AGGREGATE AND IDIOSYNCRATIC RISK AND THE BEHAVIOR OF INDIVIDUAL PREFERENCES UNDER MORAL HAZARD

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We consider the effect of alternative individual preference towards effort conditional on aggregate risk in a principal-agent relationship under moral hazard. We find that agents can explore a negative correlation between individual preference towards effort and aggregate risk to further diversify idiosyncratic risk and increase expected utility under moral hazard. The variation of individual preference towards effort may mitigate the impact of moral hazard on the risk premium, but we find this to be quantitatively small.

JELit Classification Codes: D8, D82, E0, G12

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I. INTRODUCTION

This paper examines a simple agency problem where an agent chooses effort levels that positively influence the individual productivity, but create disutility. This framework leads to a moral hazard problem that can be effectively mitigated by a principal's incentive mechanism. We add aggregate risk so that the state of the macroeconomy can influence both the agent's and principal's choices. In particular, it is important to include relevant information about the state of the macroeconomy, say a recession or an expansion, in the information set of the parties involved in contractual relationships under asymmetric information, and to understand how this information can affect choices and contract between parties.

The basic framework under moral hazard involves endogenous partial risk sharing of the idiosyncratic risk between the agent and the principal. We take a step further by considering the implications of the agent preference towards effort conditional on aggregate risk. This is an important problem because a fundamental ambiguity arises in the correlation between individual preferences towards effort and the aggregate state of the economy, say a recession or an expansion.

The problem is as follows: Suppose the macroeconomy is experiencing an expansion, say the aggregate state is good; then it is likely that the disutility created by effort varies relative to the case of a recession, i.e. the bad aggregate state. However, the variation can be plausibly positive, negative or null.[1] This creates a fundamental ambiguity in individual

[1] For example, the relative magnitudes of substitution and wealth effects can easily give variation in any direction.

preference towards effort in the presence of aggregate risk. This fundamental ambiguity impacts upon the contractual relationship between principal and agent creating an important and subtle incompleteness in the contract. The contractual incompleteness is due to transactions costs involved in predicting and/or describing the ambiguity in the agent's preference towards effort, and it is in the spirit of the contract incompleteness discussed in Hart and Moore (1999).[2]

In turn, a risk averse agent can use its own behavior towards effort in utility, conditional on aggregate risk, to further transfer idiosyncratic risk to the principal. The main result of the paper is that when the individual preference towards effort and the aggregate risk are negatively correlated, the agent can effectively further diversify individual risk and increase expected utility. In the traditional mean-variance framework, idiosyncratic risk is fully diversifiable under full information. With asymmetric information, in the principal-agent framework of this paper, we show that a mean-variance (expected utility vs. idiosyncratic risk) tradeoff may endogenously emerge as the individual preference towards effort varies positively with aggregate risk.[3]

[2] Hart and Moore (1999) base contract incompleteness upon the ability to describe events and states of nature; in this paper the incompleteness is based on the transactions costs that arise given the possible ambiguity of a fundamental preference parameter of the agent's utility conditional upon aggregate risk.

[3] The ambiguity of the effect of aggregate risk on heterogeneous individuals is examined in a dynamic adverse selection model in Bianconi (2003a). Here, we focus on a different case or the effect of aggregate risk on individual preference towards effort under moral hazard. Phelan (1994) is an important contribution which examines private information in the class of overlapping generation dynamic models with aggregate risk. See also more recently Altissimo and Zaffaroni (2003) for an empirical investigation of the relationship between aggregate risk and individual heterogeneity using PSID data.

We first study the effects of the alternative preference towards effort conditional on aggregate risk analytically. However, the analytical results are restricted by nonlinearities and complexity, even in the simple static setting. In particular, we are able to obtain analytical results that are partial equilibrium. The crucial general equilibrium effects are then obtained through a quantitative assessment of the model and they reveal important limitations of the partial equilibrium analysis.[4]

In this framework, individual consumption is less than perfectly correlated and more volatile than aggregate consumption which provides a step in the right direction to explain the equity premium puzzle. Thus, we also examine the implications of alternative preference towards effort on the risk-free return and the risk premium. Using the moral hazard model with incomplete risk sharing, Kahn (1990) had shown that moral hazard can plausibly increase the risk premium. Kocherlakota (1998) showed that once Khan's arbitrary restrictions on the set of traded assets were removed, the effect on the equity premium becomes negligible. Our contribution here is to examine how individual preference towards effort, conditional on aggregate risk, impacts on the risk-free return and risk premium under moral hazard.[5] We find that adding the aggregate risk channel on individual preferences can mitigate the moral hazard (upward) effect on the risk premium, i.e. it can move the premium downwards because there

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[4] The problem studied here is specific to agency under moral hazard. However, the ambiguity of individual preference towards aggregate states is fairly general, for example, in manager/worker relationships involving teams.

[5] The paper by Bianconi (2001) examines the effects of labor-leisure choice on asset allocation and returns under adverse selection.

may be less demand for assets to diversify idiosyncratic risk. However, the effects are quantitatively small.

The paper is organized as follows. In section II we present the basic framework and the agency problem. Section III presents the main analytical results of the effect of variation in individual preference towards effort, conditional on aggregate risk, on the agency relationship. Section IV presents the analytical risk-free and risk premium implications. Section V is the quantitative evaluation of the general equilibrium effects, while section VI concludes.

II. BASIC MODEL AND AGENCY

We consider economies populated by a large number of individuals with each individual denoted by the name i. Individuals may have private information about their work effort in the production of a single good. In particular, there may be an infinite number of actions/effort taken by the individual so that the action/effort is unobserved by the general public.

Systematic or aggregate risk is denoted by the aggregate state variable, θ, which affects the distribution of the agent's output, conditional upon the unobserved work effort. Individuals can observe the aggregate state, θ, before their choice of work effort, thus making work effort contingent upon the aggregate state.[6]

The production side is as follows. Each individual named i chooses a state contingent action/effort, denoted $e(\theta) \geq 0$, in order to operate a

[6] The intuition is that an individual's work effort choice is made conditional upon the aggregate state as given. For example, an individual starts the workday under a given aggregate state making effort choices conditional on the aggregate state.

production technology that yields individual stochastic output denoted y. The individual output has two possible outcomes,

$$y_z, \quad for\ z = g\ ("good"),\ b\ ("bad").$$

The probability distribution of the individual output is binomial, and assumed to depend upon the state contingent work effort as:

$$y_g \text{ with probability } p(e(\theta);\theta),$$

$$y_b \text{ with probability } 1\text{-}\ p(e(\theta);\theta);$$

$$y_g > y_b \text{ all } i$$

where $p(e(\theta);\theta) > 0$ is a strictly increasing and strictly concave function of effort, $e(\theta)$, contingent on the aggregate state, or $p' > 0$, $p'' < 0$. Intuitively, the larger (lower) the work effort for a given aggregate state, the larger (lower) the probability of higher output produced by the individual. The function p is well defined and is dependent on the aggregate state θ. Also, given the aggregate state, the individual exogenous output in the "good" state, y_g, is uniformly higher than in the "bad" state, y_b. Thus, the aggregate state has an affect on the individual productivity through the probability function p, so that effort is also a function of the aggregate state.

Aggregate or systematic risk is assumed to follow a binomial distribution as well. The average or aggregate per individual output is denoted Y_θ, for $\theta = G,B$. The probability distribution of average output is given by

$$Y_G \text{ with probability } \pi,$$

$$Y_B \text{ with probability } 1\text{-}\ \pi;$$

$$Y_G > Y_B$$

where $\pi \geq 0$ is a simple probability. Average (aggregate per individual) output is endogenously determined as

$$Y_G = p(e(G);G)\, y_g + [1-p(e(G);G)]\, y_b \qquad (1a)$$

$$Y_B = p(e(B);B)\, y_g + [1-p(e(B);B)]\, y_b\,. \qquad (1b)$$

Expressions (1a,b) simply state average output as a linear combination of individual outputs. In particular, (1a,b) show that average output is an increasing function of the effort supplied by the individual. We can easily compute the mean and variance of aggregate and individual output in this economy as

$$E[Y] = \pi\, Y_G + (1-\pi)\, Y_B = E[y] \qquad (2a)$$

$$var\,(Y) = \pi\ (1-\pi)\ (Y_G - Y_B)^{\,2} \qquad (2b)$$

$$var(y) = [\pi\, p(e(G);G)+(1-\pi)\, p(e(B);B)] \times$$

$$[1-\pi\, p(e(G);G)-(1-\pi)\, p(e(B);B)]\ (y_g - y_b)^2 \qquad (2c)$$

where we used the law of large numbers to express the dependence on the individual type $z = g,b$ only through Y_θ, given in (1a,b), and the average aggregate and individual output are identical. Henceforth, given effort, the effect of the aggregate state on the individual productivity is given by

$$p(e(.);G) > p(e(.);B) \qquad (3)$$

determining the impact of aggregate risk on individual productivity and consequently on effort.

The demand side is as follows. An individual derives utility from consumption of the single good and disutility from effort according to an additively separable function

$$U = u\,(c_z(\theta)) - v(e\,(\theta\,);\theta\,) \tag{4}$$

where $c_z(\theta)$ is the individual state contingent consumption, and u is strictly increasing and strictly concave, $u' > 0,\ u'' < 0$, i.e. an individual is assumed to be risk averse regarding the consumption prospect.

The function v captures (dis)utility of effort, and it is assumed strictly increasing and convex, $v' > 0,\ v'' \geq 0$ in effort. It could be linear in effort, indicating the special case where the individual is risk neutral regarding the disutility of labor. The function v also depends on the aggregate state θ. As we will see in more detail below, this is meant to capture possible differences in the agent's disutility of labor depending on the aggregate state. In particular, allowing an agent to choose her preference towards effort in the presence of aggregate risk can provide an additional channel to diversify idiosyncratic risk and explore a tradeoff between mean and variance. While the principal can observe the aggregate state, θ, when offering a contract, she cannot observe how the agent chooses preference toward effort in the presence of aggregate risk. This is the source of fundamental ambiguity, or incompleteness, in the principal-agent relationship and can be plausibly caused by transactions costs in explicitly writing such contract clauses.

The expected utility, over individual type z and aggregate state θ, of a consumer i is given by

$$\begin{aligned} E[U] = \pi\,\{\, & p(e(G);G)\,u\,(c_g\,(G)) + [1\text{-}p(e(G);G)]\,u\,(c_b\,(G)) - \\ & v(a(G);G)\} + (1\text{-}\pi)\,\{\,p(e(B);B)\,u\,(c_g(B)) + \\ & [1\text{-}p(e(B);B)]\,u\,(c_b(B)) - v(a(B);B)\,\}. \end{aligned} \tag{5}$$

Given the moments in *(2a,b,c)*, we note that $E[Y]=E[C]$, $var(C)=var(Y)$ and that the variance of individual consumption is

$$var(c)= \pi \{ p(e(G);G)(c_g(G)-E[C])^2 + [1-p(e(G);G)](c_b(G)-E[C])^2 \} + (1-\pi) \{ p(e(B);B)(c_g(B)-E[C])^2 + [1-p(e(B);B)](c_b(B)-E[C])^2 \} \qquad (2d)$$

The variance (or standard deviation) of individual consumption will be the measure of idiosyncratic risk borne by the agent. Thus, a tradeoff may emerge between more or less expected utility (more or less mean) and more or less risk (more or less variance of individual consumption).

The agency structure is as follows. An individual (agent) negotiates with a principal a consumption bundle subject to idiosyncratic and aggregate risk. Due to risk aversion, individuals want to minimize the idiosyncratic risk in their consumption bundle by sharing this risk with the principal. The principal is assumed to play the role of a benevolent planner by maximizing the expected utility of the agent over idiosyncratic and aggregate risk in expression (5).

The basic setup is simple enough to accommodate a linear sharing rule.[7] Because there are two aggregate and two idiosyncratic states (2×2 case), the principal can basically offer a linear sharing rule contingent upon the final observable outcomes y_z and Y_θ. In particular, we can postulate a linear consumption rule for an individual i, of the form

$$c_z(\theta) = \alpha_\theta\, y_z + (1-\alpha_\theta)\, Y_\theta, \quad each\ \theta = G,B;\ z = g,b \qquad (6)$$

where $\alpha_\theta \in [0,1]$ is a choice variable in the principal's problem of maximizing the expected utility of the agent subject to the appropriate

[7] Linear sharing rules under moral hazard and their optimality are surveyed in Holmstrom and Hart (1987), and more recently in Bianconi (2003b).

incentive compatibility constraints. In effect, α determines the extent of risk sharing between the principal and the agent. If $\alpha=0$, all idiosyncratic risk is borne by the principal and the agent is fully insured against idiosyncratic risk. If $\alpha=1$, all idiosyncratic risk is borne by the agent and the principal does not bear any idiosyncratic risk. When $\alpha\in(0,1)$ it determines the level of endogenous risk sharing among the parties.

III. CONTRACTS, AGGREGATE RISK AND IDIOSYNCRATIC RISK, AND INDIVIDUAL PREFERENCE

The level of effort of the individual is assumed to be continuous. We thus apply the First Order approach, e.g. Rogerson (1985), Jewitt (1988), and obtain the appropriate incentive compatibility constraint.[8] The appropriate incentive compatibility constraint is the one that maximizes the expected utility, over individual type z, by choice of the level of effort $e(\theta)$ of an individual, subject to consumption following the linear sharing rule given in (4), all conditional on the aggregate state θ, and taking the principal's share parameter α as given (hence taking consumption as given). The problem may be written as

$$\underset{\{e(\theta)\geq 0\}}{Max}\quad p(e(\theta);\theta)\, u(c_g(\theta)) + [1-p\,(e(\theta);\theta)]\, u(c_b(\theta)) - v(e(\theta);\theta) \qquad (7)$$

subject to (6),

[8] The First Order approach is well defined in this case given the properties of the probability function p, i.e. strictly increasing and strictly concave.

with $\{\alpha_\theta, Y_\theta\}$ taken as given by the agent. Substituting the constraint into the objective function and computing the necessary first order conditions of the resulting unconstrained problem yields the expression

$$p'(e(\theta);\theta)[\,u(\alpha_\theta y_g + (1-\alpha_\theta)Y_\theta) - u(\alpha_\theta y_b + (1-\alpha_\theta)Y_\theta)] = v'(e(\theta);\theta),$$
$$\text{all } \theta. \tag{8}$$

The solution in (8) is familiar from asymmetric information problems where the tradeoff between incentives and risk sharing arises, e.g. Holmstrom (1979). The first best would be to provide full insurance to the risk averse individual over the idiosyncratic (non-systematic) risk, i.e. full risk sharing. Full insurance for the idiosyncratic risk in this context implies that $\alpha_\theta = 0$ for all θ. This is because with $\alpha_\theta = 0$ in (6), consumption is just the average across individuals, $c_z(\theta) = Y_\theta$, for each $\theta = G,B$ and all $z = g,b$. This implies, from expression (8) that

$$v'(e(\theta);\theta)\,/\,p'(e(\theta);\theta) \to 0, \text{ all } \theta \iff v' \to 0 \text{ or } p' \to \infty. \tag{9}$$

Hence, expression (9) shows that under the first best or full insurance for the idiosyncratic risk, the effort is minimum, $e \to 0$, since the agent has no incentive to provide effort, i.e. the classic moral hazard or free rider problem. The solution is for the principal to provide partial insurance to the individual idiosyncratic risk, $\alpha \in (0,1)$. In the second best with partial insurance, the agent has an incentive to provide effort above the minimum level, and we observe the usual tradeoff between incentive and risk sharing.

The principal's problem is to maximize expected utility over individual and aggregate risk. First, the principal has the advantage of recognizing that its own actions have an effect on the effort of the agent, i.e. α has an impact on *e.* Second, the principal does not recognize the effect of aggregate risk, θ, on the agent's preference, *v*; i.e. the principal observes θ but cannot observe the way the agent chooses the correlation between *v* and θ. Hence, the effect of aggregate risk on the agent's preference is assumed to be beyond the control of the principal and the transactions costs associated with writing contracts is a plausible motive for this assumption, as in the work of Hart (1995) and Battigalli and Maggi (2002). The principal's problem is

$$Max_{\{\alpha\theta\in(0,1)\}}\ \pi\,\{p(\,(G);G)\ u(c_g\,(G)) + [1\text{-}p\ (e\,(G))]\ u(c_b\,(G)) - v(e\,(G);G)\}+$$

$$(1\text{-}\pi)\{p(\,(B);B)\ u(c_g\,(B)) + [1\text{-}p\ (e\,(B))]\ u(c_b\,(B)) - v(e\,(B);B)\} \qquad (10)$$

subject to (1a,b),(4), and (6),

The necessary first order condition is given by

$$p(e(.);.)\ u'(c_g\,(.))[y_g - Y_{(.)}\,] + [1\text{-}p(e(.);.)]\ u'(c_b(.))\ [y_b - Y_{(.)}\,] + [\partial e/\partial \alpha\,(.)]\times$$

$$\{\ p'(e(.);.)\ [u\ (c_g\,(.))\text{-}u\ (c_b\,(.))] + (1\text{-}\alpha_{(.)}\,)\ p(e(.);.)\times$$

$$[u'(c_g\,(.))\text{-}u'(c_b\,(.))]\ p'(e(.);.)(y_g - y_b\,)\ \text{-}\ v'(e(.);.)\} = 0, \qquad each\ \theta. \quad (11)$$

where $\{c_g\,(.),Y_{(.)}\,\}$ can be substituted from (1a,b) and (6), and $[\partial e/\partial \alpha\,(.)]$ is computed from (8) as

$$[\partial e/\partial \alpha\,(.)] = p'(e(.);.)\ \{\ u'(c_b\,(.))[y_b - Y_{(.)}\,]\ \text{-}\ u'(c_g(.))\ [y_g - Y_{(.)}\,]\}\ /$$

$$p''(e(.);.)\ [u(c_g\,(.))\ \text{-}\ u(c_b(.))] + p'(e(.);.)^2\ (1\text{-}\alpha_{(.)}\,)[u'(c_g\,(.))\text{-}u'(c_b\,(.))]\times$$

$$p'(e(.);.)(y_g - y_b\,)\ \text{-}\ v''(e(.);.), \qquad each\ \theta. \qquad (12)$$

Expressions (11)-(12) provide a solution for $\alpha\in(0,1)$. We can show that the term $[\partial e/\partial \alpha\,(.)]>0$ is strictly positive so that, all else constant, as α

increases and the agent bears more of the idiosyncratic risk, there is an incentive to provide more effort thus increasing the probability of the best outcome to occur. This is the main tool used by the principal to induce effort on the part of the agent.

In this paper, we focus on a potential incompleteness of the contractual relationship presented above. The agent cannot affect the principal's choice of the share α and thus cannot directly affect its own consumption for the choice of effort in problem (7). However, the existence of aggregate risk and the potential dependency of v on θ may allow the agent to affect its own consumption and thus the share α. In other words, the agent may use its own preference towards effort, in particular the curvature $v''(e(.);\theta)$, for a given level of effort, to affect the magnitude of $[\partial e/\partial \alpha (.)]$ in its own best interest of insuring against idiosyncratic risk and increasing expected utility. While the contractual relationship is designed to give incentives for the agent to provide high effort, it comes to the agent at a cost of partial insurance to the idiosyncratic risk. The agent can use its own preferences towards effort to mitigate these costs, thus transferring some risk back to the principal. The agent may be able to explore a potential incompleteness in the contract regarding preference towards effort in the presence of aggregate risk, thus effectively using aggregate risk to diversify the idiosyncratic risk. It is important to note that, even when the principal cannot observe the agent's choice for the cost of effort, the solution to the problem continues to be subgame perfect since chosen effort is what in fact the agent reports to the principal, i.e. the report is truthful.[9] In effect, the principal infers a preference parameter from the agent, say an implied curvature $v''(e(.);\theta)$, but cannot distinguish whether the parameter is due to the intensity of effort or due to the change in preference through aggregate risk, given the level of effort. It is this second channel that is the source of fundamental contractual incompleteness which can be explored by the agent in its best interest.

The incompleteness is based on the fact that an agent's behavior can be fundamentally ambiguous regarding the way aggregate risk affects the (dis)utility of effort. Suppose an agent starts under a good aggregate state, say a boom in the macroeconomy. Its own (dis)utility of effort could vary in two potential distinctive ways:

(i) The aggregate state is good and, for each level of effort, the agent derives higher disutility of effort, say the v function becomes close to linear or $v''(e(.);\theta) \to 0$, and the agent has less incentive to provide effort, preference toward effort and the aggregate state are negatively correlated;[10]

(ii) The aggregate state is good and, for each level of effort, the agent derives lower disutility of effort, say the v function becomes more convex or $v''(e(.);\theta) > 0$, and the agent has more incentive to provide effort, preference toward effort and the aggregate state are positively correlated.

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[9] Subgame perfect equilibrium refers to the consistency between the principal and agent behavior under contractual agreement. See for example Kreps (1990) for a discussion of the subgame perfect equilibrium concept.

[10] Recall that the probability function of the individual also changes with the aggregate state, being the way aggregate risk impacts on the individual productivity in production, e.g. equation (3).

This fundamental source of ambiguity is the source of contractual incompleteness, and it is assumed beyond the principal's control. It thus can be effectively used by the agent to diversify idiosyncratic risk measured by both the share α and the variance of consumption, *var(c)*.[11]

We can compute the local effect of a small change in the aggregate state on the expected utility of the individual, from expression (4), where the agent cannot affect the consumption bundle provided by the principal, thus obtaining

$$\partial E[U]/\partial \theta = [\partial p(.;\theta)/\partial \theta]\ [u(c_g(.)) - u(c_b(.))] - [\partial v(.;\theta)/\partial \theta], \text{ all } \theta \quad (13)$$

where we made use of the Envelope theorem to eliminate the effect on effort. All else constant, it is clear that $\partial v(.;\theta)/\partial\theta < 0$ is in the best interest of the agent by increasing the magnitude of the change in expected utility.[12] The case $\partial v(.;\theta)/\partial\theta < 0$ means that it is in the best interest of the agent to provide more effort in the good aggregate state, case (ii) above. In effect, setting $\partial v(.;\theta)/\partial\theta < 0$ implies that $v''(.;\theta)$ is larger in magnitude (more curvature in the function) and by inspection of expression (12), we note that the magnitude of $[\partial e/\partial \alpha (.)]$ is also lowered. This in turn confirms that the principal's main tool to induce effort on the agent becomes less effective allowing the agent to bear less idiosyncratic risk for

[11] As mentioned above, transactions costs are a plausible motive for the lack of principal's control over individual preferences, e.g. Hart (1995) and Battigalli and Maggi (2002); and the contractual incompleteness is in the spirit of Hart and Moore (1999).

[12] When consumption is a function of effort directly, without the principal's involvement or full information, the effect of $\partial v(.;\theta)/\partial \theta < 0$ would be mitigated by the strict concavity of the utility function in consumption. This can be easily seen in the context of effort choice, say a Robinson Crusoe case, where given the strict concavity of utility of consumption $\partial v(.;\theta)/\partial \theta < 0$ would decrease expected utility, not increase it.

each level of effort. The case $\partial v(.;\theta)/\partial\theta > 0$ means that the agent provides more effort in the bad aggregate state, case (i) above; $v''(.;\theta)$ is smaller in magnitude (less curvature in the function) and $[\partial e/\partial \alpha(.)]$ increases. One way or the other, it confirms that the principal's main tool to induce effort on the agent may be affected.

It is important to recognize that the agent takes consumption as given, so the effects discussed above are partial equilibrium. The particular choice of $\partial v(.;\theta)/\partial\theta < 0$ by the agent will have an ultimate effect on consumption through the principal's choice of α. However, it will also have an effect on the variance of individual consumption. The general equilibrium effects are important because while in expression (13), setting $\partial v(.;\theta)/\partial\theta < 0$ is beneficial for expected utility, it may or may not have a detrimental effect on the variance of individual consumption, hence a mean-variance tradeoff may emerge. We evaluate the general equilibrium effects numerically in section V, given the complexity and nonlinearities involved in the analytical evaluation of the general equilibrium effects.

IV. ASSET RETURNS

Under the arrangements described in section III, we can now describe optimal state contingent consumption in terms of a portfolio of assets. We let an individual hold a portfolio with three assets.

First, we have a private asset subject to the own individual risk, then we have two other macro assets. The characteristics of the assets are as follows: (i) The private risky asset yields the return y_z representing the own individual risk; (ii) One aggregate risky asset yields the average per individual output, Y_θ , representing aggregate macro risk; and (iii) The other macro asset is a risk-free asset yielding the risk-free total return R_f, in zero supply. Therefore, the state contingent individual consumption is replicated by holding a portfolio with the three assets expressed as

$$c_z(\theta)=\alpha_\theta y_z+(1-\alpha_\theta)[sY_\theta+(1-s)R_f],\ each\ \theta=G,B;\ z=g,b \tag{14}$$

where $s\in[0,1]$ is the share of the risky asset in the portfolio of macro assets. Indeed, $\alpha\in[0,1]$, measures the extent of partial risk sharing between the principal and the agent.

The first question is the extent to which the introduction of moral hazard affects asset returns, e.g. Kahn (1990), Kocherlakota (1998). The most important question here is the effect the agent's use of preference towards effort to diversify idiosyncratic risk has on asset returns. Towards an answer, first we consider the risk-free return, R_f. We obtain the endogenous value for R_f using the zero-level pricing method: Maximize expected utility of an individual by choice of the share of macro assets, s, taking the risk-free return, R_f as given. Then, we set the share of the risk-free macro asset on the portfolio to zero, i.e. $s=1$, and find the appropriate R_f that makes the risk-free asset in zero supply, i.e. the value of the asset is the appropriate shadow value that makes the agent indifferent between owning it or not. The specific problem may be written as

$$Max_{\{s\in[0,1]\}}\ \pi\{p(e(G);G)u(c_g(G))+[1-p(e(G);G)]\ u(c_b(G))-v(e(G):G)\}\ +$$
$$(1-\pi)\ \{\ p(e(B));B)\ u\ (c_g(B))\ +\ [1-p(e(B);B)]\ u\ (c_b(B))-v(e(B);B)\}$$
$$subject\ to\ (14), \tag{15}$$

taking $\{\alpha_\theta,\ e(\theta),\ R_f\}$ as given. The necessary first order condition is

$$\pi\ (1\text{-}\alpha_G)(Y_G - R_f)\ \{p(e(G);G)\ u'(c_g(G))+[1\text{-}p(e(G);G)]\ u'(c_b(G))\} +$$
$$(1\text{-}\pi)(1\text{-}\alpha_B)(Y_B - R_f)\{p(e(B);B)\ u'(c_g(B))+$$
$$[1\text{-}p(e(B);B)]\ u'(c_b(B))\} = 0 \qquad (16)$$

where $c_z(.)$ is given in (14). Applying the zero-level pricing method involves solving the first order condition (16) for R_f , and evaluating at $s=1$, yielding

$$R_f^* = E[\ u'(c_z(\theta))\ (1\text{-}\alpha_\theta)\ Y_\theta] \,/\, E[u'(c_z(\theta))(1\text{-}\alpha_\theta)] \qquad (17)$$

where the expectation is over z and θ. The economy with idiosyncratic risk shows a risk-free return that depends upon the marginal utility of individual consumption and the linear sharing value, besides the usual macro factors.

Next, we compute the risk premium $E[Y]\text{-}R_f^*$. Using expressions (17), (2,a,b,c), and the usual covariance decomposition formula, we obtain

$$E[Y] - R_f^* = -\,cov\,(\,u'(c_z(\theta))\ (1\text{-}\alpha_\theta),\ Y_\theta) \,/\, E\,[u'(c_z(\theta))(1\text{-}\alpha_\theta)] \qquad (18)$$

This is a familiar formula for the risk premium except for the presence of the term relating to the principal's share value $(1\text{-}\alpha)$. When there is no private information, full insurance (FI) yields $\alpha=0$, and evaluating at $s=1$ or $c_z(\theta)=Y_\theta$, the risk premium takes the familiar form

$$E[Y] - R_f^*\,|_{FI} = -\,cov\,(\,u'(Y_\theta),\ Y_\theta) \,/\, E\,[u'(Y_\theta)]. \qquad (19)$$

In practice, the covariance of the marginal utility with the risky asset is negative since in the good state consumption is high and the marginal utility is low, i.e. the risk premium is positive. Thus, the higher the covariance (the less negative), the lower the risk premium.

Next, we examine the effect of moral hazard on the risk premium. The share $\alpha > 0$ is necessary to induce effort, but, at the same time, $\alpha > 0$ affects the asset returns as seen in (18)-(19). With moral hazard, there is partial insurance for the idiosyncratic risk and agents bear some of their own idiosyncratic risk in consumption. This implies that, in addition to aggregate risk, individuals must take into account idiosyncratic risk thus making the marginal utility more variable relative to the case of full insurance.

For example, when there is full insurance to the idiosyncratic risk, or $\alpha = 0$, the risk premium is given in expression (19) and it is equal to the term $-cov(u'(Y_\theta), Y_\theta)/E[u'(Y_\theta)]$ (as in the full information case) because individual consumption $c_z(\theta) = Y_\theta$ for all z, and all variation in the marginal utility comes from the aggregate risk. When there is partial insurance to the idiosyncratic risk, $\alpha > 0$, there is the additional variation of the individual idiosyncratic risk in consumption, because $c_z(\theta) \neq Y_\theta$, thus increasing the variation of the marginal utility. In this case, the risk premium is given in (18), and we have that

$$- cov\,(u'(c_z(\theta))(1-\alpha_\theta), Y_\theta) / E\,[u'(c_z(\theta))(1-\alpha_\theta)] \geq$$
$$- cov(u'(Y_\theta), Y_\theta)/E[u'(Y_\theta)] \qquad (20)$$

exactly because of the additional variation of the marginal utility in the second best.[13] Hence, the risk premium, in the presence of contracts that

[13] A proof of inequality (20) can be constructed using arguments analogous to Hansen and Jagannathan (1991). Using $cov(u'(Y_\theta), Y_\theta) = \rho_{12}\sigma_1\sigma_2$, for $\{\sigma_1, \sigma_2\}$ the standard deviations of the first and second arguments in the covariance function, and ρ_{12} their correlation; we obtain from (19), $E[Y - R_f^*] = - \rho_{12}\sigma_1\sigma_2 / E\,[u'(Y_\theta)]$. Hence, rearranging and taking absolute values yields $|\rho_{12}|\,\sigma_1 / E\,[u'(Y_\theta)] = |E[Y - R_f^*]| / \sigma_2$. Given that $|\rho_{12}| \leq 1$, implies $\sigma_1 / E\,[u'(Y_\theta)] \geq |E[Y - R_f^*]| / \sigma_2$, so that a large risk

mitigate moral hazard, may be potentially larger relative to the case of full information.

The crucial issue here is the effect of the fundamental incompleteness where agents can vary the preference towards effort across aggregate states. We have examined in section III that, in terms of expected utility (mean), it is in the best interest of the agent to report $\partial v(.;\theta)/\partial \theta<0$ which implies that $[\partial e/\partial \alpha (.)]$ is lowered, for a given level of effort, i.e. α is lowered. The key result here is that the variation in preference towards effort by the agent may mitigate the effect of moral hazard on asset prices moving the risk premium downwards. The intuition is simple: As α is lowered, the agent bears less idiosyncratic risk and there is less need to provide additional premium to the risk averse agent who holds assets. However, this is partial equilibrium. In general equilibrium, alternative individual preference towards effort will ultimately lead to a change in the level and variance of consumption as well, and the premium may move upwards or downwards depending on the nature of the endogenous mean-variance tradeoff. Hence, alternative individual preference towards effort may mitigate or enlarge the moral hazard effect on asset returns given in (20) once general equilibrium effects are fully accounted for.

Next, we provide a quantitative evaluation of the general equilibrium effects of agents' variations in preference towards effort under moral hazard and aggregate risk.

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premium is necessarily accompanied by a large standard deviation of the marginal utility. The marginal utility of $c_z(\theta)$ is at least as volatile as the marginal utility of Y_θ, see expression (6), and the proof in complete.

V. QUANTITATIVE EVALUATION

The quantitative evaluation of the model is performed with the following functional forms. The utility of consumption has the usual CRRA form:

$$u(c) = c^{1-\rho} / 1-\rho, \qquad \rho > 0 \tag{21}$$

where ρ is the coefficient of relative risk aversion.

The probability function p is given by

$$p(e(.);\theta) = a(\theta)\, e(.)^{\lambda}, \qquad \lambda \in (0,1), \ \text{all } \theta \tag{22}$$

for $a(\theta)>0$, a free parameter denoting the dependency of the probability function on the aggregate state, i.e. the way aggregate risk affects the productivity of individuals [see expression (3)]. The function is strictly increasing and strictly concave.

The disutility of effort function takes the form

$$v(e(.);\theta) = e(.)^{1+\delta(\theta)} / 1+\delta(\theta), \qquad \delta(\theta) \geq 0, \ \text{all } \theta \tag{23}$$

for $\delta(\theta) \geq 0$, all θ determining the extent of the effect of the aggregate state on the function v. Setting $\delta = 0$ indicates that total utility is linear in effort, and given the level of effort as δ increases, say $\delta > 0$, the lower the disutility of effort in total utility. In this latter case, an individual tolerates more effort when δ increases, i.e. has more "risk aversion" in effort. In terms of the results discussed in section III, we have a mapping between δ and $\partial v(.;\theta)/\partial\theta$ as

$$d\delta/d\theta \gtreqless 0 \ \Leftrightarrow \partial v(.;\theta)/\partial\theta \lesseqgtr 0. \tag{24}$$

For a given level of effort $e(.)$, as δ increases (decreases) with the aggregate state and $v''(.;\theta)$ increases or becomes more convex (decreases or becomes less convex), then $\partial v(.;\theta)/\partial\theta <(>)0$. This is because as δ increases (decreases) with the aggregate state, the lower (higher) the disutility of effort and the higher (lower) the utility, i.e. $\partial v(.;\theta)/\partial\theta <(>) 0$.

Hence, the dependency of the parameter δ on the aggregate state conveniently captures the fundamental ambiguity in preference towards effort discussed in section III. When δ increases with the aggregate state, then $\partial v(.;\theta)/\partial\theta <0$ and as the macroeconomy is in a good state, the individual tolerates more effort in preference, and preference and aggregate state are positively correlated. When δ decreases with the aggregate state, then $\partial v(.;\theta)/\partial\theta >0$ and as the macroeconomy is in a good state, the individual tolerates less effort in preference, and preference and aggregate state are negatively correlated. Also, δ may be invariant to the aggregate state, then $\partial v(.;\theta)/\partial\theta =0$; and all cases are plausible.

We evaluate the general equilibrium and asset prices for the economy by choosing a base parameter set with two basic characteristics: (i) The standard deviation of individual consumption and output is several times higher than the standard deviation of aggregate per individual consumption and output, as in the real world data, see e.g. Deaton (1991, 1992), Pischke (1995); (ii) The parameter space is constrained so that the probability function is well defined, or $p(.;.)\in(0,1)$.[14] We choose a base parameter set as:

[14] The quantitative evaluation is meant to provide a qualitative evaluation of the general equilibrium effects of individual preference behavior, so that we do not pursue a formal calibration exercise here.

$$\{\delta(G)=\delta(B)=4.0; \rho=2.0; \lambda=0.25; \pi=0.5;$$

$$y_g=6.25;\ y_b=0.5;\ a(G)=0.9;\ a(B)=0.8\} \quad (25)$$

which implies a benchmark equilibrium where:

$e(G)=0.352$	$E[Y]=4.240$
$e(B)=0.332$	$E[C]=4.240$
$\alpha(G)=0.104$	$var(c)=0.120;\ std(c)=0.347$
$\alpha(B)=0.071$	$var(y)=7.520; std(y)=2.742$
$p(G)=0.694$	$var(C)=0.062; std(C)=0.249$
$p(B)=0.607$	$var(Y)=0.062;\ std(Y)=0.249$
$E[U] = -0.240$	$E[Y]-R_f=0.03$

This benchmark equilibrium is one where effort is around and over *1/3*, the extent of risk sharing reflected in α is between *7* and *10%*, the probability of good individual output is between *60* and *70%*. The standard deviation of individual income is about 11 times the standard deviation of aggregate per individual income, and the standard deviation of individual consumption is about 1.4 times the standard deviation of aggregate per individual consumption. Since there is no investment, aggregate output and consumption are identical and so are their variances.

This is a plausible benchmark to examine the effects of alternative preferences toward effort in the presence of aggregate risk. The tables present percentage changes from the benchmark of $\delta(G)=\delta(B)=4.0$. Table 1 presents the results where in column I, we increase δ uniformly to $\delta(G)=\delta(B)=5.0$, that is $\partial v(.;\theta)/\partial\theta<0$ or $v''(e(.):\theta)$ increases uniformly. Effort increases across aggregate states by an average of about *18%*, the risk sharing measured by α decreases between *2.9* and *5.6%*, the probability of the good state in individual output increases by an average *4.6%*. The consumption risk borne by the agent decreases by *1.4%* and expected utility increases by *4.2%*. It is clear that, across aggregate states, the agent can use preference toward effort to counter the principal's main incentive inducing tool in expression (12), $[\partial e/\partial \alpha (.)]>0$. The effect on the risk-free return and premium is rather small. The risk-free return increases by *16* basis points and the premium remains virtually unchanged.

The second column, II, presents the case where δ increases in the good aggregate state only, $\delta(G)=5.0$ and $\delta(B)=4.0$, reflecting behavior of tolerating more effort when the aggregate state is good and less effort when the aggregate state is bad; that is $\partial v(.;G)/\partial G<0$ or $v''(e(.);G)$ increases, and preference and aggregate state are positively correlated. While the effect on effort, risk sharing and probability of success is symmetric, the effects on the last four rows are instructive. When $\delta(G)$ increases, effort leads to more consumption in the good aggregate state (the bad aggregate state remains unchanged) and the consumption risk borne by the agent increases substantially. Even though the risk sharing amount reflected in α decreases, the agent is not diversifying much of the idiosyncratic risk because the variation in preference is positively related to the outcome of the aggregate state. However, expected utility increases, so that a mean-variance tradeoff emerges.

The results in the highlighted column III illustrate those important issues. Column III presents the case where δ increases in the bad aggregate state only, $\delta(B)=5.0$ and $\delta(G)=4.0$; that is $\partial v(.;B)/\partial B<0$ or $v''(e(.);B)$ increases. This reflects behavior of tolerating more effort when the aggregate state is bad and less effort when the aggregate state is good, i.e. the variation in preference is negatively correlated to the aggregate outcome. Now, when $\delta(B)$ increases, effort leads to more consumption in the bad aggregate state (the good aggregate state remains unchanged) and the consumption risk borne by the agent decreases substantially. The agent is diversifying individual risk using aggregate risk by adjusting the preference parameter towards effort. Not surprisingly, expected utility also increases in this case (it increases across all columns since $\partial v(.;\theta)/\partial\theta <0$). The effects on asset returns remain negligible.

The last two columns, IV and V present the cases where δ increases in the good aggregate state and bad aggregate state but not uniformly. In column IV, $\delta(G)=5.0$ and $\delta(B)=4.5$; that is $\partial v(.;G)/\partial G<0$ or $v''(e(.);G)$ increases by more than $\partial v(.;B)/\partial B<0$ or $v''(e(.);B)$. Again, we note that the risk borne by the agent in terms of standard deviation of consumption increases. The highlighted column V is where $\delta(G)=4.5$ and $\delta(B)=5.0$; that is $\partial v(.;B)/\partial B<0$ or $v''(e(.);B)$ increases by more than $\partial v(.;G)/\partial G<0$ or $v''(e(.);G)$. It confirms the diversification result with the standard deviation of consumption decreasing substantially. The risk-free return increases in both cases but less that in the symmetric case and still by very small amounts.

The striking result of Table 1 is that agents can indeed use aggregate risk to diversify idiosyncratic risk thus affecting the main tool of the principal to provide incentives. By having a preference behavior of tolerating more effort when the aggregate state is bad and less effort when the aggregate state is good, i.e. the variation in preference is negatively correlated with the aggregate outcome, the agent can effectively diversify idiosyncratic risk and increase expected utility under moral hazard. Alternatively, by having a preference behavior of tolerating less effort when the aggregate state is bad and more effort when the aggregate state is good, i.e. the variation in preference is positively related to the aggregate outcome, the agent looses the opportunity to further diversify idiosyncratic risk and an endogenous mean-variance tradeoff emerges under moral hazard.

Tables 2 and 3 present sensitivity analysis regarding risk aversion in consumption and the parameter reflecting the (semi-) elasticity of the probability function with respect to changes in effort. In Table 2, we increase the consumption CRRA coefficient to $\rho = 3.0$ and perform the same experiment of Table 1. The pattern emerging across Table 1 is not changed. Relative to Table 1, more consumption risk aversion magnifies effort, consumption and variance of consumption relative effects. The asset returns effect remains negligible. In Table 3, we increase the (semi-) elasticity of the probability function with respect to effort to $\lambda = 0.4$, making the probability function more sensitive to effort. The pattern emerging across Table 1 is not changed as well. Relative to Table 1, the most notable effect is on the larger magnitude of the changes in the probability function across columns. The asset return effect is relatively larger, but still remains at below a quarter of a percent, thus negligible.

The conclusion from the general equilibrium quantitative assessment is that variation in preference toward effort under moral hazard can be an effective instrument to diversify idiosyncratic risk in the presence of aggregate risk. However, while moral hazard per se does have an effect on asset returns and the premium; actions of the agent using preference towards effort to diversify idiosyncratic risk do not seem to have a significant quantitative impact on the risk-free return and the risk premium.

V. CONCLUSIONS

In this paper, we have examined the effects of variation in individual preferences towards effort in the presence of aggregate and idiosyncratic risk under moral hazard. Our results center around a fundamental ambiguity in the preference towards effort in the presence of aggregate risk. This fundamental ambiguity implies incompleteness in the standard contract of the principal-agent relationship under moral hazard. We show that this incompleteness can be conveniently explored by the agent, effectively allowing for diversification of the idiosyncratic risk with aggregate risk.

The main result is that by having a preference behavior consistent with the variation in preference being negatively related to the aggregate outcome, the agent can effectively diversify idiosyncratic risk and increase expected utility under moral hazard. Alternatively, when the variation in preference is positively related to the aggregate outcome, the agent looses the opportunity to diversify idiosyncratic risk and an endogenous mean-variance tradeoff between expected utility and consumption risk emerges under moral hazard. In all cases, the agent is better off in terms of expected utility by setting preference towards effort that tolerates more effort symmetrically across aggregate states. The key is that by differentiating the preference behavior across aggregate states in a manner that is negatively correlated with the aggregate state allows idiosyncratic risk diversification.

However, we found that the quantitative effect of the variation in preference towards effort on the risk-free return and the risk premium is negligible and less than a quarter of a percent in the best case scenario.

Several avenues of future research are worth pursuing. First it is an important issue to understand the way individuals form preferences toward effort under aggregate risk and this seems to be an important avenue. The most challenging seems to be an extension to the dynamic case where principal and agent can interact and learn about each other actions possibly converging to a scheme that can restore the principal's full ability to induce effort, along the lines of Maskin and Tirole (1990), Hart and Tirole (1988).

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Table 1: Effect of Alternative Preference Toward Effort Conditional on Aggregate Risk

Percentage change from base set: $\delta(G)=\delta(B)=4.0$; $\rho=2.0$; $\lambda=0.25$

$\{\pi=0.5;\ y_g=6.25;\ y_b=0.5;\ a(G)=0.9;\ a(B)=0.8\}$

$\rho=2.0$ $\lambda=0.25$	$\delta(G)=5.0$ $\delta(B)=5.0$ I	$\delta(G)=5.0$ $\delta(B)=4.0$ II	$\delta(G)=4.0$ $\delta(B)=5.0$ III	$\delta(G)=5.0$ $\delta(B)=4.5$ IV	$\delta(G)=4.5$ $\delta(B)=5.0$ V
e(G)	*17.8*	*17.8*	*0*	*17.8*	*9.4*
e(B)	*18.4*	*0*	*18.4*	*9.6*	*18.4*
$\alpha(G)$	*-2.9*	*-2.9*	*0*	*-2.9*	*-1.0*
$\alpha(B)$	*-5.6*	*0*	*-5.6*	*-2.8*	*-5.6*
p(G)	*4.8*	*4.8*	*0*	*4.8*	*2.2*
p(B)	*4.3*	*0*	*4.3*	*2.3*	*4.3*
std(c)	*-1.4*	*16.9*	*-15.6*	*6.9*	*-8.3*
E[U]	*4.2*	*2.9*	*0.8*	*3.8*	*2.5*
R_f (*)	*0.16*	*0.06*	*0.09*	*0.11*	*0.13*
$E[Y]-R_f$ (*)	*0.00*	*0.02*	*-0.02*	*0.01*	*-0.01*

(*) Percentage point change (difference) from base set.

Table 2: Effect of Alternative Preference Toward Effort Conditional on Aggregate Risk

Percentage change from base set: $\delta(G)= \delta(B)=4.0; \rho=3.0; \lambda=0.25$

$\{\pi=0.5; y_g=6.25; y_b=0.5; a(G)=0.9; a(B)=0.8\}$

$\rho=3.0$ $\lambda=0.25$	$\delta(G)=5.0$ $\delta(B)=5.0$ I	$\delta(G)=5.0$ $\delta(B)=4.0$ II	$\delta(G)=4.0$ $\delta(B)=5.0$ III	$\delta(G)=5.0$ $\delta(B)=4.5$ IV	$\delta(G)=4.5$ $\delta(B)=5.0$ V
$e(G)$	23.5	23.5	0	23.5	12.2
$e(B)$	23.9	0	23.9	12.1	23.9
$\alpha(G)$	0.0	0.0	0	0.0	0.0
$\alpha(B)$	-3.4	0	-3.4	-1.7	-3.4
$p(G)$	5.5	5.5	0	5.5	3.0
$p(B)$	5.5	0	5.5	3.0	5.5
$std(c)$	1.4	27.0	-20.8	13.0	-9.9
$E[U]$	9.1	9.1	3.0	9.1	6.1
R_f (*)	0.19	0.06	0.11	0.13	0.16
$E[Y]-R_f$ (*)	0.00	0.04	-0.02	0.02	-0.01

(*) Percentage point change (difference) from base set.

Table 3: Effect of Alternative Preference Toward Effort Conditional on Aggregate Risk

Percentage change from base set: $\delta(G)= \delta(B)=4.0; \rho=2.0; \lambda=0.40$

$\{\pi=0.5; y_g=6.25; y_b=0.5; a(G)=0.9; a(B)=0.8\}$

$\rho=2.0$ $\lambda=0.40$	$\delta(G)=5.0$ $\delta(B)=5.0$ I	$\delta(G)=5.0$ $\delta(B)=4.0$ II	$\delta(G)=4.0$ $\delta(B)=5.0$ III	$\delta(G)=5.0$ $\delta(B)=4.5$ IV	$\delta(G)=4.5$ $\delta(B)=5.0$ V
$e(G)$	15.6	15.6	0	15.6	8.2
$e(B)$	15.9	0	15.9	8.4	15.9
$\alpha(G)$	0.0	0.0	0	0.0	0.0
$\alpha(B)$	-2.4	0	-2.4	-1.2	-2.4
$p(G)$	5.9	5.9	0	5.9	3.2
$p(B)$	6.1	0	6.1	3.3	6.1
$std(c)$	0.1	19.1	-14.7	8.6	-7.5
$E[U]$	5.3	3.8	1.1	4.5	3.4
R_f (*)	0.20	0.08	0.12	0.14	0.16
$E[Y]-R_f$ (*)	-0.01	0.03	-0.02	-0.01	-0.01

(*) Percentage point change (difference) from base set.