Information, Uncertainty and Sudden Stops in Real Investment

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Abstract

The concept of Knightian uncertainty has been used liberally to both describe the current financial crisis and to explain the subsequent Great Recession of 2007-09. This paper lays out a simple two-period model with both risk and uncertainty in financial intermediation technology, to investigate more precisely how unanticipated increases in uncertainty might bring about a significant downturn in the real economy. We compare similar economies with and without uncertainty and demonstrate how an increase in the amount of uncertainty regarding the role of financial intermediaries can have a dramatic effect on the real economy. In addition, we explore how the unanticipated arrival of information about the quality of financial intermediaries, in an environment with Knightian uncertainty, can also have a dramatic negative effect on the real economy regardless of the precise nature of that information.

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1 Introduction

“We are in a minefield. No one knows where the mines are planted and we are just trying to stumble through it.”

–Drew Matus, Lehman Brothers, August 15, 2007

Stumbling through a minefield is hardly the sort of metaphor that a Madison Avenue advertising firm would use to market the activities of a Wall Street financial services client. Rather than an image of confidence, experience and knowledge built on the scientific assessment of risk and reward, it conveys an image of dread, imminent doom, and operating in a world of not merely the unpredictable, but of the unknowable. Mr. Matus was not alone in his assessment of the situation. News reports and pundits accounts of the financial crisis of 2007 and 2008 and the subsequent Great Recession, commonly attribute not knowing what is on the balance sheets of financial institutions and not knowing what type of policy response the US federal government would adopt, as root causes of the crisis. The situation was not just a tricky forecasting problem that involved predicting which outcome among a list of random possibilities might happen, but rather a situation in which decision makers were either unable to create such a list of possibilities or given a list, unable to quantify the relative odds of different outcomes actually occurring. Among leading macroeconomists advocating such an interpretation of recent events are Roubini (2007), Caballero and Krishnamurthy (2008), and Blanchard (2009).

There is a long, but until recently somewhat dormant, tradition in economics of studying situations in which decision makers are faced with “not knowing the odds” of a gamble, starting with Knight (1921), continuing on with Ellsberg (1961), and more recently Bewley

(1986) and Gilboa and Schmeidler (1989). But until very recently, macroeconomic theory has been built on expected utility theories of risk, which among other things, quantify an unpredictable future with a single probability distribution. When confronted with the possibility of uncertainty or ambiguity about the nature of the random process generating future outcomes, decision makers are assumed to simply weight all possibilities random processes using prior beliefs, reducing the problem to one of a single distribution which is then used to assess risks. This paper explores the macroeconomic consequences of behavior in a world economic uncertainty, that is, environments in which future events aren’t merely unpredictable, they cannot be quantified with a single probability distribution. (There are a variety of competing labels for decision making in this type of an environment, e.g., Knightian uncertainty aversion, ambiguity aversion, and robust control. At the risk of confounding some subtle distinctions in these concepts, we refer simply to this situation as one of “Knightian uncertainty.”) In this paper we develop some of these ideas in the context of a very simple macroeconomic model, and try to sort through in a somewhat more systematic way, the relationship between the economic uncertainty that is commonly attributed to be both the cause and the consequence of the financial crisis, and the severe worldwide recession that followed.

2 Knightian uncertainty

A dramatic increase in Knightian uncertainty is not a new feature specific to the recent crisis. Prati and Sbracia (2001) describe the dramatic increase in the dispersion of consensus forecasts of macroeconomic variables around a financial crisis. For the current crisis, Roubini (2007) provides a compelling description of the nature of the uncertainty about the net asset position of financial institutions: “First, you take a bunch of shaky and risky subprime
mortgages and repackage them into residential mortgage backed securities (RMBS); then you repackage these RMBS in different (equity, mezzanine, senior) tranches of cash CDOs that receive a misleading investment grade rating by the credit rating agencies; then you create synthetic CDOs out of the same underlying RMBS; then you create CDOs of CDOs (or squared CDOs) out of these CDOs; and then you create CDOs of CDOs of CDOs (or cubed CDOs) out of the same murky securities; then you stuff some of these RMBS and CDO tranches into SIV (structured investment vehicles) or into ABCP (Asset Backed Commercial Paper) or into money market funds.” And the implications of these asset trades for uncertainty: “So combine an opaque and unregulated global financial system where moderate levels of leverage by individual investors pile up into leverage ratios of 100 plus; and add to this toxic mix investments in the most uncertain, obscure, misrated, mispriced, complex, esoteric credit derivatives (CDOs of CDOs of CDOs and the entire other alphabet of credit instruments) that no investor can properly price; then you have created a financial monster that eventually leads to uncertainty, panic, market seizure, liquidity crunch, credit crunch, systemic risk and economic hard landing.” It would seem that the only thing certain about such a situation is, ironically, the economic uncertainty that it entails. What remains to be seen, however, is the macroeconomic consequences of this uncertainty.

Experimental evidence demonstrates that decision makers prefer to “know the odds.” A simple example demonstrates what has been called Ellsberg’s paradox. A decision maker receives a monetary payoff based on the color of a ball drawn from an urn that has 300 balls in total, of which 100 are red and 200 are either green or blue. The precise number of green and blue balls is left unspecified. The decision maker is then asked to choose between (A) a gamble that pays $3 if the ball drawn from the urn is red and $0 if it is either blue or green, and (B) a gamble that pays $3 if the ball is blue and zero if it is either red or green. Overwhelmingly, experimental subjects choose the first of these gambles, i.e., A is preferred to B. There is nothing paradoxical about this choice, since standard expected utility
maximization would simply argue that the decision maker had a perfectly reasonable prior belief that put some weight on the possibility that the urn contained fewer than 100 blue balls, resulting in an expected payoff of less than $1 for the second bet. The paradox emerges when the same decision maker is subsequently asked to choose between two other gambles based on a draw from the same urn: (C) $3 if the ball drawn is either red or green and $0 if it is blue, and (D) $3 if it is either blue or green and $0 if it is red. Since the comparison of A and B established the fact that the decision maker had a prior belief that put some weight on there being fewer than 100 blue balls in the urn and, hence, a prior belief that put some weight on there being more than 100 green balls in the urn, the expected payoff of the first choice must greater than $2, which is the expected payoff of the second choice, i.e., if A is preferred to B, then expected utility predicts that C must then be preferred to D. Nonetheless, experimental subjects routinely choose the second of these gambles which is a clear violation of the standard logic of expected utility maximization.\(^2\)

The behavioral feature that emerges from this body of experimental evidence is that economic decision makers exhibit a preference for knowing the odds. And there can be little doubt that the concept of uncertainty rather than risk is a better description of the state of affairs of financial intermediaries in 2007 and 2008. The experimental evidence suggests, therefore, that there is a utility cost associated with this uncertainty as it is internalized by average households. The relevance of this uncertainty for observed aggregate economic activity, however, is less than clear, and requires further analysis in the context of a well-specified model.

\(^2\)See Camerer and Weber (1992) for a review of this experimental evidence. There is also a growing body of neuro-economics evidence that the human brain processes risk and uncertainty differently (see Glimcher and Rustichini (2004)).
3 Recent recessions

Robert Hall (2009) has argued that the last three US recessions are fundamentally different than other postwar recessions. Absent empirical evidence of shocks to total factor productivity, Hall argues that these recessions were the consequence of events originating in financial markets: “We all know that the 1990-91 recession was caused by the savings and loan crisis, the 2001 recession by the tech crash, and the 2009 recession by the housing collapse, not productivity disappointments.” Further, he argues that traditional business cycle analysis, whether Keynesian or neoclassical in spirit, does not provide much insight: “...nobody has created a workable modern model that explains why these events should cause economywide softening of the labor market.”

It is hard to argue with Hall’s assessment of the timing of these events, and it is hard to argue that empirical evidence could support the hypothesis that these three recessions were caused solely by real productivity shocks. If financial markets were the cause as Hall suggests, however, it isn’t immediately obvious how this might work.

There are two sides to every financial contract. When prices go up there are both winners and losers, likewise when prices go down. It isn’t clear why the realization of financial risk, which can have a substantial impact on the cross-sectional distribution of wealth, would reduce the productive opportunities in the economy, and why it might lead to a substantial decrease in aggregate employment and output. For example, home mortgage lenders have an implicit put option on the asset value of the home arising from the default option of the borrower. Presumably, both borrowers and lenders entered this contract on mutually agreeable terms, including the terms for the implicit equity option. The fact that this option ends up being in the money should be of no great macroeconomic consequence. Literally millions of financial options expire “in the money” every day, yet rather than causing a crisis,
this is viewed as routine business. Pooling, tranching, and distributing ownership of these contracts worldwide, if anything, should lessen the macroeconomic consequences of these types of arrangements, since these activities should help to distribute the risk in an efficient manner to those most able to bear it. There is nothing in this logic specific to mortgage or consumer finance. It applies equally well to corporate securities.

Another possibility is that the cause is simply a productivity shock in the financial intermediation industry itself. This seems plausible, though the magnitude of such a shock doesn’t seem big enough to account for the size of the recession we are experiencing. For example, imagine that 8% of the value added in the entire economy originated in the financial services sector, and this sector was hit with a massive negative shock, a 25% decrease in value added, say. The net effect of this massive shock on this very large industry would amount to something on the order of a 2% shock to the overall economy. One could debate the significance of a shock of this magnitude, but most people would agree that it doesn’t approach a magnitude that would constitute a global economic crisis. It would seem that if this was the source of the crisis, then there must be other factors at work that modify and amplify these financial shocks. Uncertainty seems like a natural place to start.

4 A simple 2-period model with risky financial intermediation

We begin with a simple intertemporal capital model, similar in spirit to Hansen and Sargent (2000) and Routledge and Zin (2006). We abstract from completely from labor/leisure choice by households and firms, since in the current crisis, this seems to have been a secondary response to the investment crisis. (Adding a labor market to our model would not entail
much added complication and would not detract from the main results.) A representative consumer makes consumption and investment decisions to maximize lifetime utility defined over current consumption, \( c_t \) and future consumption \( c_{t+1} \),

\[
u(c_t) + \beta E_t u(c_{t+1}),
\]

where \( 0 < \beta < 1 \) is a discount factor, and \( E_t \) is an expected value formed at date-\( t \). We will assume that utility per period has the standard iso-elastic form

\[
u(c) = c^\rho; \; \rho < 1
\]

where the parameter \( \rho \) governs intertemporal substitution and relative risk aversion. At date-\( t \) the consumer makes a feasible consumption and investment decision:

\[
c_t + i_t = f(k_t)
\]

where \( i_t \) is the capital investment choice, and \( f(k_t) \) is the output that can be produced using the current capital stock, \( k_t \). For simplicity, assume that the technology is linear and deterministic: \( f(k) = k \). Adding curvature and a productivity shock to this production technology is straightforward, but since those features don’t contribute to our model of uncertainty in financial intermediation, they are suppressed for simplicity.

The financial intermediation process itself is a black box: investment is converted to future capital at random rate, \( z_{t+1} \), that is not known at the time the investment is made. The source of this shock is left unspecified, but could capture a wide range of possible activities of the financial intermediary. When \( z_{t+1} > 1 \) this might include things like identifying productive investment opportunities, matching investors with investment opportunities, and facilitating efficient risk sharing. When \( z_{t+1} < 1 \) this might include things like fraud, inefficient risk
shifting, and moral hazard. The capital stock in the future, therefore, is given by

\[ k_{t+1} = z_{t+1}i_t + (1 - \delta)k_t, \]

where \( 0 < \delta < 1 \) is the rate at capital depreciation. We can think of this model as a reduced-form version of the models considered in Bernanke and Gertler (1995), and similar in spirit to the model of Cooper and Ejarque (2001).

Finally, future consumption exhausts all available resources:

\[ c_{t+1} = k_{t+1}. \]

We focus on the investment decision, since the implications for other quantities like output and consumption, follow directly from resource constraints. In addition, the financial crisis seems to have had its biggest impact on things like consumer durable expenditures and plant and equipment expenditure by firms, which correspond directly to the accumulation of physical capital in our simple model. The optimization problem for the representative consumer, therefore, is given by an investment strategy that maximizes utility:

\[
\max_t \left\{ (k_t - i_t)^\rho + \beta E_t (z_{t+1}i_t + (1 - \delta)k_t)^\rho \right\}
\]

In the case of multiple distributions that could conceivably be used by the investor to calculate the expected value of utility, we adopt the now standard Gilboa and Schmeidler (1989) “Max-Min Expected Utility” model. Let \( \pi \) denote a particular probability distribution in the set of possible distributions \( \Pi \). Then the objective function for the uncertainty averse
investor is given by

\[ \max_{i_t} \min_{\pi \in \Pi} \left\{ (k_t - i_t)^\rho + \beta E_\pi (z_{t+1}i_t + (1 - \delta)k_t)^\rho \right\}, \]

where \( E_\pi \) denotes an expected value calculated using the probability distribution \( \pi \). Note that we can re-scale this problem by expressing all quantities as fractions of the current capital stock (which is equal to current income given the linear technology):

\[ \max_{\hat{i}_t} \min_{\pi \in \Pi} \left\{ (1 - \hat{i}_t)^\rho + \beta E_\pi (z_{t+1}\hat{i}_t + (1 - \delta))^{\rho} \right\}, \]

where \( \hat{i}_t = i_t/k_t \). (Figures 1 through 7 below plot this investment-capital ratio and corresponding scaled utility.)

For the sake of comparison, we consider two wildly different distributions characterizing the possible effects on the future capital stock of financial intermediation: one that is not very risky in which the intermediary adds a lot of value, and the other a more risky process which has the intermediary destroying a lot of value. At this point, neither of these distributions needs to be thought of as objective reality. Rather this set of possible distributions quantifies the uncertainty aversion preference of the representative agent.

Distribution 1: Value-adding intermediary

\[ z_{t+1} \in \{z_H = 1.51, z_L = 1.49\}, \text{Prob}[z_{t+1} = z_L] = 1/2 \]

with the probability of each outcome equal to 1/2. The expected value is 1.5 and the standard deviation of 0.01, implying that the intermediation process adds a lot of value to the capital accumulation process, without much risk.
Distribution 2: Value-destroying intermediary

\[ z_{t+1} \in \{z_H = 0.6, z_L = 0.4\}, \text{Prob}[z_{t+1} = z_L] = 1/2 \]

with the probability of each outcome equal to 1/2. The expected value is 0.5 and the standard deviation of 0.1, implying that the intermediation process greatly inhibits the capital accumulation process, and adds a lot of risk to the investor’s problem.

We set the other parameters of the model to uncontroversial values:

\[ \rho = -2, \quad \beta = 0.90, \quad \delta = 0.10. \]

The main findings of the numerical examples remain the same for a wide variety of values for these parameters.

Figure 1 depicts the optimal level of investment (as a fraction of the capital stock/income) for an extremely optimistic investor who thinks that Distribution 1 applies without uncertainty. Not too surprisingly, optimal investment is large, and the economy exhibits healthy growth.

Figure 2 depicts the optimal level of investment for an extreme pessimist who thinks that Distribution 2 applies without uncertainty. Note that the optimal investment in this case is negative! In a closed economy, investment is constrained to be at least zero. (We could add a foreign sector to this economy to support negative investment as the sale of domestic physical capital to the foreign economy.) With a zero level of investment, the risk of financial intermediation is irrelevant, and the economy shrinks over time, since only 90% of current capital remains undepreciated to support production and consumption in the future.

Figure 3 depicts the traditional Bayesian expected utility solution to this uncertainty. The
representative agent is assumed to have a uniform prior belief (i.e., the household attaches a probability of 1/2 to each possible distribution), and investment decisions are based on this weighted average, or Bayesian posterior, distribution. In this case, investment falls, but does not go to zero.

Finally, Figure 4 depicts the optimal investment for the uncertainty averse representative agent who maximizes utility under the worst-case scenario. Note that the worst-case scenario changes from Distribution 2 when considering positive investments (i.e., the worst case is investing current resources through a value-destroying intermediary), to Distribution 1 when considering negative investment (i.e., the worst case when shorting is when the intermediary turns out to be value creating). The optimal investment decision, therefore, is zero, even though the investor is not dogmatic about the role of the intermediary. They are fully aware
that the intermediary could be creating a lot of future value (i.e., Distribution 1), but are driven to maximize under the worst-case scenario by their preference to know the odds, i.e., their uncertainty aversion.

5 Information dynamics and uncertainty

There has been a lot of general discussion about the role played by financial information in the current crisis, and mark-to-market accounting in particular. We try to capture some of the features of this discussion with a simple model in which the financial intermediary is audited after the investment decision is made. An information signal is revealed that has an
uncertain relationship with the ultimate realization of the intermediation shock. We explore the consequences of this dynamic arrival of uncertainty in the following example.

Assume that there are two shocks that affect the financial intermediation technology. The first is an information signal, $s_{t+}$ that tells the investor something about the likelihood that the intermediary is a “good” type, $s_{t+} = G$, or a “bad” type, $s_{t+} = B$. The + superscript on the time subscript denotes that this signal arrives just after the investment decision is made. Assume that the probability of getting a “good” signal is a known value, i.e., no Knightian uncertainty, such that $\text{Prob}[s_{t+} = G] = 1/2$. The second shock is the intermediation shock which can take on two values equal in magnitude to the expected values of the two distributions considered in Section 4, $[z_H = 1.5, z_L = 0.5]$, with a similar interpretation (i.e.,

Figure 3: Standard Model with a Weighted Average Distribution.
value-creating or value-destroying intermediation) for each of these outcomes. The unconditional probability of these two outcomes is known to the investor, \( \text{Prob}[z_{t+1} = z_L] = 1/2 \), which implies an unconditional expected value of 1 and a standard deviation of 0.5. The Knightian uncertainty for this investor lies in the relationship between the information signal about the type of the intermediary, and the subsequent physical shock to intermediated investment.

Distribution 3: (perfect positive signal)

\[
\text{Prob}[z_{t+1} = 1.5 \mid s_{t+} = G] = 1 \quad \text{and} \quad \text{Prob}[z_{t+1} = 0.5 \mid s_{t+} = B] = 1.
\]
Distribution 4: (perfect negative signal)

\[
\text{Prob}[z_{t+1} = 1.5 \mid s_{t+} = G] = 0 \quad \text{and} \quad \text{Prob}[z_{t+1} = 0.5 \mid s_{t+} = B] = 0.
\]

The assumption of perfect correlation isn’t necessary for the examples below. It is used here just to keep the number of free parameters to a minimum. All that is really needed to generate these examples is the sign of the correlations to be different across distributions.

Before the information signal about the intermediary’s type is revealed, there are two possible joint distributions for the signal and the shock \((s_{t+}, z_{t+1})\). But even though there is extreme uncertainty about the nature of the correlation of this information shock and the intermediation shock, i.e., it could be either perfectly positively correlated under Distribution 3 or perfectly negatively correlated under Distribution 4, the two joint distributions are identical and assign probability of 1/2 to each of the possible values for \(z_{t+1}\). The uncertainty, therefore, is of no consequence for the optimal investment decision, since investment behavior is invariant to the uncertain correlation parameter. The investor is naturally hedged against this Knightian uncertainty. (For similar examples, see Backus, Routledge and Zin (2005).)

Figure 5 displays the optimal investment policy for either of the possible distributions. The uncertainty is irrelevant, and investment is 7% of the capital stock.

Now we can ask what would happen if we revealed the type of financial intermediary, and allowed the investor to make a new plan. Surprisingly, the uncertainty reappears and has a significant effect on optimal investment. If the intermediaries are revealed to be the “bad” type, then the worst case scenario is that this information is perfectly positively correlated with the actual intermediation shock, and the low value of the shock occurs with perfect certainty: \(\text{Prob}[z_{t+1} = 0.5] = 1\). This case is depicted in red in Figure 6. Note that
investment falls from its previous value by almost 60%. Under the worst case scenario of positive correlation, optimal investment would be 3% of the capital stock.

Alternatively, it might be revealed that the financial intermediary is the “good” type. In this case, the worst case scenario is the negative correlation. In that case, once again, the investor will act as if the worst value of $z_{t+1}$ will occur with probability 1, and optimal investment would fall by 60% in this case as well. This is depicted in red in Figure 7. The surprising feature of this example is that the mere arrival of news itself is sufficient to send this economy into a crisis. The exact nature of that news is of no consequence.

This example is analogous to the sort of financial crisis that is described in Gorton (2009). When new information and new trading opportunities are created, in Gorton’s view this

Figure 5: Natural Uncertainty Hedge.
would correspond to the introduction of mortgage-backed securities index contracts, everyone seems to be made worse off. People on both sides of the market who were previously content with their asset holdings, panic about both market and counter-party risk, forcing substantial collateral calls and large liquidity trades, which in Gorton’s analysis, created the liquidity crisis of 2007. Note that it is very difficult to achieve this sort of negative information externality from any type of standard expected utility model (see Heaton, Lucas and McDonald (2009)). The feature that panic is generated by the arrival of any news is strictly an artifact of investors maximizing under the worst-case scenario. Note that a Pareto improvement can be achieved by simply eliminating the information signal. This seems like a strong argument against mark-to-market accounting. When unanticipated trading opportunities arise, firms who are operating in a world of Knightian uncertainty and who
are maximizing under the worst-case scenario must revalue their asset positions which can destroy real value and create economy-wide liquidity shocks regardless the nature of that news. Note that this sort of information externality could also spark a systemic bank run along the lines Uhlig (2009).

Finally, if the representative agent was aware of the possibility of re-planning based on the revelation of the information signal, then the original investment plan would be time inconsistent. Solving the problem recursively would result in a much more conservative investment strategy from the start, with no subsequent dramatic change after the arrival of information. However, once again, a Pareto improvement could be achieved by simply eliminating the intermediate information.

Figure 7: **Good News Worst Case.**
6 Conclusion

Whether uncertainty about the role of financial intermediation simply induces investors to act in a more conservative fashion, or whether an increase in uncertainty can cause dramatic changes to the real economy necessary depends on the quantitative details of the macroeconomic model that is used to characterize the problem. In this paper we demonstrate that even in a very simple dynamic macroeconomic model, Knightian uncertainty about the technology that intermediates the investment-to-capital transformation, if extreme enough, can have a dramatic negative effect and cause a severe downturn in the economy even in the absence of traditional productivity shocks or labor market frictions. We think this is an important avenue for further research, especially in the context of an optimal policy response to an increase in Knightian uncertainty.

References


