Furthermore, the Great Recession itself further increased uncertainty, leading the initial slowdown to be propagated and amplified over time.

For a rough calculation of the magnitude of the impact of uncertainty, I start with the drop in GDP during the Great Recession. This appears to be about 9 percent, consisting of the 3 percent drop in GDP over 2008 and 2009 versus the 6 percent rise that would have occurred if GDP had followed trend growth. Next, we need to estimate the impact of uncertainty on GDP growth. We can do this several ways, all of which yield reassuringly similar answers of about a 3 percent drop in GDP (around one-third of the total decline). One way is to take the 1 percent drop in GDP as estimated from vector autoregressions after an *average* uncertainty shock (Bloom 2009), and triple this, remembering that the 2008–2009 rise in uncertainty was about triple the "normal" uncertainty shock. Another approach is to take the structural model estimates from Bloom et al. (2012) of a 1.3 percent drop in GDP in the year after an *average* recessionary uncertainty shock, and again triple this. Finally, we can use the estimates from Stein and Stone (2012) who aggregate up from micro-data instrumental variable results, again finding that an uncertainty shock the size of the one experienced during the Great Recession reduced output by about 3 percent.

Concluding Thoughts

A range of evidence shows that uncertainty rises strongly in recessions, at both the macro and micro levels. More speculatively, I have argued this is because

increases in uncertainty are both part of the impulse arising from bad news shocks that start recessions, and because uncertainty amplifies recessions by rising further as growth slows.

The empirical literature on uncertainty is still at an early stage with many open research questions. First and most immediately, the question over the causality of uncertainty and growth is still unclear, and more work exploiting both natural experiments and structural models would be very valuable. Second, our measures of uncertainty are far from perfect and in fact are best described as proxies rather than real measures. Developing a wider set of uncertainty measures is important. For example, there is little data on the time horizon of uncertainty (short-run versus long-run uncertainty), on types of uncertainty (demand versus supply, technology versus policy), or on the nature of uncertainty (risk versus Knightian).

The literature on the policy implications of uncertainty is also at an early stage. The basic lessons seem to be twofold. First, uncertainty shocks appear to lead to short, sharp drops and recoveries in output, which if a policymaker wanted to stabilize, would require a similarly short, sharp macroeconomic stimulus to achieve stabilization. Second, policy should try to address the root cause of the uncertainty—an approach more likely to be effective than treating the symptoms (the drop in output). For example, during the Great Recession, I believe that one of the most important policy responses was to stabilize the financial system, helping to stem the rise in financial uncertainty.

But many policy questions remain. If public policy becomes more rule based, would this help to reduce policy uncertainty, or, by limiting flexibility, would rules impede the ability of policymakers to address uncertainty by judicious interventions? For example, quantitative easing has been used heavily by US monetary authorities to try and stabilize demand, but is clearly different from the recent history of interest rate manipulation. If public policy was communicated more transparently, would this act to reduce uncertainty, or would it introduce greater volatility by generating more frequent jumps in financial markets after each policy pronouncement? The Federal Reserve is grappling with these questions as it seeks to be more transparent in signaling the path of monetary policy.

While the empirical progress on fluctuations in uncertainty over the last decade has been exciting, there is still much about uncertainty about which we remain uncertain.

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