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Fluctuations in Uncertainty

By

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Abstract: This review article tries to answer four questions: (i) what are the stylized facts about uncertainty over time; (ii) why does uncertainty vary; (iii) do fluctuations in uncertainty matter; and (iv) did higher uncertainty worsen the Great Recession of 2007-2009? On the first question both macro and micro uncertainty appears to rise sharply in recessions. On the second question the types of exogenous shocks like wars, financial panics and oil price jumps that cause recessions appear to directly increase uncertainty, and uncertainty also appears to endogenously rise further during recessions. On the third question, the evidence suggests uncertainty is damaging for short-run investment and hiring, but there is some evidence it may stimulate longer-run innovation. Finally, in terms of the Great Recession, the large jump in uncertainty in 2008 potentially accounted for about one third of the drop in GDP.

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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 non-economic events like war and climate change. In this essay, I try to address four questions about uncertainty.

First, what are some facts and patterns about economic uncertainty? I argue both macro and micro uncertainty appears 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? I argue 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 rise further during recessions, as the economic slowdowns increases micro and macro volatility.

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.

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 U.S. GDP. So it was a substantial factor in the Great Recession.

Much of this 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, on-line news databases and surveys, have facilitated empirical work. Third, the increase in computer power has made it possible to include uncertainty shocks in a wide range of models, allowing economists to abandon assumptions like certainty equivalence. But while there has been substantial progress a range of questions remain open, particularly around the measurement, cause and effect of uncertainty, making this a fertile area for continued research.

The Facts of Uncertainty[2]

Frank Knight (1921), the famous Chicago economist, created the modern definition of *uncertainty*. Knight's started by defining the related concept of *risk*, which he argued describes a known probability distribution over a set of events. For example, flipping a coin is risky – for a fair toss there is a 50% chance of heads and a 50% 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, an impossible task for most people.

In this article I'll refer to a single concept of uncertainty, but this will typically be a stand-in for a mixture of risk and uncertainty. Not surprisingly, given this broad definition of uncertainty 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. Based on these proxies I start by highlighting four key facts about uncertainty.

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 – 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 1a 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 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. The VIX index is clearly countercyclical, rising by 58 percent on average in recessions (the shaded areas as dated by the National Bureau of Economic Research). Figure 1b shows the *realized* volatility of daily returns on the S&P500 – that is the standard-deviation within each month of the actual daily returns on the S&P500 - which again clearly rises in recessions. Figure 1c shows realized and implied stock-market volatility both lead the cycle – they start to rise about 3 months in advance of a slowdown in industrial production – so they provide a leading indicator of economic activity since these volatility measures are available real-time.

[2] 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 http:// www.stanford.edu/~nbloom/JEPdata.zip.

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). And it is not just stock-markets which become more volatile in recessions. Other financial prices like exchange-rates and bond yields also have 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 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*" up to "*6+*". We plot the mean of forecasters' subjective uncertainty calculated using these probabilities in Figure 2 (solid line, circles) alongside the forecast mean (dot-dash line, crosses), plus for comparison the disagreement across forecasters' (dash line, squares). We see that both uncertainty and disagreement more than doubled during the Great Recession, with a milder rise of about 50 percent during the recession of 2001.

Yet another proxy for uncertainty is the frequency of newspaper articles about economic uncertainty. Figure 3a shows the Baker, Bloom and Davis (2013) 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. Again, this is clearly countercyclical, rising by 51 percent 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 FOMC meeting. Even here we see evidence for higher uncertainty in recessions - the word "uncertainty" is used 52% more often during recessions (Baker et al. (2013). Figure 3b shows this newspaper index of uncertainty leads the cycle – it starts rising about 3 months ahead of slowdowns in industrial production – so it is a leading indicator of economic activity since it is available real-time.

An eclectic mix of other indicators of macro uncertainty also rise 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) like for things like non-farm 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 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 (the whole economy) to looking at micro data (individual industries, firms and plants). Intriguingly, at every level, uncertainty appears to rise during recessions. This result is in some senses 'fractal' - at each level of disaggregation uncertainty rises in recession.

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 get hit hard. This increased dispersion is a proxy for industry level uncertainty as 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 et al. (2001) report how 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 et al. 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 for Great Recession of 2008-2009 (the solid line) against their values for pre-recession of 2005-2006 (the dashed line). The variance of plant 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.

This increase in both macro and micro uncertainty during recessions is also true on the global scale. For example, Figure 6 plots growth rate for 60 developed and developing countries on the horizontal x axis in deciles of their annual GDP growth rates. On the vertical y axis it plots 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 if 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) and Heathcote, Perri and Violante (2009)). This is particularly true for lower wage workers, whom Guvenen, Ozkan and Song (2013) show face a particularly large surge in income volatility during recession. So the increasing volatility of macro, industry, firm and plant outcomes in recessions translates into high 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 2013 Development Report was themed "*Risk and Opportunity*," focusing on how households and firms in developing countries face a huge variety of macro and micro risks. In the panel of 60 countries shown in Figure 6 those with low incomes (less than $10,000 GDP per capita) had 50% higher volatility of growth rates, 12% higher stock-market volatility and 35% higher bond-market volatility, so overall developing countries experience about one-third higher uncertainty.

Why Does Uncertainty Vary?

Having established some facts about uncertainty it is useful to discuss some of the factors that might be causing these variations in uncertainty. I will first focus on factors that 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, like oil-price shocks, terrorist attacks, and wars. For example, Bloom (2009) 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 of these events were dramatic shocks that 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.

So why does good news so rarely cause an uncertainty shock? One possible reason is that 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, never causing large jumps in uncertainty. Indeed, it is hard to come up with any large good news shocks in recent US history.

A second reason is that 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. Certainly, the theory literature highlights several 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 et al. (2012)). But when business is bad this activity slows down, reducing the flow of new information thereby raising uncertainty. Second, individuals are more confident in predicting the future when "business as usual" prevails in a growing economy. But forecasting is harder during recessions (Orlik and Veldkamp, 2012). 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. Lubos and Pastor (2012) 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 at al. (2013) 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, the 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 are also quite volatile: 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, the question is does this matter? To answer this I want to start by discussing the theory on the impact of shocks to uncertainty, and then turn to the empirical evidence. Starting with the theoretical literature, this 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 – because for example, 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.[3] Hiring adjustment costs include recruitment, training and severance pay, which Nickell (1986) and Bloom (2009) estimate are about 10 to 20 percent of annual wages. Schaal (2013) 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, since 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

[3] The literature distinguishes two families of adjustment costs. There are lumpy "non-convex" adjustments costs, which are fixed-costs (a one-off cost to buy/sell capital) and partial irreversibility (a cost per unit of capital sold). These "non-convex" 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).

delay would be extremely costly, then the option to delay is not valuable, breaking the negative real-options effect of uncertainty on investment.

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 impact on the profitability of investment next period, leading to no option value from waiting. So 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, there is an analogous channel 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. 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 non-durable like food and entertainment is harder, so the real-options effects of uncertainty on non-durable 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' durable expenditure 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 stimulus policy may need to be more aggressive during periods of higher uncertain.[4]

This channel of uncertainty reducing 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-

[4] A related argument is that aggressive stimulus policies are helpful for reducing uncertainty, by providing reassurance that the Government will stabilize the economy.

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 the fall in productivity growth in 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, 2009; Gilchrist, Sims and Zakrasjek, 2010).

Another mechanism related to risk premia is the *confidence* effect of uncertainty in models where consumers have pessimistic beliefs (e.g. 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, these kinds of agents become more pessimistic, cutting back on investment and hiring. Of course if certain economic agents are excessively optimistic, as is sometimes suggested in the literature about the risk orientation of chief executive officers (for example, Malmendier and Tate 2005) then this result can reverse, with uncertainty increasing growth.

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, Fernandez-Villaverde et al. (2011) argue that rising uncertainty can be crippling for growth, particularly 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 sight it would seem that uncertainty may have potentially positive effects – by encouraging consumers to save, this will increase investment (since savings equals investment in closed economies). But as several recent papers have noted[5] if prices are sticky, as New Keynesian models assume, uncertainty shocks can lead to recessions even in closed economics because prices do not fall enough to clear markets. The intuition is that uncertainty increases consumers desire to save, which should cut interest rates and output prices, stimulating an offsetting rise in investment. But if prices are sticky this never happens – prices and interest rates do not fall enough to encourage the offsetting rise in investment – so that output falls. This impact of uncertainty is particularly damaging if interest rates are constrained at zero by the lower bound, as has been the case through-out much of the last five years.

Another precautionary effect of uncertainty may impact 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 they 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

On the other side, 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 potential prize. Papers like 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. For example, consider a pharmaceutical company developing a new drug, which 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.[6]

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

[5] In particular, Leduc and Liu (2012), Basu and Bundick (2013) and Fernandez-Villaverde et al. (2013).

[6] This is sometimes called the "good news principle" that only good news matters in growth-options as bad news is capped by closing down the project. The origin of this phrase comes in fact 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 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.

firms starting new websites was losing their development costs, while the best outcome looked ever more profitable as the range of uncertainty about of the internet expanded. Since developing websites took time, building one was seen as investing in a "call-option" on the future success of 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 have growth-options are particularly important for R&D 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[7]. This highlights 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 like a mean-preserving increase in uncertainty (it gets 50% of bad outcomes and 200% of good outcomes). The factory is partly-insured against bad-outcomes by being able to contract and has the option to expand on 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-Able effects are typically not very strong in the short-run (because of adjustment costs), they can be powerful in the medium and long-run.

Why Might Fluctuations in Uncertainty Matter: Empirics

Having discussed the theory of uncertainty shocks the obvious question is what is the evidence for the impact of uncertainty shocks? I start by noting that the evidence on the impact of uncertainty is still 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, raising a question over causality.

To identify the causal impact of uncertainty on firms and consumers the literature has taken three approaches. One approach relies on timing – estimating the movements in output, hiring and investment that follow jumps in uncertainty. This works 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 impact of uncertainty shocks. This approach is conceptually well grounded, but like many structural models is sensitive to

7 After Oi (1961), Hartman (1972) and Abel (1983)

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 summary view is the literature provides suggestive – but not conclusive - evidence that uncertainty damages short-run (quarterly and annual) growth, reducing output, investment, hiring, consumption and trade. The longer-run evidence on output is far more limited, and while my personal view is that uncertainty is damaging for growth, I recognize it is extremely hard to definitively show this. One reason is that while uncertainty appears to reduce short-run hiring and investment it may stimulate research and development, as some of the very latest 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 uncertainty would be valuable, particularly work which can identify a clear causal relationship.

Timing approaches to estimating the impact of uncertainty shocks

A standard approach in macroeconomic analysis has been to look at short-term economic fluctuations separately from long-term economic growth. The classic macro study of uncertainty by Ramey and Ramey (1995) challenged this separation. Looking both at a broad sample of 92 countries from 1960-85, and also at a narrower sample of high-income countries from 1950-1988. They looked at 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 (for example, as measured by the uncertainty expressed by contemporary forecasters) 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 pre-war period. Handley and Limao (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 U.S. 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 on 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 finding 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. Bloom, Bond and Van Reenen (2007) 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 impact 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 counter-cyclical micro and macro uncertainty. We find that the average increase in uncertainty that happens during recessions reduces output by about 3% 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 due to 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 and 2013) have two papers modelling general equilibrium models with heterogeneous agents and capital adjustment, finding much smaller impacts of uncertainty on growth. Their models differs 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, highlighting the need for richer micro and macro moments to pin down these types 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%. Hence, for oil firms it is extremely important to consider both the level and the uncertainty of future oil prices before drilling wells. Intriguingly, he also shows firms appear to use oil futures and derivatives from the New York Mercantile Exchange to predict future oil prices and volatility (rather simply extrapolating from historic prices), suggesting sophisticated forward looking behavior on the part of drilling firms.

Using natural experiments to estimate the impact of uncertainty

The most 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 in economic losses, or as resulting in a political regime, 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.

More recently, 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 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 2008–10, 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 over the importance of uncertainty in driving the recent Great Recession and sluggish recovery.

Certainly, policy makers believe uncertainty has played an important role. For example, in 2008 the Federal Reserve noted that "*participants reported that uncertainty about the economic outlook was leading firms to defer spending projects until prospects for economic activity became clearer.*" (FOMC, 2008). In 2009 the International Monetary Fund's chief economist, Olivier Blanchard, wrote "*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*" (Economist, 2009), while the Head of the Council of Economic Advisers, Christina Romer, noted "*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*." (JEC, 209)

This claim on the damaging impact of uncertainty has 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 EU 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*" (VOX, 2013), while the International Labor Organization 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*" (ILO, 2013).

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 the 2008. As shown in Figures 1 to 4, the level uncertainty around 2008-2009 was more than triple 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 – also 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.

To calculate the magnitude of the impact of uncertainty I first calculate the drop in GDP during the Great Recession. This appears to be about 9 percent, coming from 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. Second, 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 drop). One way is to take the 1 percent drop in GDP in estimated from vector auto regressions after an *average* uncertainty shock (Bloom, 2009), and triple this, nothing the 2008-2009 rise in uncertainty was about triple the "normal" uncertainty shock. Another way 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 a micro-data instrumental variable results, again finding a Great Recession uncertainty shock reduced output by about 3%.

Concluding Thoughts

I have provided a range of evidence showing 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.

However, the empirical literature on uncertainty is still at an early stage with many open research questions. 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. So developing a wider set of measures is important. Moreover, these measures are still rather narrow. 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 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, shocks to uncertainty are likely to require large, rapid but short-lived stimulus responses to stabilize output. Uncertainty shocks appear to lead to short, sharp drops and recoveries in output, requiring similar short, sharp stimulus to achieve stabilization. Second, policy should try to address the root cause of the uncertainty – which is likely to be more effective than treating the symptoms (the drop in output). For example, during the Great Recession I think 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. For example, should policy become more rule based? Will this help to reduce policy uncertainty, or by limiting flexibility do rules impede policymakers ability 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. And what is the role of policy communications? For example, the Federal Reserve Bank has recently tried to be more transparent in signaling the path of monetary policy, presumably in part to reduce uncertainty. But has this worked, or has it introduced greater volatility by generating more frequent jumps in financial markets after each monetary policy pronouncement?

So, as this article highlights, while the empirical progress on fluctuations in uncertainty over the last decade has been exciting, there is still much about uncertainty we remain uncertain about.

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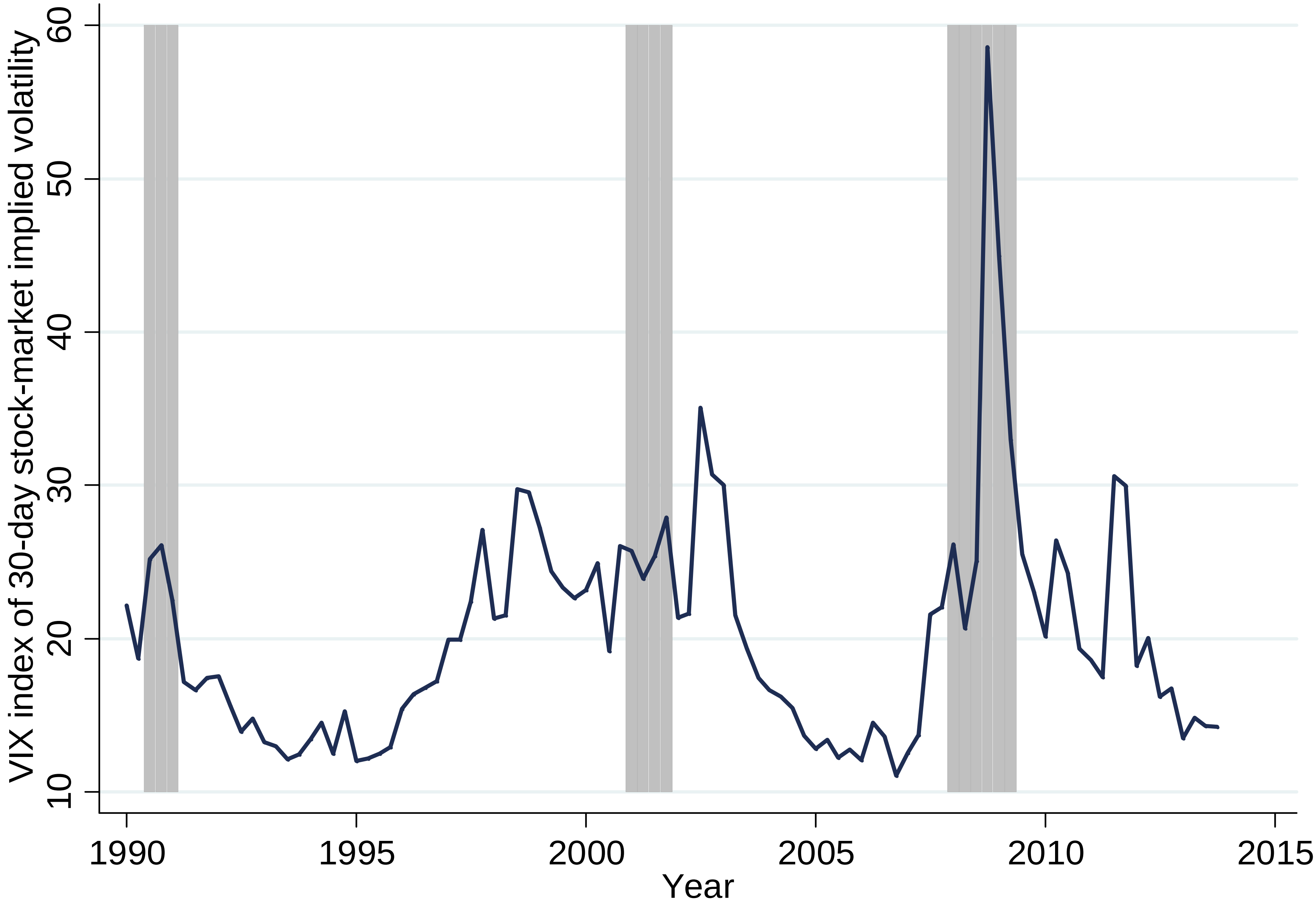
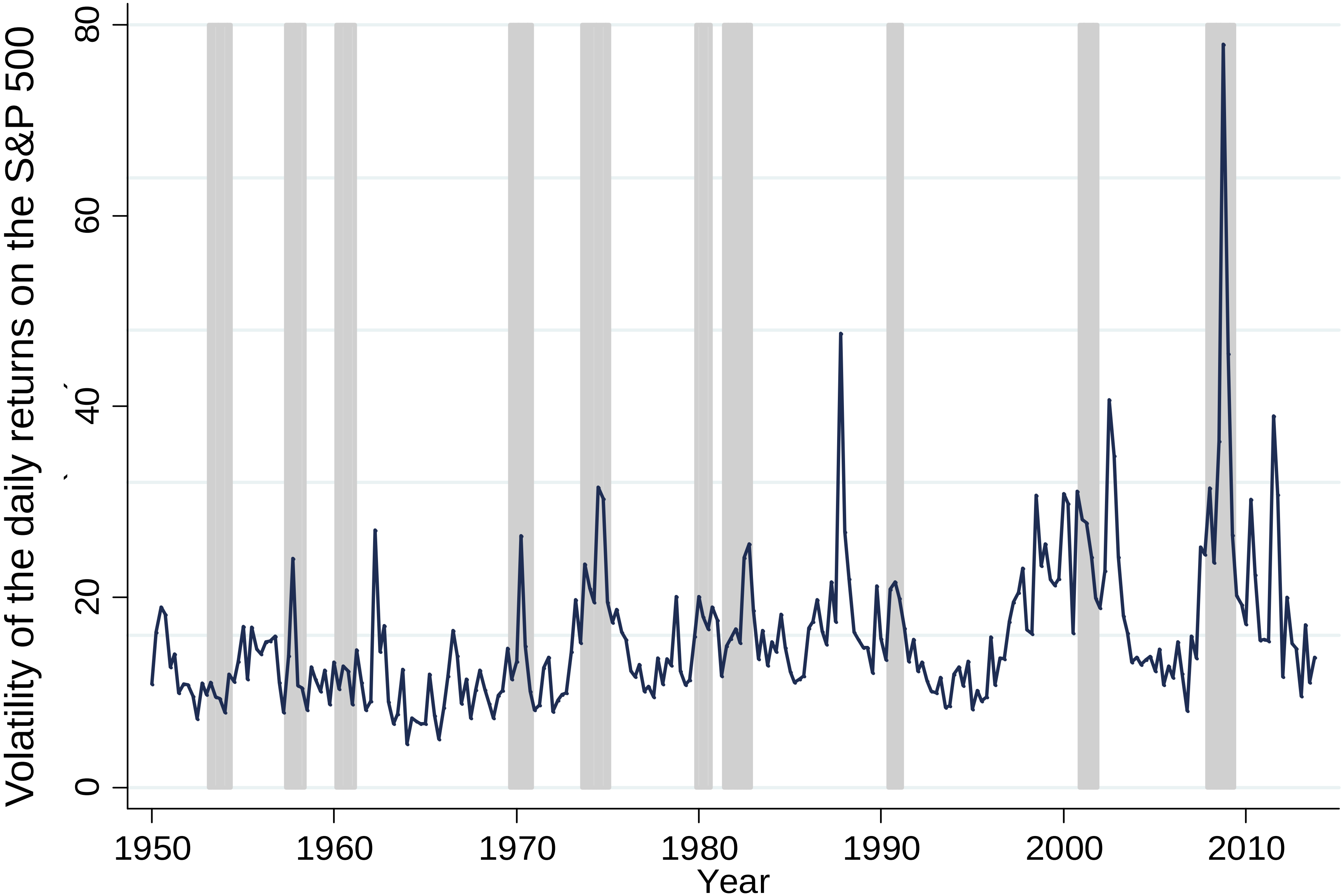
Figure 1a: Stock-market implied volatility is higher in recessions



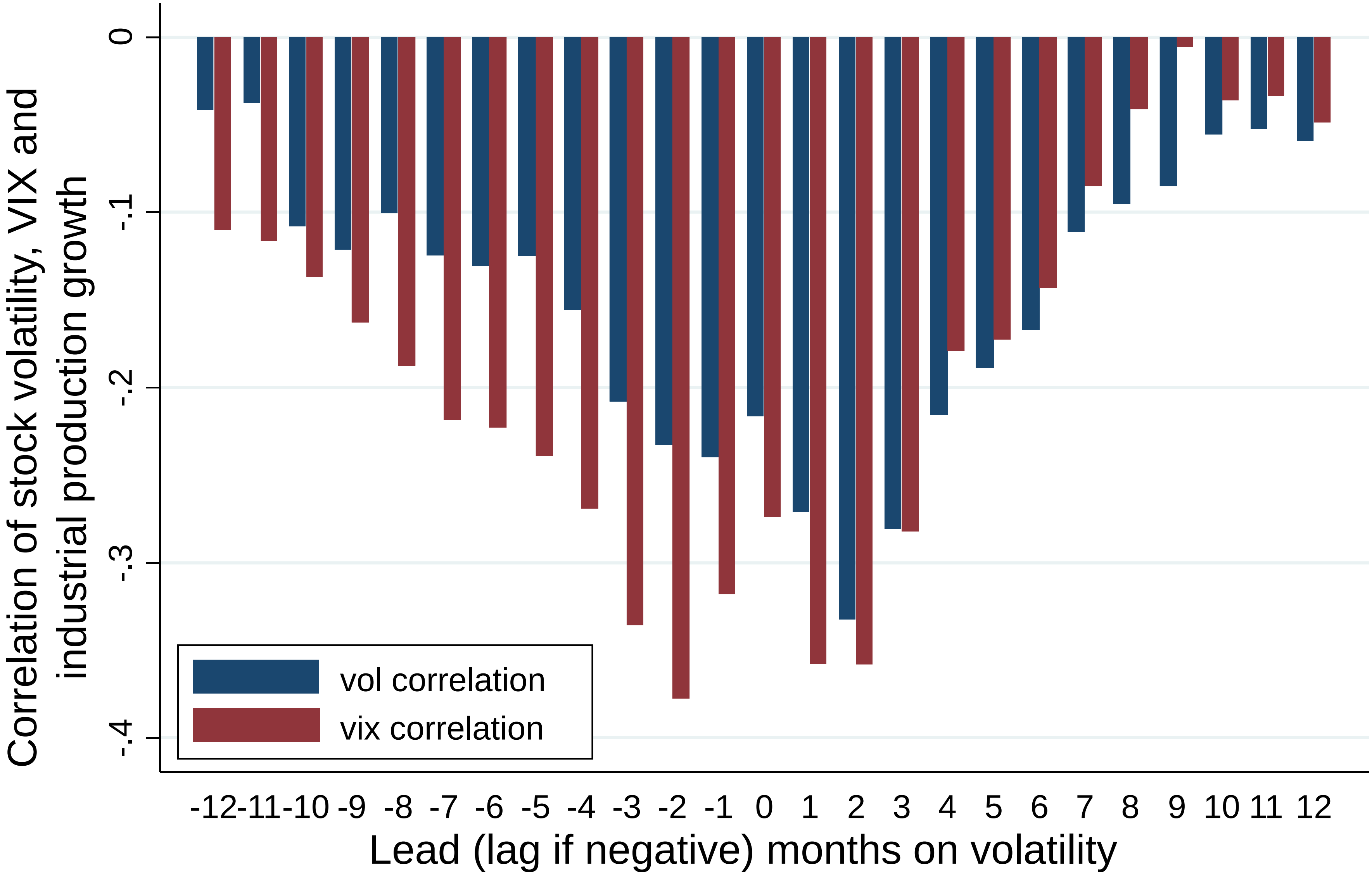
Source: VIX is the implied volatility on the S&P500, averaged to the quarterly level, provided by the Chicago Board of Options and Exchange. The VIX is the markets implied level of stock-market volatility over the next 30-days, where values are in standard-deviations on the S&P 500 at an annualized level. Grey bars are NBER recessions. Data spans 1990Q1-2013Q4.

Figure 1b: Stock-market realized volatility is also higher in recessions



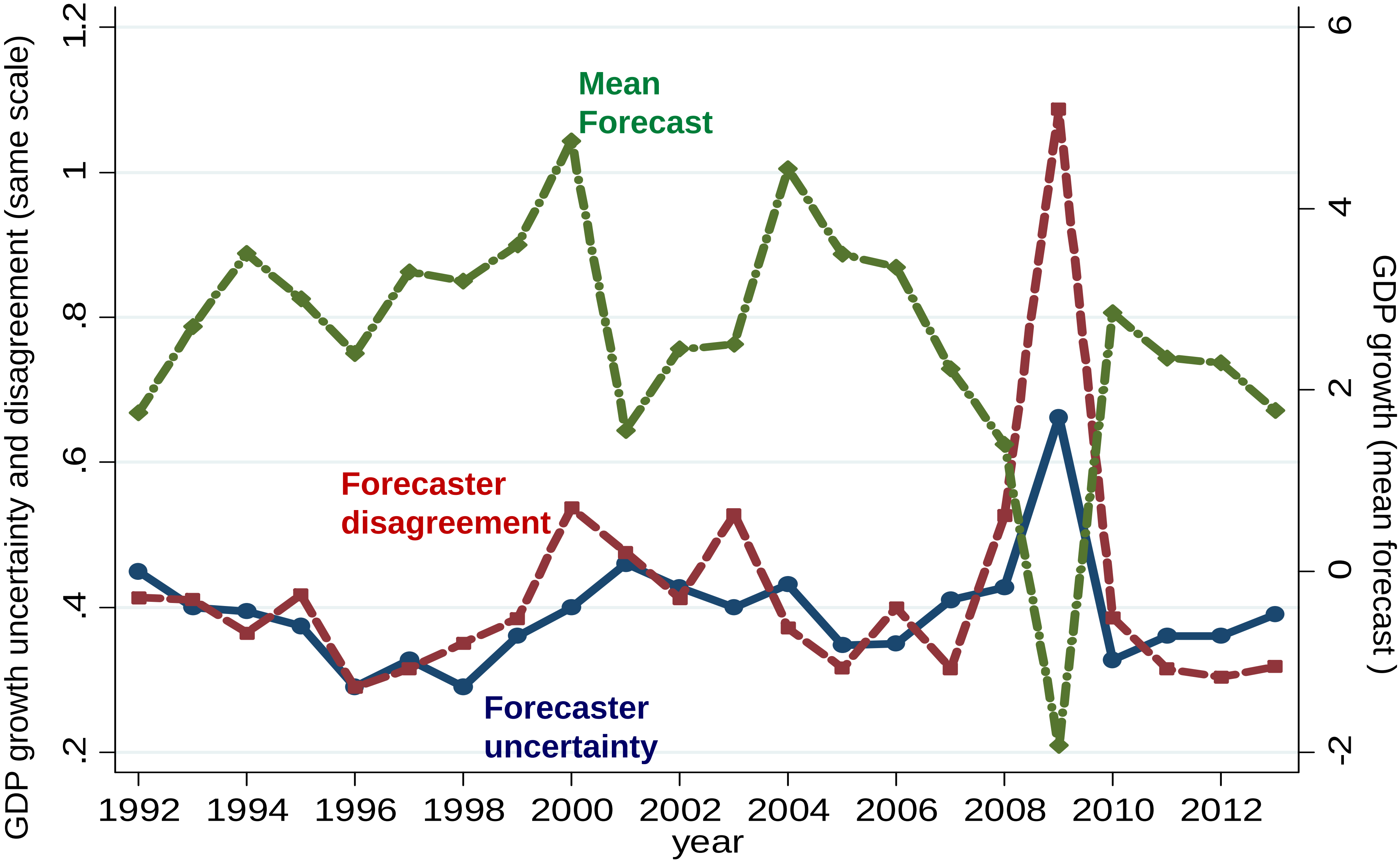
Source: Monthly volatility of the daily returns on the S&P500 at an annualized level. Grey bars are NBER recessions. Data spans 1950Q1-2013Q4.

Figure 1c: Stock-market volatility (implied and realized) predicts real activity: it starts rising 3 months ahead of dropping industrial production



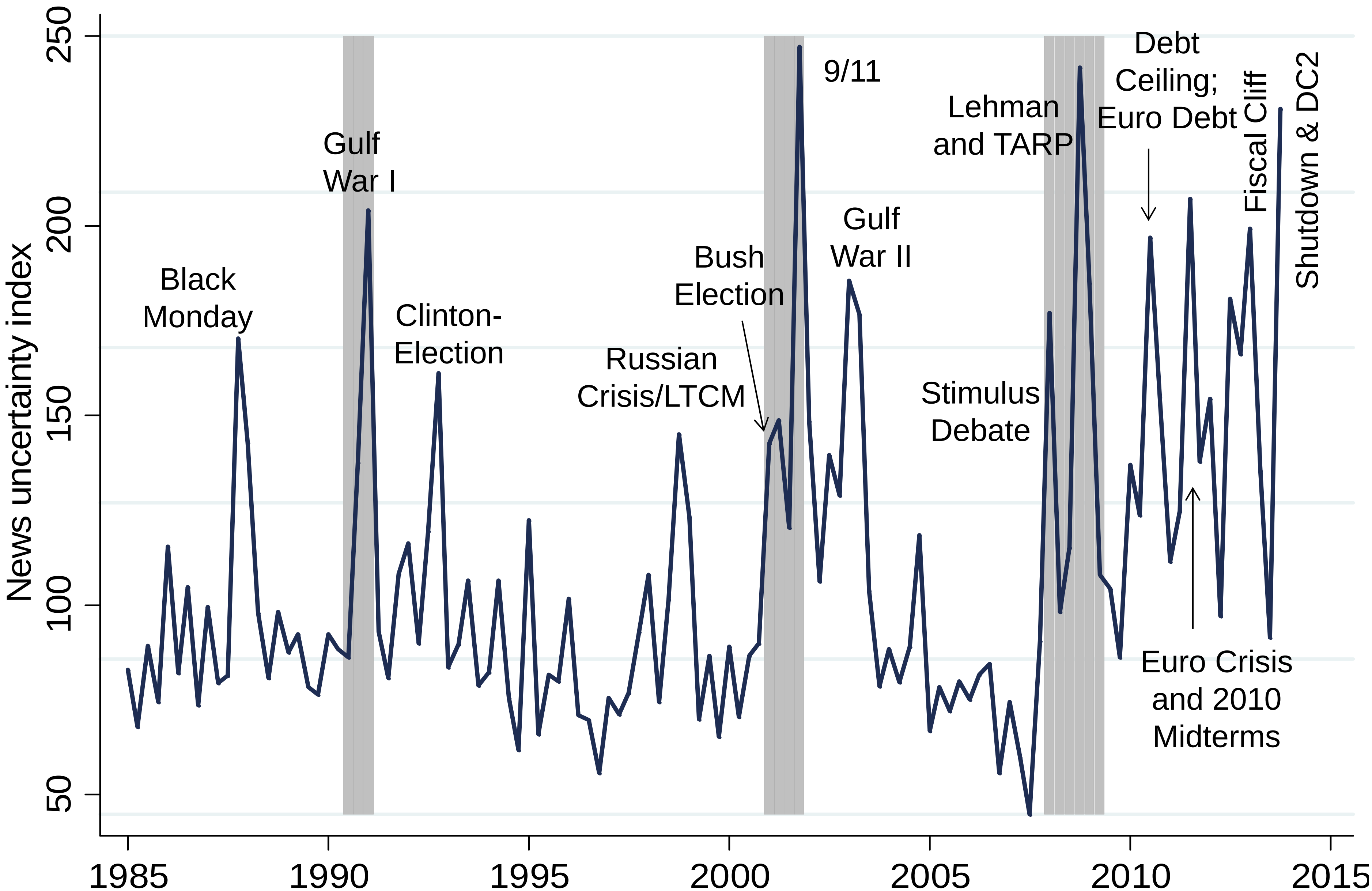
Source: Chart plots the correlations of monthly industrial production growth (from Federal Reserve Board) defined as IP(t)/IP(t-1) with monthly realized stock market volatility (using daily data) and the VIX. These are ordered by the number of leading/lagging periods for stock-volatility data. For example, the +3 point shows the correlation of vol(t+3) and vix(t+3) have a correlation of -0.27 with IP(t)/IP(t-1). Results based on monthly correlations data from 1970 for vol (realized volatility) and vix (implied volatility).

Figure 2: GDP growth forecaster uncertainty and disagreement both rose significantly during the Great Recession



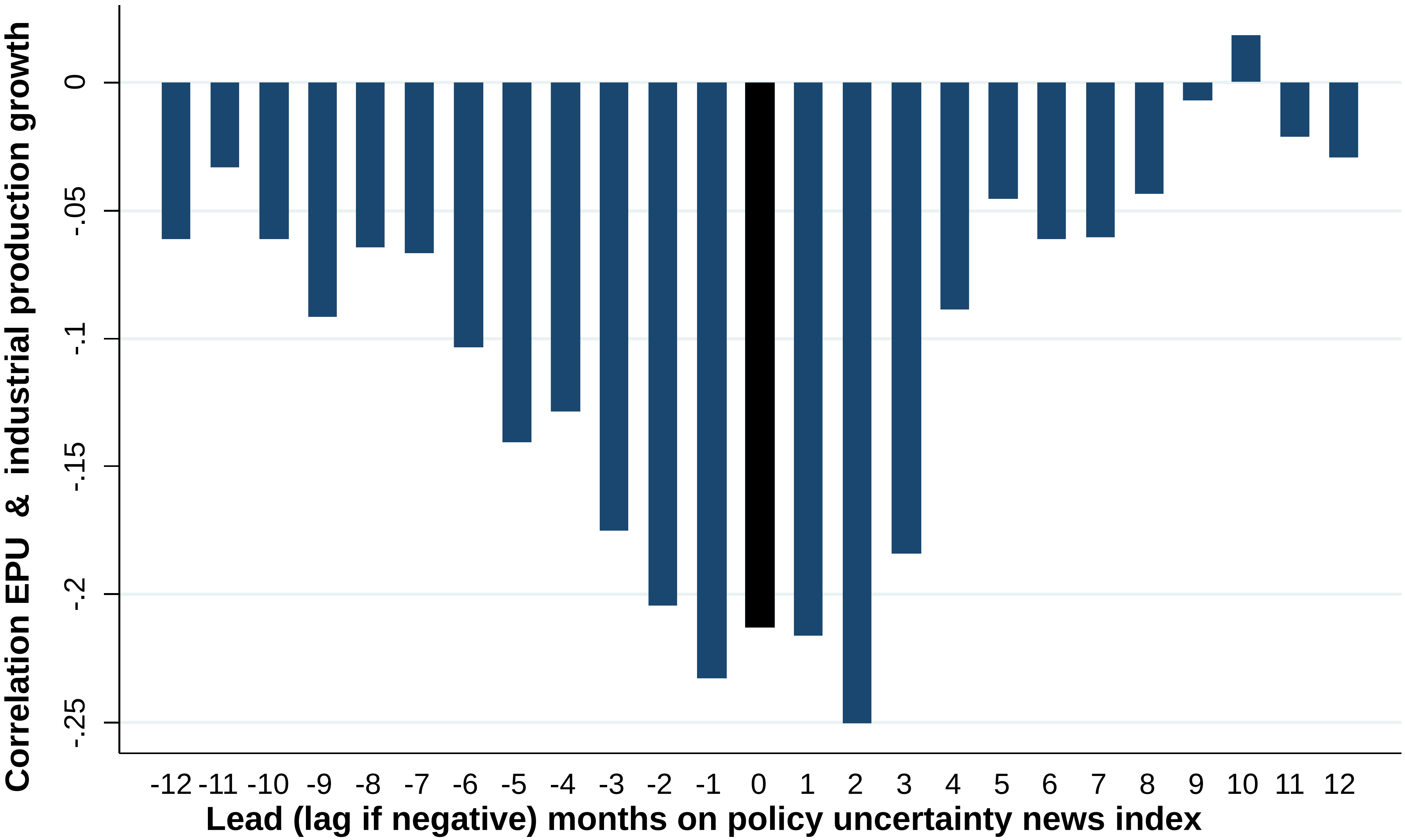
Notes: Data from the probability changes of GDP annual growth rates from the Philadelphia Survey of Professional Forecasters. **Mean forecast** is the average forecasters expected GDP growth rate, **forecaster disagreement** is the cross-sectional standard-deviation of forecasts, and **forecaster uncertainty** is the median within forecaster subjective variance. Data only available on a consistent basis since 1992 Q1, with an average of 48 forecasters per quarter. Data spans 1992-20013.

Figure 3a: Newspaper policy uncertainty index is 51% higher in recessions



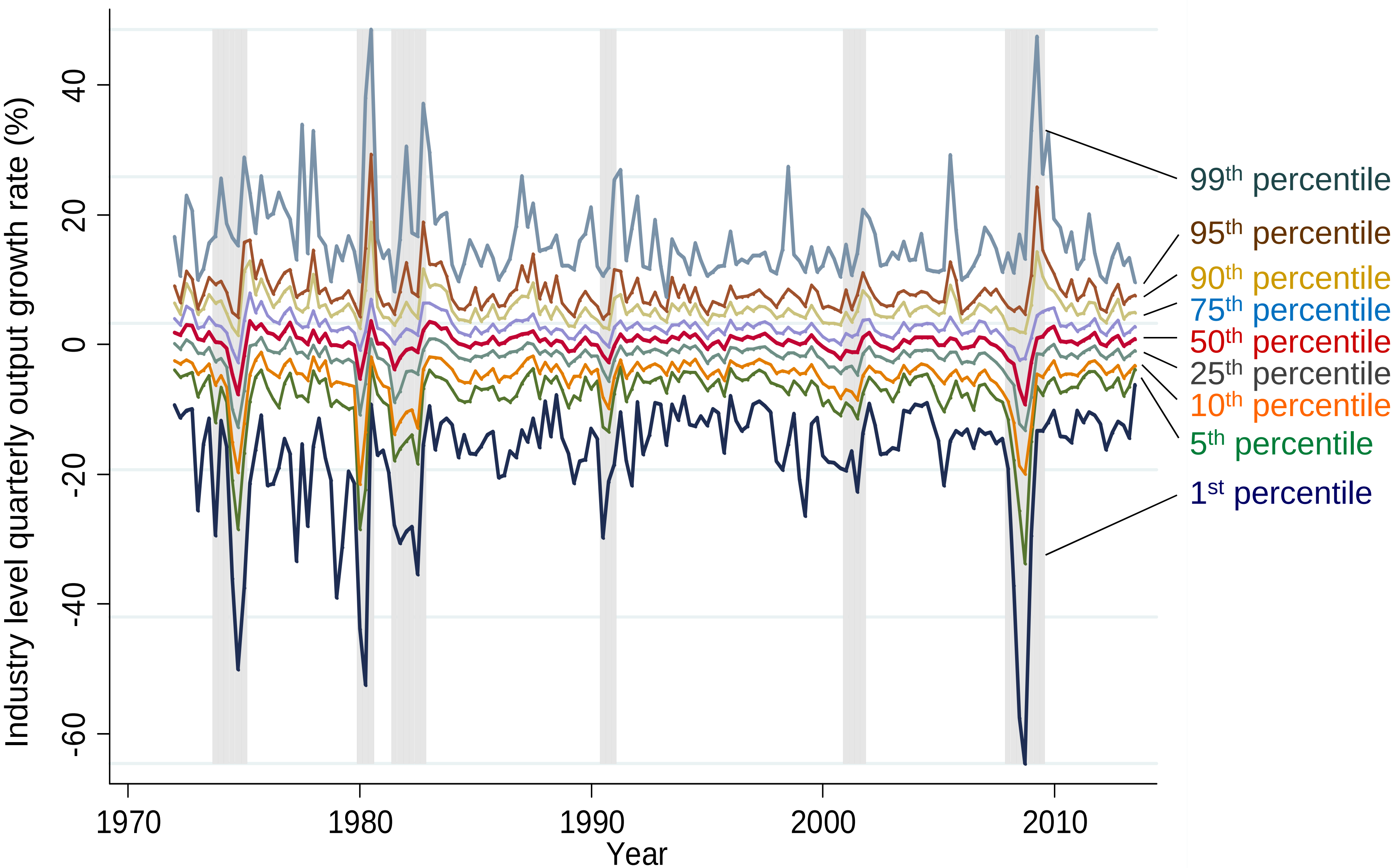
Notes: Source Baker, Bloom and Davis (2013) policy uncertainty news index. Frequency of newspaper articles in 10 US papers about economic policy uncertainty. Data from Q1 1985 to Q4 2013, normalized to 100 prior to 2010. Grey bars are NBER recessions. Data spans 1985Q1-2013Q4.

Figure 3b: Newspaper coverage of policy-uncertainty predicts real activity: it starts rising 3 months ahead of dropping industrial production



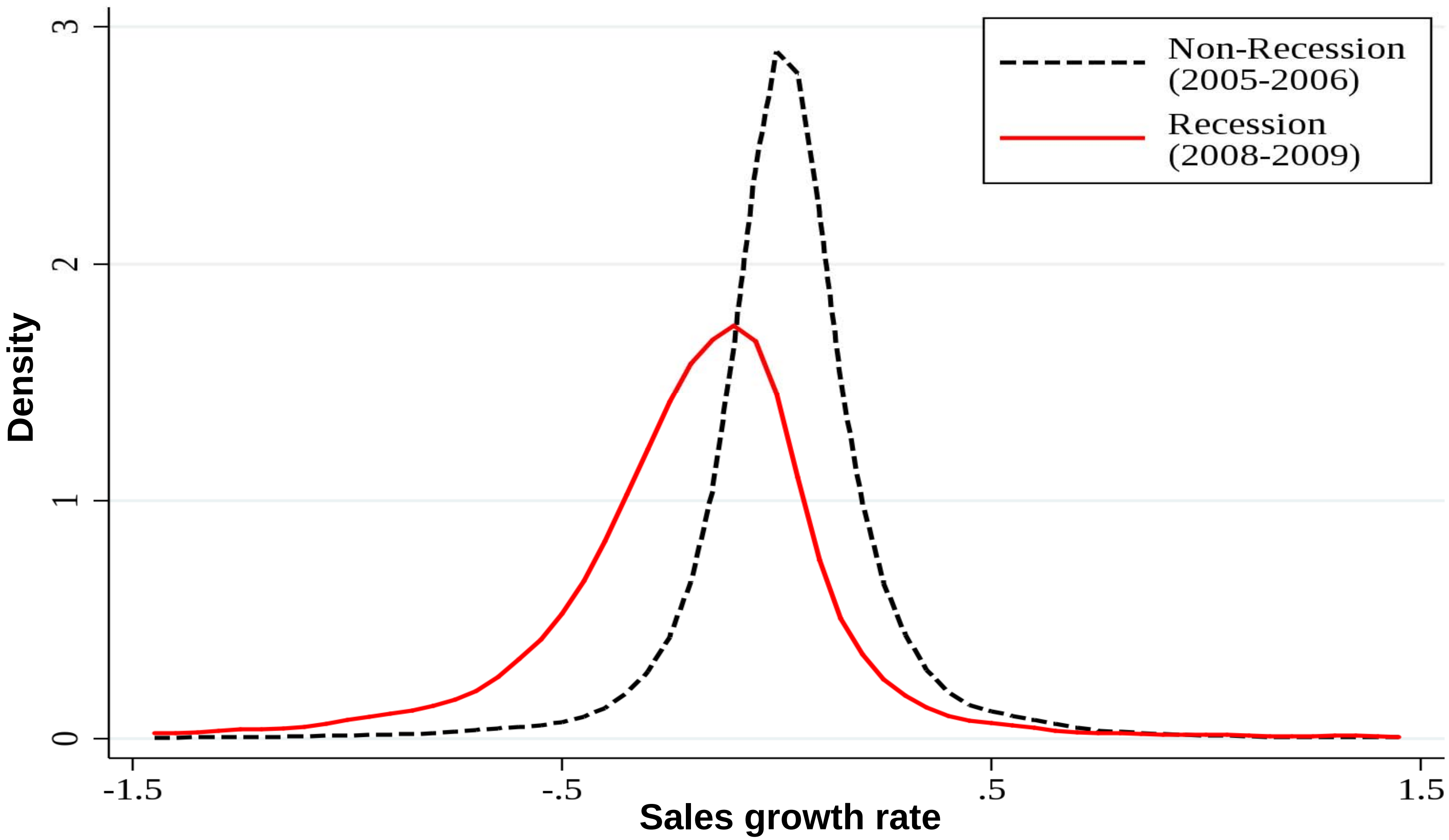
Source: Chart plots the correlations of monthly industrial production growth (from Federal Reserve Board) defined as IP(t)/IP(t-1) with the economic policy uncertainty index from www.policyuncertainty.com These are ordered by the number of leading/lagging periods for stock-volatility data. For example, the +3 point shows the correlation of EPU (t+3) has a correlation of -0.18 with IP(t)/IP(t-1). Results based on monthly correlations data from 1985-2014.

Figure 4: Industry growth rate spreads increase in recessions



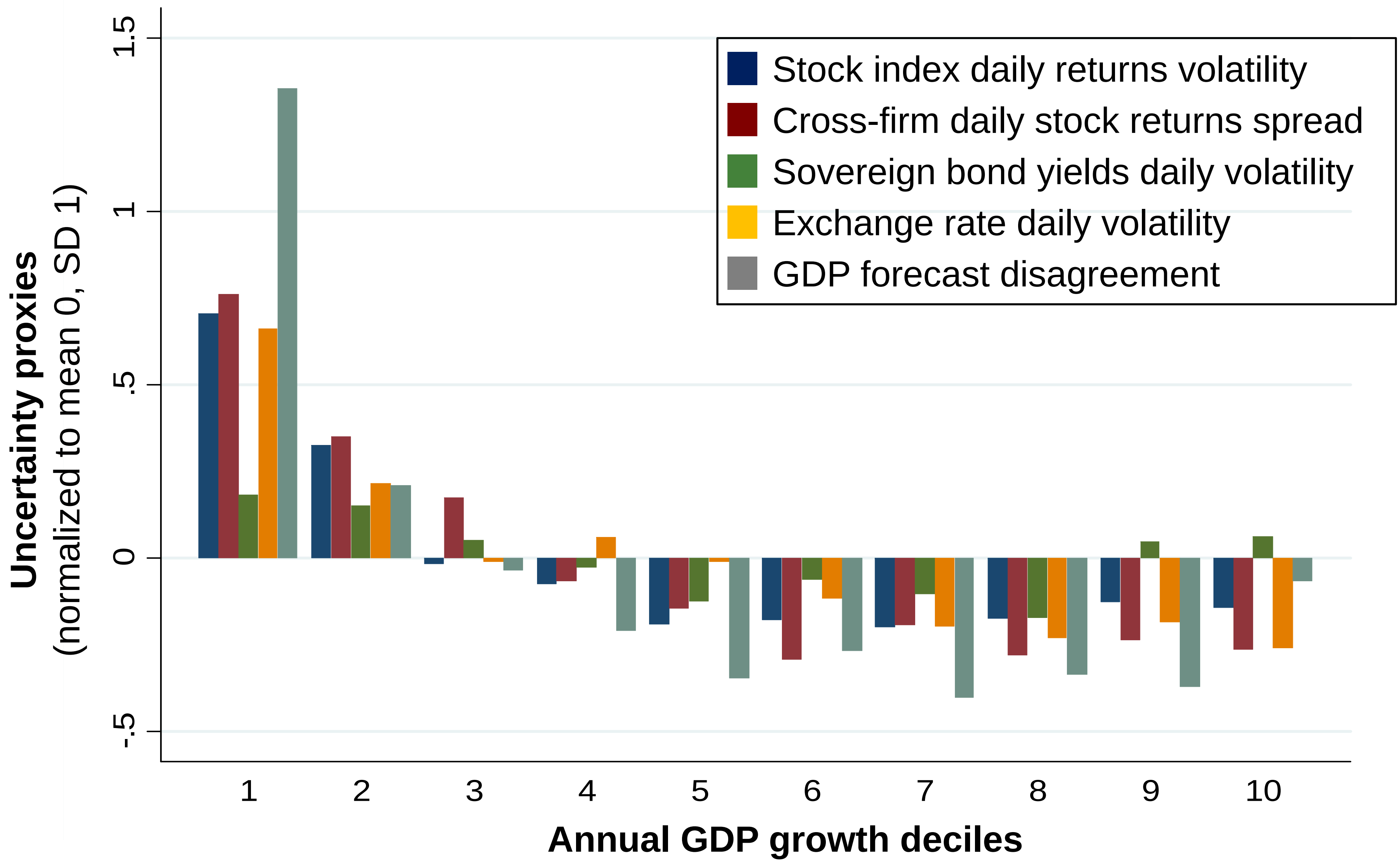
Notes: 1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th and 99th percentiles of 3-month percentage growth rates of industrial production. All 196 manufacturing NAICS sectors in the Federal Reserve Boards' industry database. Data spans 1972Q1-2013Q3.

Figure 5: Plant uncertainty – sales growth dispersion



Notes: Source Bloom, Floetotto, Jaimovich, Saporta and Terry (2013)**.** Constructed from the Census of Manufactures and the Annual Survey of Manufactures using a balanced panel of 15,752 establishments active in 2005-06 and 2008-09. Moments of the distribution for non-recession (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.

Figure 6: Uncertainty measures are countercyclical across countries



Notes: Source Baker and Bloom (2013). Volatility indicators constructed from the unbalanced panel of data from 1970 to 2012 from 60 countries. Stock index, cross-firm, bond yield and exchange rate data calculated using daily trading data. Forecasts disagreement is calculated from annual forecasts within each year. All indicators are normalized for presentational purposes to have a mean of 0 and a standard-deviation of 1 by country. GDP growth deciles are calculated within each country.