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Model Uncertainty and Policy Design

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Summary:

This article illustrates the main challenges and forces that emerge in optimal policy design when there are doubts about the probability model of uncertainty. Model doubts can stem from either the side of the public or the side of the policymaker, and they can give rise to cautious probabilistic assessments. A basic idea that surfaces in setups with model uncertainty is the management of the public's pessimistic expectations by the policymaker. The article also presents several implications of this idea.

Key findings:

1. Both the public and governments struggle with model uncertainty, especially in unprecedented times.
2. Lack of confidence in the probability model of the economy gives rise to cautious probabilistic assessments by all economic actors.
3. Policymakers can affect the course of the economy by managing the public's pessimistic expectations. Depending on the application, they may mitigate or amplify the public's pessimism.

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Introduction

Severe economic contractions such as the current pandemic or the 2008 financial crisis pose unique challenges to individuals, firms, and governments. On the one hand, decisions we make during these periods have a big impact on our welfare. On the other hand, it is harder to make decisions when the economy is experiencing a large, unusual shock. Many decisions require conjectures about future outcomes, and these conjectures are highly uncertain in unprecedented circumstances. Individuals, when deciding how much of their current income to save, need to assess the elevated risk of not having a job at the end of the month. Airlines, when deciding how to manage the size of their fleet and staff, must become proficient in epidemiology to predict how many customers will be flying in their airplanes during the next month. Governments, when deciding whether to supplement unemployment benefits, must make conjectures about the future evolution of the pandemic and predict how it will influence aggregate demand and supply. During a pandemic or financial crisis, not only are our forecasts likely to be imprecise, but we also fear that the *models* we routinely use to produce forecasts are *wrong*.

How should firms and households make decisions when they are uncertain not just about the future but are also concerned that their framework for predicting the future is misspecified or plainly wrong? How should policymakers respond to these concerns when designing policy? These questions are related to the deeper meaning of *uncertainty*, a concept that has a long history in economics, going back to the work of Knight in the early '20s. Knight (1921) tried to distinguish between *objective* uncertainty, or *risk*, that is easily measurable, and *subjective* uncertainty, or *ambiguity*, that is hard to quantify. In this article, I describe a coherent strategy for economic agents (individuals, firms, and policymakers) to make decisions in the presence of ambiguity and analyze optimal policy design in this setting.

I consider economic agents who are averse to ambiguity; that is, they prefer known odds to those that are unknown. Such agents display prudent behavior and form *cautious* probabilistic scenarios. I show that it is optimal for policymakers to actively monitor and *manage* the private sector's beliefs. Rather surprisingly, how expectations are managed depends on the application. In some settings, it is optimal for policymakers to take actions that *mitigate* the private sector's pessimism and in others there is a role for policy makers to *exacerbate* the respective pessimism.

The first part of this article provides a summary of a particularly useful and tractable approach of introducing model uncertainty in macroeconomics. The second part of the article illustrates the powerful incentive to manage the pessimistic expectations of the private sector and delves into the repercussions for the design of fiscal and monetary policy.

Model Uncertainty

One of the great achievements of rational expectations in macroeconomics was to incorporate in a consistent way economic agents that face objective uncertainty. Agents are modeled as having a *unique* probability model of the economy, which is actually *correct*. This assumption has far-reaching implications and revolutionalized the way we think about policy.

Turning to the realm of subjective uncertainty or ambiguity, we approach the lack of precise probabilistic knowledge by having economic agents who entertain *multiple* probability models. Economic agents do not just "average" across multiple models but, as mentioned in the introduction, exhibit aversion to this model uncertainty. If we want to take the idea of a set of probability models and the aversion toward it seriously, we are left with a nagging question: what is the *relevant* set of probability models? This obviously depends on the application in hand and the actors of the economic environment. This article focuses on a particular approach to ambiguity aversion by using the *multiplier* preferences of Hansen and Sargent (2001). Hansen and Sargent (2001) provide a simple, intuitive, and practical way of constructing the set of probability models that facilitates the introduction of ambiguity aversion to macroeconomics.[1]

Analytical Framework

Since every model is an approximation, the essence of the approach in Hansen and Sargent (2001) relies on starting with a probability model that is a "good" approximation of reality in the eyes of the economic agent. As such, this model acts as a *reference* point. The economic agent is afraid that the reference model may be misspecified and surrounds it with a "ball" of models. The agent is averse to model ambiguity and forms worst-case scenarios. Such cautious behavior allows economic agents to derive decision rules that are *robust* to model misspecification; that is, rules that perform well even if the worst-case scenario takes place. The next paragraphs provide a bird's-eye view on the analytics.[2]

Exponential tilting. Let s denote a random event, or *state of the world*. We assume that s belongs to a discrete set of alternatives S. The event s captures in an abstract way the event

[1] We are not doing justice here to a vast literature in decision theory and statistics. See Savage (1954) for the axiomatic approach that leads to decision makers who act 'as if' they have a unique (yet not necessarily correct) probability measure. See Ellsberg (1961) for the seminal article on ambiguity aversion and the violation of the Savage axioms, and Gilboa and Schmeidler (1989) for an axiomatization of ambiguity-averse behavior. The interested reader is referred to Machina and Siniscalchi (2014) for a survey of a very active literature in decision theory.

[2] Hansen and Sargent (2008) provide a textbook treatment of how to incorporate ambiguity aversion and misspecification concerns in macroeconomics. See also their respective chapter in the *Handbook of Monetary Economics* (Hansen and Sargent (2011)).

that our decision maker (DM) is uncertain about. The DM does not know the probability model that governs s. She contemplates a probability model that she considers a "good" approximation of the true unknown model. We call this probability model the *reference* model and denote it by $\pi(s) \geq 0, s \in S$, where $\pi(s)$ add to unity, $\sum_s \pi(s) = 1$, since π is a probability measure.

Assume now that the DM *doubts* the reference model, since she is afraid that it may be misspecified, and that she considers a "ball" of *alternative* models $\tilde{\pi}$ around the reference model π, with $\tilde{\pi}(s) \geq 0, s \in S$ and $\sum_s \tilde{\pi}(s) = 1$. To measure the radius of the ball, we need a metric of statistical discrepancy between probability distributions. Hansen and Sargent (2001) use the expected logarithmic likelihood ratio, or *relative entropy*, as a measure of discrepancy between distributions.[3] The DM then calculates her expected utility (a measure of welfare) according to these alternative models, and she contemplates the "worst-case" model (denoted by an asterisk as $\tilde{\pi}^*$); that is, the probability model that brings the *least* expected utility. The DM is averse toward uncertainty and makes decisions *as if* the worst-case model is the relevant one.

I want to note several takeaways from the exposition above. First, the size of the ball of models reflects how *much* the DM doubts the model. If the set of probability models is a *singleton*, then the DM has *full* confidence in the reference model. Second, the worst-case model assigns *high* probability (relative to the reference model) on events that bring *low* utility. A simple mathematical formula operationalizes these ideas:

$$\frac{\tilde{\pi}^*(s)}{\pi(s)} = \frac{\exp\left(-\frac{V(s)}{\theta}\right)}{\sum_s \pi(s) \exp\left(-\frac{V(s)}{\theta}\right)} \tag{1}$$

for all $s \in S$, where $\theta > 0$ a positive penalty parameter that captures the confidence of the DM in the probability model π and $V(s)$ the utility of the DM at state s.[4] Formula (1) shows that the DM assigns high probability (relative to the reference model π) on unwelcome events that provide *low* utility. This is the notion of *pessimism* that emerges when agents are averse toward model ambiguity. The parameter θ penalizes deviations from the reference model π.[5] Higher values of θ capture higher confidence in π. When the penalty parameter becomes arbitrarily *large* (θ is equal to infinity), then $\tilde{\pi}^*(s) = \pi(s)$, for all states of the world s.

[3]See Maccheroni et al. (2006) for examples of alternative measures of discrepancy between probability distributions and Strzalecki (2011) for an axiomatic foundation of the multiplier preferences.

[4]For simplicity, we do not write utility as an explicit function of the actions of the DM at s.

[5]The "constraint" preferences of Hansen and Sargent (2001) have as a primitive the *size* of the ball around π. The "multiplier" preferences have as a primitive the penalty parameter θ. The two formulations are connected because θ can be thought of as the Lagrange *multiplier* in the problem of minimizing expected utility within the ball of models.

Therefore, the DM obtains full confidence in the reference model π, and the decision criterion reverts back to subjective expected utility. The exponential form in (1) comes from the use of relative entropy as the measure of statistical discrepancy, and leads to substantial *tractability*, a feature that has led to the popularity of this approach (or close variants) in macroeconomic models that try to incorporate ambiguity aversion.[6]

Structured and unstructured models. In this article, I focus on "unstructured" models around the reference model to create the set of models toward which the DM is ambiguity averse. We could well think of a situation where the DM has a set of "structured" models with particular features that she considers relevant. Nothing prevents us from thinking that s indexes a broader notion of uncertainty in (1). For example, s could represent a probability *model*, and π could stand for the subjective *prior* that the DM is assigning on these models. If the DM is ambiguity *neutral* (as a Bayesian would be), then the DM would just average across models s using π. An ambiguity *averse* DM who would not trust *fully* her prior π would tilt the relevant probability assessments as in (1). In recent work, Hansen and Sargent (2020a,b) show how to combine *both* structured *and* unstructured models.[7]

Detection error probabilities. A crucial question that arises is about the *value* of the positive parameter θ in (1). The applied macroeconomist may want to use a value of θ that induces a "plausible," not overly pessimistic, worst-case model relative to the reference model. In principle, the more data we have, the easier it becomes to distinguish between alternative probability models. Given the fact though that we have time-series of macroeconomic data of *limited* length, we are interested in values of θ so that the likelihood of data of finite length generated by $\tilde{\pi}^*$ is *close* to the likelihood of data of finite length generated by π. Such value of θ would make it difficult to distinguish among probability models, lending credibility to fears of model misspecification of our decision maker. This is the essence of the proposal of Hansen and Sargent (2008), who suggest to calibrate θ by employing the notion of *detection error* probabilities, a metric that concisely captures the difficulty of distinguishing between two models.[8]

[6]For some examples of analysis of ambiguity aversion (featuring the same or similar theories of decision making) in macroeconomics, policy, and finance, see references in Hansen and Sargent (2008), Barlevy (2011) and Epstein and Schneider (2010).

[7]Hansen and Sargent (2020a,b) started to differentiate in terminology between model *ambiguity*, the case where the DM has uncertainty over different *structured* models, and *misspecifications* concerns, the case where the DM is afraid that these models may be misspecified and surrounds them with a ball of *unstructured* models. In the current article I am not reserving the terminology of ambiguity only for structured models; instead, I use the two terms interchangeably.

[8]Assume we had models A and B on the table. Models that are "close" to each other imply high detection error probabilities; that is, a statistician may reject wrongly model A (B) in favor of B (A), although the data are actually generated by model A (B). In contrast, models that are far from each other imply small

What Is Uncertainty about, and Who Faces It?

Now that we have an analytical framework in hand, we can talk in more detail about the sources of uncertainty. Is there uncertainty about the probability model that generates the *shocks* that hit the economy? Is there uncertainty about the *parameters* that may capture characteristics that determine the endogenous decision rules of economic agents? Is there uncertainty about the *structural* relationships in the economy?

All these types of uncertainty may be of interest. For example, a firm may be doubting the probability model of technology or demand shocks. In a similar vein, a consumer may have multiple models about government spending shocks. Concerning *parameter* uncertainty, a central banker may have doubts about the parameters that capture how frequently prices adjust, altering therefore the inflation-output tradeoff that she is facing.[9] Another example comes from the field of climate change economics. One important parameter that is surrounded by substantial uncertainty is the *climate* sensitivity. The climate sensitivity governs how greenhouse gas emissions translate to temperature increases. In addition, we are mostly ignorant with respect to the *damage* sensitivity; that is, the parameter that governs the economic losses caused by higher temperatures. These two sources of uncertainty are instrumental in any kind of policy exercise we may conceive.[10] Lastly, the ongoing pandemic that has threatened lives and livelihoods has painfully laid bare the fundamental uncertainty that surrounds parameters such as the reproduction number, mortality rates, or the mass of asymptomatic carriers.[11]

I have asked questions about the sources of uncertainty, but I have been vague about *who* faces this uncertainty. These two questions are interconnected and can have different answers when multiple agents are at work. In principle, *every* economic agent (policy maker or private agent) faces uncertainty.[12] Depending on the identity of the decision maker, the object of uncertainty can be different. For example, the policy maker may have some uncertainty about parameters that describe the best responses of the private sector. Private agents may have

detection error probabilities. Hansen and Sargent (2008) consider a value of detection error probabilities that are no smaller than 10% as plausible for the applied macroeconomist. The reader is obviously invited to use *introspection* about the relevant detection error probabilities; after all, this notion refers to something inherently subjective.

[9] See Giannoni (2002) and Giannoni (2007) for optimal monetary policy rules subject to this type of uncertainty.

[10] See Barnett et al. (2020) for stressing these uncertainties in climate economics. See Hale et al. (2019) for the Federal Reserve conference on the economics of climate change. See Hansen (2020) for an essay on the importance of uncertainty and ambiguity for markets and policy.

[11] Even in normal times, policymakers constantly face uncertainty about the structure of the economy and update their structural model(s). Recognizing this real-time model uncertainty, Tetlow (2015) considers the robustness and performance of various policy rules in forty-six (!) vintages of the FRB/US model of the Federal Reserve.

[12] In this article, I am abstracting from the uncertainty that is faced by an *econometrician*, who is *outside* the model(s). There is a long literature in statistics and econometrics coping with these issues. See Gospodinov (2018) for an illuminating discussion.

uncertainty about the parameters of the monetary policy rule that a central banker is following.

It may well be the case that both the policymaker and private agents experience doubts about the specification of the probability model of exogenous shocks, either to the same or a different degree. In the next section, I put particular emphasis on the case where the private sector exhibits fears of model misspecification and the policy maker *recognizes* this fear.[13]

Managing Pessimistic Expectations

The theory of cautious probability assessments that we posited in (1) features a notion of *endogenous* pessimism. Economic agents form *forward-looking* expectations that depend on their utility, which is an endogenous object affected by economic outcomes. Economic outcomes, and therefore utility, are jointly determined by exogenous conditions, the actions of economic agents and *policy* decisions.[14] As a result, a policymaker who faces a forward-looking pessimistic private sector can affect the private sector's beliefs through the choice of policy variables. In a sense, the policymaker manages the public's *pessimistic expectations*. This channel is novel and goes above and beyond the conventional ways of how a policymaker affects the course of the economy in rational expectations models.

There are some natural questions that arise in the context of optimal policy design: *How* should a policymaker manage the expectations of private agents? To which effect? How does the pessimism of private agents interact with the pessimism of the government? The next sections provide partial answers to these questions.[15]

Fiscal Policy

Pessimistic expectation management features prominently in Karantounias (2013), which was the first paper that displayed this notion in the literature of ambiguity aversion and policy design. Karantounias (2013) analyzes a classic problem of government finance: consider an

[13] Hansen and Sargent (2012) devise a useful nomenclature about three types of ambiguity when *only* the policy maker faces model uncertainty. Type I ambiguity is a situation where the policy maker doubts the reference probability model of exogenous shocks *and* the probability model that a forward-looking private sector is using in forming expectations (even if the private sector has no doubts about the model). Type II ambiguity refers to a situation where the policymaker doubts the reference probability model of shocks only. Type III ambiguity refers to a situation where both the policy maker and the private sector do *not* doubt their reference model of shocks. However, the policy maker doubts the model that the private sector is using in forming expectations for the future. The work of Dennis (2008) is relevant for type I ambiguity. The monograph of Hansen and Sargent (2008) provides an example of type II ambiguity. Woodford (2010) and Adam and Woodford (2012) are prominent examples of type III ambiguity.

[14] To focus on the impact of policy, we could write utility at state s in (1) as $V(s) \equiv U(s, \tau(s))$, where $\tau(s)$ the policy decision at s. Thus, $\tau(s)$ affects the welfare of the decisionmaker at s, and therefore its worst-case beliefs $\tilde{\pi}^*(s)$ through (1).

[15] The ideas that follow are based on Karantounias (2013, 2020) and Ferrière and Karantounias (2019).

economy with exogenous and uncertain government spending shocks that need to be financed with distortionary labor income taxes or by issuing state-contingent debt.[16] The representative consumer (household) has a reference probability model of government expenditures that may be misspecified.[17] She is averse to this model ambiguity and forms worst-case scenarios as in (1). The fiscal authority shares the same reference model of spending but has *full* confidence in the reference model.[18] The fiscal authority ranks the welfare of alternative policy options according to the reference model and uses an expected utility criterion. The fiscal authority chooses taxes and debt to maximize its welfare objective.

In a fiscal policy environment, the worst-case beliefs of the household are affected by *taxes*. High taxes on a particular state of the world reduce welfare, making the cautious household assign high probability on these states of the world, altering its worst-case scenario. How should the fiscal authority manage the household's pessimistic expectations?

To answer this question, we need to understand the tradeoffs that the fiscal authority is facing. The fiscal authority decides how much government spending will be financed by taxes and how much by issuing new debt (and therefore shifting taxes to the future). The cost of new debt issuance is captured by the *price* of government debt or, more generally, *interest rates*. If government debt is cheap, then the fiscal authority has incentives to shift taxes to the future, whereas the opposite holds if debt issuance becomes prohibitively expensive. Worst-case assessments affect asset prices and therefore the *market* value of government debt. Karantounias (2013) shows that the fiscal authority manages the worst-case beliefs of the household so as to make the price of debt higher, lowering therefore interest rates. Making debt effectively *cheaper* relaxes the government budget and allows less welfare-reducing taxes.

Business Cycles

How would a policymaker design policy when households have doubts about the probability model of the *business cycle*? A major driver of business cycles is *productivity* shocks. Assume that the household is afraid that the reference probability model of productivity shocks is misspecified. The household is cautious and forms worst-case scenarios as in (1).

Imagine now a policymaker who chooses utility-providing government expenditures (in contrast to Karantounias (2013)), labor taxes, and debt to maximize the welfare criterion of the household, an exercise conducted in Ferrière and Karantounias (2019).[19] With full

[16] Government spending provides no utility in this economy. Think of it as a "war" shock that destroys resources.

[17] The applications illustrated in this article focus on *aggregate* outcomes and abstract from heterogeneity and *redistribution*–a major goal for a policymaker. Such directions are obviously worthy of future research.

[18] Hansen and Sargent (2012) call the setup of Karantounias (2013) type 0 ambiguity.

[19] See Ilut and Schneider (2014) for the implications of ambiguity aversion on business cycles.

confidence in the model, optimal surpluses, as share of output, are *constant*. In addition, there is no incentive to either accumulate or decumulate public debt. The government keeps public debt constant, on average.

With doubts about the model, the government is now managing the household's pessimistic beliefs about the cycle. High taxes or low government expenditures reduce the utility of the household, making it twist its cautious beliefs toward these unwelcome scenarios. When interest rates are very responsive to shocks, a situation which requires a sufficiently low intertemporal elasticity of substitution, optimal policy under ambiguity changes drastically: the government follows optimally an *austerity* policy by setting high taxes in bad times of low productivity shocks, and low taxes in good times of high productivity shocks. Furthermore, if doubts about the model are unfounded and the data-generating process actually coincides with the reference probability model, then the government *front-loads* tax distortions and *decumulates* government debt until it reaches a *balanced* budget in the long run. The optimality of fiscal austerity is noteworthy because it takes place in a model without risk of sovereign default or any kind of financial frictions that lead to excessive leverage.

Other Applications

A large firm facing a competitive fringe. There is nothing that forbids the application of these ideas in other areas of economics. Karantounias (2020) considers an application where a large firm is facing many small competitors—in other words, a *competitive fringe*. Both the large firm and the competitive fringe doubt the probability model of demand shocks. They form pessimistic beliefs by assigning high probability to low-*profitability* events, which are associated with low-demand shocks. The large firm has *market power* and acts as a *leader* in setting prices, taking into account the pessimistic beliefs of the competitive fringe (follower). How does the large firm manage the pessimistic beliefs of the fringe? The large firm manages the pessimistic beliefs in order to *reduce* the market share of the fringe, which it achieves by making the fringe *more* pessimistic; that is, by making it assign even higher probability on low-demand shocks. This increased pessimism makes the fringe reduce its quantity produced and increases the profits of the large firm.

Monetary policy? The same ideas about ambiguity-averse firms emerge in monetary policy applications. Consider, for example, a firm that harbors doubts about the probability model of productivity shocks. Productivity shocks are inversely related to the *marginal cost* of the firm and thus affect optimal pricing policies. A cautious firm assigns high probability on low-profit events that are associated with low productivity shocks. How should a monetary authority control inflation in such an environment? As in the fiscal policy applications I illustrated earlier, monetary policy affects profits and thus the worst-case scenarios of the firms. Note that even if firms are not pessimistic, investors who price equity shares of the firm in a stock market may be. This cautious behavior of investors leads again to pessimistic scenarios that assign high probability to low-utility events associated with low productivity shocks. Doubts about the model inflate the equity premium and alter the inflation-output tradeoff that a monetary authority is facing. Benigno and Paciello (2014) conduct an in-depth study of these mechanisms and show how price stability may survive as an optimal target in an environment of model uncertainty.

Mitigating or Amplifying Pessimism?

I have refrained so far from making a general statement about the optimal *direction* of the management of pessimistic expectations. Should a policymaker, who engages in the active management of the endogenous worst-case beliefs of the private sector, *mitigate* or *amplify* the private sector's pessimism? The answer depends on the particulars of the application.

The general message that arises independent of the application is that the policymaker should treat the channel of the endogenous beliefs as an *additional* tool that helps fulfill her objectives. What are these objectives in the applications that we considered? In the fiscal policy applications, the general objective of the policymaker is to minimize (some) measure of welfare distortions that are associated with taxes. To achieve that, the policymaker is trying to *improve* the tradeoffs of taxing today versus issuing debt and postponing taxes into the future. Consequently, the policymaker has an incentive to make (some measure of) debt *cheaper*. Similarly, in the industry application, the profit-maximizing large firm has an incentive to manipulate the fringe's endogenous beliefs to make it *reduce* its level of production.

Getting into the specifics, consider the government finance problem in Karantounias (2013). The pessimistic household is assigning high probability on high spending shocks that provide no utility, and low probability on low spending shocks. The policymaker wants to insure against spending shocks by running deficits against "bad" times of high spending and surpluses against "good" times of low spending. To achieve this *fiscal hedging*, the policymaker sells debt contingent on good times and buys assets contingent on bad times, which help him finance the deficit. The optimal policy commands a high tax rate on good times of low spending shocks and a low tax rate on adverse times with high government spending. Such a policy, by reducing utility in good times and increasing utility in bad times, makes the household twist its probability towards good times, increasing the price of government debt contingent on good times, therefore reducing the respective interest rate. But the pessimistic household does not consider good times very probable. Consequently, in its effort to improve the tax-debt tradeoff, the government is *mitigating* the pessimism of the household.

In contrast, in the industry application in Karantounias (2020), to achieve its objective of increasing profits and decreasing the share of the fringe in the market, the large firm is trying to *amplify* the fringe's pessimistic beliefs by making it assign even lower probability on "bad," low demand shocks. Or in an environment where government expenditures provide utility as in Ferrière and Karantounias (2019) and the intertemporal elasticity of substitution is low (leading to strong reactions of the value of surpluses in marginal utility units), the mitigation of pessimism result can be reversed.[20] This discussion leads us, then, to conclude that the devil is in the details; we cannot make a general statement about mitigating or amplifying pessimism unless the particular structure of the economic environment is specified.[21]

Paternalism?

What should the objective of the policymaker be if she believes that the model is misspecified? If the policymaker thinks that the private sector holds *unreasonable* beliefs, how should the policymaker evaluate policy alternatives? Should the policymaker calculate welfare under the worst-case beliefs of the private sector, or under different, more "reasonable" beliefs? The answers to these questions are not clear when we enter the realm of subjective uncertainty.

One potential approach could be to assume a policymaker who always uses the preferences of the private sector. For lack of better terminology, I call this policymaker *'benevolent'*, in the sense that she does not impose her own evaluations of welfare; she merely adopts the criterion of the private sector, *whatever* this criterion is. Another approach would be to explicitly recognize the potential *disagreement* of the policymaker and the private sector about the probability of a particular event, and assume a policymaker who is *paternalistic*, in the sense that she uses her own probability assessments when she ranks the welfare implications of various policy options.

To capture a plethora of welfare objectives, Karantounias (2020) considers a fiscal policy problem with a policymaker who doubts the probability model *more*, the *same*, or *less* than the representative household.[22] The extent of disagreement is reflected in the *ratio* of the worst-case beliefs of the household over the respective worst-case beliefs of the paternalistic government (which is merely unity if the policymaker is benevolent). Paternalistic incentives

[20] This happens exactly because the value of surpluses can be high as a result of high marginal utility in bad times of low productivity shocks, leading to an incentive for the fiscal authority to amplify the average value of the government portfolio, by twisting the beliefs of the household toward bad times.

[21] Although different in essence, the issue of amplification or mitigation of the endogenous pessimism of the private sector-follower has an interesting, superficial resemblance to an earlier literature that has investigated optimal policy with robustness concerns on the side of the policymaker. In particular, the question is whether model uncertainty leads to *more* or *less* aggressive policy responses relative to the full confidence case. See Giannoni (2002) and Tetlow and von zur Muehlen (2001) for prominent examples in this line of research and Barlevy (2009) and Barlevy (2011) for a comprehensive review.

[22] In the terminology of Hansen and Sargent (2012), the setup nests both type 0 and type II ambiguity.

influence the optimal plan in a distinct way and can work either in the same direction as, or the opposite direction from, the pessimistic expectation management.

To understand how paternalism works, consider a policymaker who thinks that an event is *less* probable than what the household thinks. Consequently, she assigns high distortionary taxes on this event precisely because she thinks that the probability of this event is low and, as a result, she thinks that the average welfare loss resulting from high taxes would be small. The opposite would happen if the policymaker thought that an event is more probable than the household believes.

Concluding Remarks

Policymakers constantly try to understand how the economy works and construct approximating models that guide their decision making process. Sophisticated policymakers recognize that their models may be misspecified and exhibit aversion toward this model uncertainty. Private agents, like firms and households, face similar model uncertainty in making consumption, savings, labor supply, and production decisions. In their efforts to tackle model ambiguity, cautious private agents form pessimistic beliefs by assigning high probability to events that furnish low utility or profits. Policy actions therefore can affect the *endogenous* pessimism of private agents, opening the avenue for a richer notion of expectation management that is absent in environments with full confidence in the model.

In this article I have abstracted from the issue of *learning* under ambiguity.[23] Ambiguity-averse private agents and policymakers could use historical data and make cautious inferences about the underlying model uncertainty over time. The learning process can become *fragile* in these setups, raising intriguing questions about policy design. How should a policymaker (who may also be learning) manage the endogenous fragility of the private sector beliefs? This is an open question.[24]

[23] See Cogley et al. (2008) for an analysis of learning and experimentation in U.S. monetary policy when there are robustness concerns on the side of the policymaker.

[24] I refer the interested reader to Hansen and Sargent (2007), who develop methods for learning and control under ambiguity, and to Hansen and Sargent (2010), for the notion of fragile beliefs and their impact on asset pricing.

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