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Benjamin Moll  
Robert M. Townsend  
Victor Zhorin

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### **ABSTRACT**

Motivated by evidence from the micro data that the type of financial frictions faced by individuals varies across regions within countries, we develop a general equilibrium framework that encompasses different micro financial underpinnings. We use it to compare the implications of two concrete frictions, limited commitment and moral hazard, and argue that these have potentially very different implications at both the macro and the micro level. Aggregate productivity is depressed in the two regimes but for completely different reasons: under limited commitment capital is misallocated across heterogeneous firms. In contrast, under moral hazard, productivity is endogenously lower at the firm level because entrepreneurs exert suboptimal effort. Occupational choice, productivity and firm size distribution, income and wealth inequality, and the speed of individual transitions also differ markedly. We also present an economy with different frictions in different regions. Such mixture regimes turn out to be different from simple convex combinations of the pure moral hazard and pure limited commitment regimes, and they produce interregional patterns of aggregate income, capital and labor flows and external finance that resemble rural-urban patterns observed in the data.

Benjamin Moll  
Department of Economics  
Princeton University  
106 Fisher Hall  
Princeton, NJ 08544  
and NBER  
moll@princeton.edu

Victor Zhorin  
University of Chicago Computation Institute  
5735 S. Ellis Avenue, SCL 209  
Chicago, IL 60637  
vzhorin@uchicago.edu

Robert M. Townsend  
Department of Economics, E17-230  
MIT  
77 Massachusetts Avenue  
Cambridge, MA 02139  
and NBER  
rtownsen@mit.edu

# 1 Introduction

There is evidence that even within a given economy, obstacles to trade may vary depending on location. In a companion paper, Karaivanov and Townsend (2012) estimate the financial/information regime in place for households including those running businesses using Townsend Thai data from rural areas (villages) and from urban areas (towns and cities). They find differences across these locations. For example, a moral hazard constrained financial regime fits best in urban areas and a more limited savings regime in rural areas.

More generally, there seems to be (related) regional variation. Paulson, Townsend and Karaivanov (2006) find that in both a moral hazard and a limited commitment regime, the decision to become an entrepreneur not only depends on talent but also on wealth. But the quantitative mapping differs between the two regimes, and allows one to assess regional differences. Moral hazard fits best to the data in the more urban Central region but not in the more rural Northeast. Using additional data on repayment of joint liability loans, Ahlin and Townsend (2007) seem to confirm the regional variation (though for not all specifications). Information seems to be a problem in the Central area, limited commitment in the Northeast.<sup>1</sup> Also not too surprisingly, which financial regime is inferred depends on what data is used by the econometrician, for example whether he uses data on consumption, investment or both (Karaivanov and Townsend, 2012).

As we await the final verdict from the micro data, we begin the next step in this paper and ask what difference the micro financial foundations make for the macro economy. To this end, we develop a general equilibrium framework that encompasses different types of frictions. To fix ideas, we consider two regimes of frictions: limited commitment and moral hazard. We study their implications for aggregates like national income, total factor productivity (TFP), capital accumulation, wages and interest rates, but also for micro moments such as the productivity distribution, the size distribution of firms, the dispersion in the marginal product of capital, dispersion in growth rates, inequality, and national versus sectoral level capital flows. We show that all of these look potentially very different depending on the underlying financial regime.

In our theory, a large number of households access the economy's capital market via intermediaries with which they form long-term contracts.<sup>2</sup> Households choose between being

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<sup>1</sup>More precisely, Ahlin and Townsend (2007) find the non-monotone derivative of repayment with respect to loan size in the adverse selection model of Ghatak (1999) in the Central region but not the Northeast. The negative sign with respect to the joint liability payment of the moral hazard model of Stiglitz (1990), and the model of Ghatak, is found in the Central region. The sign on screening is counter to the Ghatak model in the Northeast. Covariance of outputs raises repayment as in the two information models in the Central region. Ease of monitoring reducing moral hazard and raising repayment in the Central region. Cooperation among borrowers in decision making, which has a positive sign in the moral hazard model of Stiglitz, holds in the Central region. Sanctions for strategic default are especially effective in the Northeast.

<sup>2</sup>Once a household decides to contract with an intermediary he sticks with that intermediary forever. How-

entrepreneurs and workers. Entrepreneurs produce using labor and capital, and their productivity depends on their talent and a residual productivity term which partly depends on their effort. The intermediary can potentially insure them against residual productivity risk, but not their talent.<sup>3</sup> Workers supply efficiency units of labor to the economy-wide labor market. These depend on their effort and are potentially insurable. The interest rate and wages are determined in general equilibrium. Contracts between intermediaries and households are subject to one of two frictions: moral hazard or limited commitment. In the moral hazard regime, effort of both entrepreneurs and workers is unobserved so that providing full insurance against residual productivity or labor efficiency induces shirking. In the limited commitment regime, there is full insurance but instead entrepreneurs face simple collateral constraints that limit the amount of capital they can use in production by their personal wealth.<sup>4</sup>

Our main result is that both micro and macro implications of the two frictions – moral hazard and limited commitment – can be quite different. First, aggregate TFP in the two regimes is depressed but for completely different reasons: under limited commitment this results from a misallocation of capital across firms with given productivities. In contrast, under moral hazard, TFP is endogenously lower at the firm level because entrepreneurs exert suboptimal effort.<sup>5</sup> In a recent paper Midrigan and Xu (forthcoming) have argued that a model with collateral constraints, when calibrated to plant level data, generates fairly small dispersion of marginal products and hence TFP losses from misallocation. Our economy with moral hazard is an example in which there are sizable TFP losses even though returns to capital are equalized across all firms.<sup>6</sup> Second, occupational choice, the firm productivity and size distributions, ever, the threat of having one’s customer poached by another intermediary means that intermediaries make zero expected profits at each point in time.

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<sup>3</sup>We exogenously impose the assumption that talent shocks are not insurable in the interest of realism.

<sup>4</sup>We choose a formulation of the limited commitment problem that can be represented by a simple static collateral constraint. Alternatively, we could have worked with a more full-blown dynamic limited commitment problem as is common in the optimal contracting literature (for example Albuquerque and Hopenhayn, 2004). We choose to work with collateral constraints, mainly because it facilitates comparison with the existing literature (for example Evans and Jovanovic, 1989; Holtz-Eakin, Joulfaian and Rosen, 1994; Banerjee and Duflo, 2005; Paulson, Townsend and Karaivanov, 2006; Jeong and Townsend, 2007; Buera and Shin, 2010; Moll, 2012; Midrigan and Xu, forthcoming), and it also simplifies some of the computations.

<sup>5</sup>We here assume that entrepreneurial effort is not accurately accounted for as an input into production. That is, each entrepreneur works full time at his firm and his time is counted as part of his firm’s labor input. But effort is unobserved, implying that low effort results in low measured firm-level TFP. Alternatively, we could have assumed that a similar measurement problem also applies to *hired* labor. In this case, losses from moral hazard in measured firm-level TFP would be further amplified.

<sup>6</sup>The result that marginal products of capital are equalized across firms does make use of the exact formulation of our moral hazard problem, in particular that capital stocks can be observed and that a change in an entrepreneur’s capital stock does not change his incentive to shirk. But we think that these are reasonable assumptions – e.g. surely it is easier to observe an entrepreneur’s machines than his effort – and they allow us to illustrate in a transparent fashion that moral hazard does not *necessarily* result in capital misallocation.

and income and wealth inequality also differ markedly. Third, individual transitions are much faster in the limited commitment regime than under the moral hazard, resulting for example in more dispersed wealth growth rates. This is because in the limited commitment regime binding borrowing constraints and high marginal products of capital provide an incentive for entrepreneurs to attempt to save themselves out of these constraints. In contrast, under moral hazard individual wealth or promised utility moves slowly as output-dependent penalties and awards are spread into the future (see for example Phelan and Townsend, 1991; Karaivanov and Townsend, 2012). Finally, and as is well known, limited commitment results in individuals being borrowing constrained whereas under moral hazard they are *savings* constrained. This implies that the equilibrium interest rate is higher under moral hazard than under limited commitment.

We also present an economy with different frictions in different regions. Such mixture regimes turn out to be different from simple convex combinations of the pure moral hazard and pure limited commitment regimes. More precisely, aggregate variables such as total factor productivity can be non-monotonic functions of the fraction of the population subject to moral hazard, and we show that this is due to general equilibrium effects. As already mentioned, Paulson, Townsend and Karaivanov (2006), Ahlin and Townsend (2007) and Karaivanov and Townsend (2012) suggest that moral hazard may be more prevalent in urban areas and limited commitment in rural areas. When we take this finding at face value and interpret the moral hazard regime as urban areas or industrialized regions and the limited commitment regime as rural areas or regions of the country which are less developed overall, our economy produces interregional patterns of aggregate income, capital and labor flows and external finance that resemble rural-urban, inter-regional patterns observed in the data. In particular, regional income, the aggregate capital stock and the amount of external finance are higher in urban and industrialized areas, and both capital and labor flow from rural and agricultural to urban areas.<sup>7</sup> Of course, in practice there are likely many other factors that distinguish cities from villages and industrialized from agricultural areas (for example, cities have better infrastructure, higher population density, regions vary in resource base etc). But we nevertheless find it noteworthy that we can generate a number of observed rural-urban patterns by letting only the financial regime differ across these regions.

The bottom line is that the behavior of macro aggregates depends on micro financial underpinnings. This has important implications for the literature studying the role of financial

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<sup>7</sup>Seminal contributions in development economics emphasized rural to urban labor migration, e.g., Lewis (1954) and Harris and Todaro (1970). Within-country capital flows are somewhat harder to document. Using data from Mexico, an ongoing study by the Comisión Nacional Bancaria y de Valores (CNBV, <http://bit.ly/17NIId1F>) funded by CFSP in its efforts to improve flow of funds accounts, finds that municipalities (counties) with cities of more than 300,000 inhabitants tend to borrow from municipalities with smaller or no cities. This is consistent with the capital flows that arise in our model.

market imperfections in economic development. Most of the existing literature works with collateral constraints that are either explicitly or implicitly motivated as arising from a limited commitment problem (Evans and Jovanovic, 1989; Holtz-Eakin, Joulfaian and Rosen, 1994; Banerjee and Duflo, 2005; Jeong and Townsend, 2007; Buera and Shin, 2010; Buera, Kaboski and Shin, 2011; Moll, 2012; Caselli and Gennaioli, 2013; Midrigan and Xu, forthcoming). In contrast, there are much fewer studies that model financial frictions as arising from moral hazard. Notable exceptions are the early contributions by Aghion and Bolton (1997) and Piketty (1997), and also Ghatak, Morelli and Sjostrom (2001).<sup>8</sup> Related, some papers study environments with asymmetric information and costly state verification (as in Townsend, 1979), but there are again few of these (Castro, Clementi and Macdonald, 2009; Greenwood, Sanchez and Wang, 2010*a,b*; Cole, Greenwood and Sanchez, 2012). Finally, Martin and Taddei (2012) study the implications of adverse selection on macroeconomic aggregates, and contrast them with those of limited commitment. In either case, few authors use micro data to discipline their macro models.<sup>9</sup> Even fewer (perhaps none?) use micro data to choose between the myriad of alternative forms of introducing a financial friction into their model. This is a serious shortcoming and the goal of this paper is to make some progress by studying the macroeconomic implications of different micro financial underpinnings suggested by the micro data.

Not surprisingly, the microeconomic literature is somewhat more advanced in terms of taking seriously different micro financial underpinnings and trying to distinguish between them in the data. For example, Clementi and Hopenhayn (2006) and Albuquerque and Hopenhayn (2004) argue that moral hazard and limited commitment have different implications for firm dynamics. Abraham and Pavoni (2005) and Doepke and Townsend (2006) discuss how consumption allocations differ under moral hazard with and without hidden savings, and full information. The paper by Karaivanov and Townsend (2012) we have already discussed makes a related point but focuses on household-firms and uses Townsend Thai data to distinguish between the different regimes. Similarly, Kinnan (2012) uses a different metric based on the first order conditions characterizing optimal insurance under moral hazard, limited commitment and hidden income to distinguish these regimes in Thai data. Meisenzahl (2011) is another example trying to distinguish between different regimes using micro data, in his case between moral hazard

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<sup>8</sup>But note that these authors study overlapping generations models whereas we study an economy with long-term contracts between infinitely-lived households and intermediaries. Another difference between our setup and that of Ghatak, Morelli and Sjostrom (2001) is that in their setup, the principal-agent relationship subject to moral hazard is between entrepreneurs and workers whereas in our setup the principals are intermediaries and the agents are both entrepreneurs and workers. The only other paper we are aware of that features infinitely-lived entrepreneurs and optimal contracts under moral hazard in general equilibrium is by Shourideh (2012). But his framework differs in that moral hazard stems from the unobservability of capital as opposed to effort, there is no occupational choice, and his focus is on optimal taxation of entrepreneurial income as opposed to understanding cross-country income differences.

<sup>9</sup>Exceptions are Kaboski and Townsend (2011) and Midrigan and Xu (forthcoming).

and costly state verification and using data on small businesses in the US.

The paper is organized as follows. Section 2 develops our theory, and section 3 discusses our choice of parameter values. Section 4 compares an economy subject to limited commitment to one subject to moral hazard. Section 5 presents results for mixed regimes in which part of the economy is subject to moral hazard and the remainder to limited commitment. Section 6 discusses robustness of our results to alternative parameterizations, and Section 7 is a conclusion.

## 2 Households and Intermediaries

We consider an economy populated by a continuum of households of measure one, indexed by  $i \in [0, 1]$  and a continuum of intermediaries, indexed by  $j$ . Time is discrete. In each period  $t$ , a household experiences two shocks: an ability shock,  $z_{it}$  and an additional “residual productivity” shock,  $\varepsilon_{it}$  (more on this below). Households have preferences over consumption,  $c_{it}$  and effort,  $e_{it}$

$$v_{i0} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_{it}, e_{it}).$$

Households can access the capital market of the economy only via one of the intermediaries. Each intermediary contracts with a continuum of households and therefore also provides some insurance to households. Intermediaries compete ex-ante for the right to contract with households. Once a household  $i$  decides to contract with an intermediary  $j$  he sticks with that intermediary forever. However, the threat of having one’s customer poached by one of the remaining intermediaries means that all intermediaries make zero expected profits at each point in time.

Households have some initial wealth  $a_{i0}$  and an income stream  $\{y_{it}\}_{t=0}^{\infty}$  (determined below). When households contract with an intermediary, they give their entire initial wealth and income stream to the intermediary. The intermediary pools the income of all the households it contracts with, invests it at a risk-free interest rate  $r$  and transfers some consumption to the households. An intermediary together with the continuum of households he contracts with therefore forms a “risk-sharing group”: some of each household’s risk is shared with the other households in the group according to an optimal contract specified below. Denote by  $a_{jt}$  and  $y_{jt}$  the pooled wealth and income in risk-sharing group  $j$ . Then the risk-sharing group’s budget constraint is

$$a_{jt+1} = y_{jt} - c_{jt} + (1 + r)a_{jt}. \tag{1}$$

The optimal contract between intermediary and households maximizes the households’ utility subject to this budget constraint (and incentive constraints specified below). Risk-sharing groups make their decisions taking as given a constant (over time) wage and interest rate  $w$

and  $r$  and compete with each other in competitive labor and capital markets. We here assume that the economy is in a stationary equilibrium so that factor prices are constant over time. This is mainly for simplicity. Our setup can easily be extended to the case where aggregates vary deterministically over time at the expense of some extra notation.

## 2.1 Household's Problem

Households can either be entrepreneurs or workers. We denote by  $x_{it} = 1$  the choice of being an entrepreneur and by  $x_{it} = 0$  that of being a worker. First, consider entrepreneurs. An entrepreneur hires labor  $\ell_{it}$  at a wage  $w_t$  and rents capital  $k_{it}$  at a rental rate  $r_t + \delta$  and produces some output.<sup>10</sup> His observed productivity has two components: a component,  $z_{it}$ , that is known by the entrepreneur in advance at the time he decides how much capital and labor to hire, and a residual component,  $\varepsilon_{it}$ , that is realized afterwards. We will call the first component *entrepreneurial ability* and the second *residual productivity*. The evolution of entrepreneurial talent is exogenous and given by some stationary transition process  $\mu(z_{it+1}|z_{it})$ . Residual productivity instead depends on an entrepreneur's effort,  $e_{it}$ , which is potentially unobserved, depending on the financial regime. More precisely, his effort determines the distribution  $p(\varepsilon_{it}|e_{it})$  from which residual productivity is drawn, with higher effort making good realizations more likely. We assume that intermediaries can insure residual productivity  $\varepsilon_{it}$ . In contrast, even if entrepreneurial ability,  $z_{it}$ , is observed, it is *not* contractible and hence cannot be insured. An entrepreneur's output is given by

$$z_{it}\varepsilon_{it}f(k_{it}, \ell_{it}),$$

where  $f(k, \ell)$  is a span-of-control production function.

Next, consider workers. A worker sells efficiency units of labor  $\varepsilon_{it}$  in the labor market at wage  $w_t$ . Efficiency units are observed but are stochastic and depend on the worker's true underlying effort, with distribution  $p(\varepsilon_{it}|e_{it})$ .<sup>11</sup> The worker's true underlying effort is potentially unobserved, depending on the financial regime. A worker's ability is fixed over time.

Putting everything together, the income stream of a household is

$$y_{it} = x_{it}[z_{it}\varepsilon_{it}f(k_{it}, \ell_{it}) - w_t\ell_{it} - (r_t + \delta)k_{it}] + (1 - x_{it})w_t\varepsilon. \quad (2)$$

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<sup>10</sup>We assume that capital is owned and accumulated by a capital producing sector. This sector rents out capital to entrepreneurs in a capital rental market, and also holds the net debt of households (or more precisely, of the risk-sharing groups the households belong to) between periods. See Appendix B for details. That the rental rate equals  $r_t + \delta$  follows from a standard arbitrage argument. This way of stating the problem avoids carrying capital,  $k_{it}$ , as a state variable in the dynamic program of a risk-sharing group.

<sup>11</sup>The assumption that the distribution of workers' efficiency units  $p(\cdot|e_{it})$  is the same as that of entrepreneurs' residual productivity is made solely for simplicity, and we could easily allow workers and entrepreneurs to draw from different distributions at the expense of some extra notation.



The joint budget constraint of the risk-sharing group consisting of household and intermediary is given by (1) where  $y_{jt}$  is the sum over  $y_{it}$  of all households that contract with intermediary  $j$ .

The timing is illustrated in Figure 1 and is as follows: the household comes into the period

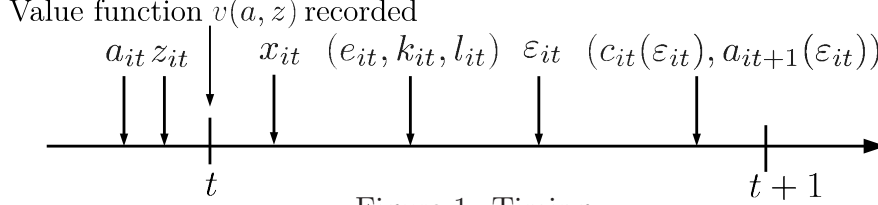


Figure 1: Timing

with previously determined savings  $a_{it}$  and a draw of entrepreneurial talent  $z_{it}$ . Then within period  $t$ , the contract between household and intermediary assigns occupational choice  $x_{it}$ , effort,  $e_{it}$ , and – if the chosen occupation is entrepreneurship – capital and labor,  $k_{it}$  and  $\ell_{it}$ . All these choices are conditional on talent  $z_{it}$  and assets carried over from the last period,  $a_{it}$ . Next, residual productivity,  $\varepsilon_{it}$ , is realized which depends on effort through the conditional distribution  $p(\varepsilon_{it}|e_{it})$ . Finally, the contract assigns the household's consumption and savings, that is functions  $c_{it}(\varepsilon_{it})$  and  $a_{it+1}(\varepsilon_{it})$ . The household's effort choice  $e_{it}$  may be unobserved depending on the regime we study. All other actions of the household are observed. For instance, there are no hidden savings.

We now write the problem of a risk-sharing group, consisting of a household and an intermediary, in recursive form. The two state variables are wealth,  $a$ , and entrepreneurial ability,  $z$ . Recall that  $z$  evolves according to some exogenous Markov process  $\mu(z'|z)$ . It will be convenient below to define the household's expected continuation value by

$$\mathbb{E}_{z'} v(a', z') = \sum_{z'} v(a', z') \mu(z'|z),$$

where the expectation is over  $z'$ .

A contract between a household of type  $(a, z)$  and an intermediary solves

$$\begin{aligned} v(a, z) = \max_{e, x, k, \ell, c(\varepsilon), a'(\varepsilon)} \sum_{\varepsilon} p(\varepsilon|e) \{u[c(\varepsilon), e] + \beta \mathbb{E}_{z'} v[a'(\varepsilon), z']\} \quad \text{s.t.} \\ \sum_{\varepsilon} p(\varepsilon|e) \{c(\varepsilon) + a'(\varepsilon)\} = \sum_{\varepsilon} p(\varepsilon|e) \{x[z\varepsilon f(k, \ell) - w\ell - (r + \delta)k] + (1 - x)w\varepsilon\} + (1 + r)a \end{aligned} \quad (3)$$

and also subject to regime-specific constraints specified below.

The contract maximizes a household's expected utility subject to a break-even constraint for the intermediary. This is because competition by intermediaries for households ensures that

any intermediary makes zero profits in expectation. Note that the budget constraint of a risk syndicate in (3) averages over realizations of  $\varepsilon$ ; it does not have to hold separately for every realization of  $\varepsilon$ . This is because the contract between the household and the intermediary has an insurance aspect which implies that consumption can be different from income less than savings. Such an insurance arrangement can be “decentralized” in various ways. The intermediary could simply make state contingent transfers to the household. Alternatively, intermediaries can be interpreted as banks that offer savings accounts with state-contingent interest payments to households.

In contrast to residual productivity  $\varepsilon$ , talent  $z$  is not insurable. *Prior* to the realization of  $\varepsilon$ , the contract specifies consumption and savings that are *contingent* on  $\varepsilon$ ,  $c(\varepsilon)$  and  $a'(\varepsilon)$ . In contrast, consumption and savings cannot be contingent on next period’s talent realization  $z'$  and hence next period’s state is  $(a', z')$ .<sup>12</sup>

The contract between intermediaries and households is subject to one of two frictions: private information in the form of moral hazard, or limited commitment. Each friction corresponds to a regime-specific constraint that is added to the dynamic program (3). In line with the findings of Paulson, Townsend and Karaivanov (2006), Ahlin and Townsend (2007) and Karaivanov and Townsend (2012) discussed in the introduction, a possible interpretation is that different financial regimes represent different locations within an economy: moral hazard in urban and industrialized areas and limited commitment in rural and agricultural areas. We will pursue this interpretation in more detail in section 5. For sake of simplicity and to isolate the economic mechanisms at work, the only thing that varies across the two regimes is the financial friction. It would be easy to incorporate some differences, say in the stochastic processes for ability  $z$  and residual productivity  $\varepsilon$  at the expense of some extra notation. We specify the two financial regimes in turn.

## 2.2 Moral Hazard

In this regime, effort  $e$  is unobserved. Since the distribution of residual productivity,  $p(\varepsilon|e)$  depends on effort, this gives rise to a standard moral hazard problem: full insurance against residual productivity shocks would induce the household to exert suboptimal effort. The contract takes this into account in terms of an incentive-compatibility constraint:

$$\sum_{\varepsilon} p(\varepsilon|e) \{u[c(\varepsilon), e] + \beta \mathbb{E}_{z'} v[a'(\varepsilon), z']\} \geq \sum_{\varepsilon} p(\varepsilon|\hat{e}) \{u[c(\varepsilon), \hat{e}] + \beta \mathbb{E}_{z'} v[a'(\varepsilon), z']\} \quad \forall e, \hat{e}, x. \quad (4)$$

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<sup>12</sup>The above dynamic program could be modified to allow for talent to be insured as follows: allow agents to trade in assets whose payoff is contingent on the realization of next period’s talent  $z'$ . On the left-hand side of the budget constraint in (3), instead of  $a'(\varepsilon)$ , we would write  $a'(\varepsilon, z')$  and sum these over future states  $z'$  using the probabilities  $\mu(z'|z)$  so that  $z'$  does not appear as a state variable next period, as its realization is completely insured and that insurance is embedded in the resource constraint.

This constraint ensures that the value to the household of choosing the effort level assigned by the contract,  $e$ , is at least as large as that of any other effort,  $\hat{e}$ . The contract in the presence of moral hazard solves (3) with the additional constraint (4). As already mentioned, to fix ideas, we would like to think of this regime as representing the prevalent form of financial contracts in urban and industrialized areas.

The literature on optimal dynamic contracts under private information typically makes use of an alternative formulation which uses promised utility as a state variable (Spear and Srivastava, 1987) and features a “promise-keeping” constraint, neither of which are present here. The connection between this formulation and ours is as follows. Consider first a special case with no ability ( $z$ ) shocks, and only residual productivity ( $\varepsilon$ ) shocks. In this case, the two formulations are equivalent, a result that we establish in Appendix C. In this sense, the insurance arrangement regarding  $\varepsilon$ -shocks is optimal. The equivalence between the two formulations no longer holds in the case with both  $z$ -shocks and  $\varepsilon$ -shocks. This is because we rule out insurance against  $z$ -shocks by assumption, whereas an optimal dynamic contract would allow for such insurance.<sup>13</sup> We would like to reiterate, however, that we do not limit insurance arrangements regarding  $\varepsilon$ -shocks, as shown by the equivalence with an optimal dynamic contract in the absence of  $z$ -shocks.

When solving the problem (3) and (4) numerically, we allow for lotteries in the optimal contract to “convexify” the constraint set as in Phelan and Townsend (1991). See Appendix D for the statement of the problem (3) with lotteries.

## 2.3 Limited Commitment

In this regime, effort  $e$  is observed. Therefore, there is no moral hazard problem and the contract consequently provides perfect insurance against residual productivity shocks,  $\varepsilon$ . Instead we assume that the friction takes the form of a simple collateral constraint:

$$k \leq \lambda a, \quad \lambda \geq 1. \quad (5)$$

This form of constraint has been frequently used in the development literature on financial frictions (see, for example, Evans and Jovanovic, 1989; Holtz-Eakin, Joulfaian and Rosen, 1994; Banerjee and Duflo, 2005; Paulson, Townsend and Karaivanov, 2006; Buera and Shin, 2010; Moll, 2012; Midrigan and Xu, forthcoming). It can be motivated as a limited commitment

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<sup>13</sup>To see the lack of insurance against  $z$ -shocks, consider the case where residual productivity shocks are shut down,  $\varepsilon = 1$  with probability one. Then our formulation is an income fluctuations problem, like Schechtman and Escudero (1977), Aiyagari (1994) or other Bewley models. One reason we rule out insurance against  $z$ -shocks is that this assumption allows for a well-defined stationary wealth distribution. Analytically, we can handle insurance against  $z$  shocks as described in footnote 12.

constraint.<sup>14</sup> The exact form of the constraint is chosen for simplicity. Some readers may find it more natural if the constraint depended on talent  $k \leq \lambda(z)a$  as well. This would be relatively easy to incorporate but others have shown that this affects results mainly quantitatively but not qualitatively (Buera, Kaboski and Shin, 2011; Moll, 2012). The assumption that talent  $z$  is stochastic but cannot be insured makes sure that collateral constraints bind for some individuals at all points in time. If instead talent were fixed over time for example, individuals would save themselves out of collateral constraints over time (Banerjee and Moll, 2010).

The optimal contract in the presence of limited commitment solves (3) with the additional constraint (5). As already mentioned, to fix ideas and in line with Paulson, Townsend and Karaivanov (2006), Ahlin and Townsend (2007) and Karaivanov and Townsend (2012), we would like to think of this regime as capturing the workings of financial markets in rural and agricultural areas.

## 2.4 Factor Demands and Supplies

Risk-sharing groups interact in competitive labor and capital markets, taking as given the sequences of wages and interest rates. Denote by  $k(a, z; w, r)$  and  $\ell(a, z; w, r)$  the common (across risk-sharing groups) optimal capital and labor demands of households with current state  $(a, z)$ . A worker supplies  $\varepsilon$  efficiency units of labor to the labor market, so labor supply of a cohort  $(a, z)$  is

$$n(a, z; w, r) \equiv [1 - x(a, z)] \sum_{\varepsilon} p(\varepsilon | e(a, z)) \varepsilon. \quad (6)$$

Note that we multiply by the indicator for being a worker,  $1 - x$ , so as to only pick up the efficiency units of labor by the fraction of the cohort who decide to be workers. Finally, individual capital supply is simply a household's wealth,  $a$ .

## 2.5 Equilibrium

We use the saving policy functions  $a'(\varepsilon)$  and the transition probabilities  $\mu(z'|z)$  to construct transition probabilities  $\Pr(a', z' | a, z)$ .<sup>15</sup> Given these transition probabilities and an initial dis-

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<sup>14</sup>Consider an entrepreneur with wealth  $a$  who rents  $k$  units of capital. The entrepreneur can steal a fraction  $1/\lambda$  of rented capital. As a punishment, he would lose his wealth. In equilibrium, the financial intermediary will rent capital up to the point where individuals would have an incentive to steal the rented capital, implying a collateral constraint  $k/\lambda \leq a$  or  $k \leq \lambda a$ . Alternatively, we could have worked with a more full-blown dynamic limited commitment problem as is common in the optimal contracting literature (for example Albuquerque and Hopenhayn, 2004). We choose to work with collateral constraints, mainly because it facilitates comparison with the existing literature, and it also simplifies some of the computations.

<sup>15</sup>In the computations we discretize the state space for wealth,  $a$ , and talent,  $z$ , so this is a simple Markov transition matrix.

tribution  $g_0(a, z)$ , we then obtain the sequence  $\{g_t(a, z)\}_{t=0}^\infty$  from

$$g_{t+1}(a', z') = \Pr(a', z' | a, z) g_t(a, z). \quad (7)$$

Note that we cannot guarantee that the process for wealth and ability (7) has a unique and stable stationary distribution. While the process is stationary in the  $z$ -dimension (recall that the process for  $z$ ,  $\mu(z'|z)$ , is exogenous and a simple stationary Markov chain), the process may be non-stationary or degenerate in the  $a$ -dimension. That is, there is the possibility that the wealth distribution either fans out forever or collapses to a point mass. Similarly, there may be multiple stationary equilibria. In the examples we have computed, these issues do however not seem to be a problem and (7) always converges, and from different initial distributions.

Once we have found a stationary distribution of states from (7), we check that markets clear. Denote the stationary distribution of ability and wealth by  $G(a, z)$ . Then market clearing is

$$\int \ell(a, z; w, r) dG(a, z) = \int n(a, z; w, r) dG(a, z), \quad (8)$$

$$\int k(a, z; w, r) dG(a, z) = \int a dG(a, z). \quad (9)$$

The equilibrium factor prices  $w$  and  $r$  are found using the algorithm outlined in Appendix A.1 of Buera and Shin (2010).

### 3 Parameterization

The next section presents some numerical results. The present section discusses the functional forms and parameter values we use when computing these.

**Functional forms** We assume that utility is separable and isoelastic

$$u(c, e) = U(c) - V(e), \quad U(c) = \frac{c^{1-\sigma}}{1-\sigma}, \quad V(e) = \frac{\chi\varphi}{1+\varphi} e^{\frac{1+\varphi}{\varphi}}, \quad (10)$$

and that effort,  $e$ , can take values in some bounded interval  $[\underline{e}, \bar{e}]$ . The parameter  $\sigma$  is the inverse of the intertemporal elasticity of substitution and also the coefficient of relative risk aversion.  $\varphi$  is the Frisch elasticity of labor supply. The production function is Cobb-Douglas

$$\varepsilon z f(k, \ell) = \varepsilon z k^\alpha \ell^\gamma. \quad (11)$$

We assume that  $\alpha + \gamma < 1$  so that entrepreneurs have a limited span of control. We assume the following transition process  $\mu(z'|z)$  for entrepreneurial ability: with probability  $\rho$  a household

keeps his current ability  $z$ ; with probability  $1 - \rho$  she draws a new entrepreneurial ability from a discretized version of a truncated Pareto distribution whose CDF is<sup>16</sup>

$$\Psi(z) = \frac{1 - (z/\underline{z})^{-\zeta}}{1 - (\bar{z}/\underline{z})^{-\zeta}},$$

where  $\underline{z}$  and  $\bar{z}$  are the lower and upper bounds on ability. We further assume that residual productivity takes two possible values  $\varepsilon \in \{\varepsilon^L, \varepsilon^H\}$  and that the probability of the good draw depends on effort as follows:

$$p(\varepsilon^H|e) = (1 - \theta)\frac{1}{2} + \theta\frac{e - \underline{e}}{\bar{e} - \underline{e}}.$$

The parameter  $\theta \in (0, 1)$  controls the sensitivity of the residual productivity distribution with respect to effort (and recall that  $\underline{e}$  and  $\bar{e}$  are the lower and upper bounds on effort). Note that under full insurance against  $\varepsilon$ , what matters for the incentive of an agent to exert effort is only  $\theta$  *relative* to the disutility parameter  $\chi$ . That is, since  $\chi$  scales the marginal cost of effort, and  $\theta$  scales the marginal benefit, what matters is the ratio  $\chi/\theta$ .

**Parameter values** Table 1 presents the parameter values we use in our numerical experiments. The preference parameters  $\beta, \sigma, \varphi$  are set to standard values in the literature.<sup>17</sup> As already noted, under full insurance against  $\varepsilon$  only the ratio  $\tilde{\chi} = \chi/\theta$  matters. In macroeconomics usually  $\theta = 1$  so that effort translates one for one into efficiency units of labor. We set  $\tilde{\chi} = \chi/\theta = 2.625$ , which lies in the range usually considered in the literature.<sup>18</sup> We set returns to scale equal to  $\alpha + \gamma = 0.7$  which is close to values considered in the literature.<sup>19</sup> The one-year depreciation rate is set at  $\delta = 0.06$ . We set the persistence of entrepreneurial talent to  $\rho = 0.75$ . This is consistent with empirical estimates (Gourio, 2008; Collard-Wexler, Asker and DeLoecker, 2011), and similar to the parameter value used by Midrigan and Xu (forthcoming) (0.74, see their Table 2).

The choice of the parameters  $(\underline{z}, \bar{z}, \zeta, \varepsilon^L, \varepsilon^H)$  is to a large extent guided by computational considerations. We set the tail parameter of the talent distribution to  $\zeta = 1$  which would correspond to Zipf's law if the Pareto distribution were unbounded. We normalize the lower bound of talent to  $\underline{z} = 1$ , and set the upper bound four times higher,  $\bar{z} = 4$ . This talent range is in line with that typically considered in the literature (for example Buera and Shin,

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<sup>16</sup>The probability distribution of  $z'$  conditional on  $z$  is therefore  $\mu(z'|z) = \rho\delta(z' - z) + (1 - \rho)\psi(z')$  where  $\delta(\cdot - z)$  is the Dirac delta function centered at  $z$  and  $\psi(z) = \Psi'(z)$  is the PDF corresponding to  $\Psi$ .

<sup>17</sup>Perhaps the most challenging among these is the Frisch elasticity  $\varphi$ . For instance Shimer (2010) argues that a range of 1/2 to 4 covers most values that either micro- and macroeconomists would consider reasonable ( $\varphi = 4$  corresponds to the value in Prescott (2004)). Our choice of  $\varphi = 2$  is in the middle of this range.

<sup>18</sup>See for example Prescott (2004) and Shimer (2010), though their parameters are not exactly comparable because the functional forms differ somewhat.

<sup>19</sup>For example, Buera, Kaboski and Shin (2011) and Buera and Shin (2010) set returns to scale equal to 0.79.

Table 1: Parameter Values in Benchmark Economy

Parameter	Value	Description
$\beta$	$1.05^{-1}$	discount factor
$\sigma$	2	inverse of intertemporal elasticity of substitution
$\varphi$	2	Frisch elasticity
$\chi$	0.525	disutility of labor
$\alpha$	0.3	exponent on capital in production function
$\gamma$	0.4	exponent on labor in production function
$\delta$	0.06	depreciation rate
$\rho$	0.75	persistence of entrepreneurial talent
$\zeta$	1	tail param. of talent distribution (truncated Pareto)
$\underline{z}$	1	lower bound on entrepreneurial talent
$\bar{z}$	4	upper bound on entrepreneurial talent
$\theta$	0.2	sensitivity of residual productivity to effort
$\varepsilon^L$	0	value of low residual productivity draw
$\varepsilon^H$	2	value of high residual productivity draw
$\lambda$	1.8	tightness of collateral constraints

2010; Buera, Kaboski and Shin, 2011, although their Pareto distributions feature thinner tails). We set the sensitivity of  $\varepsilon$  with respect to effort equal to  $\theta = 0.2$  implying that  $\chi = \tilde{\chi}\theta = 2.625 \times 0.2 = 0.525$ . In any case, we argue in section 6 below that our results are robust to a variety of alternative parameterizations. Finally, for our benchmark numerical results, we set the parameter  $\lambda$  governing the tightness of the collateral constraints, equation (5), to  $\lambda = 1.8$ . In our limited commitment economy, this results in an external finance to GDP ratio of 1.468 which is close to the values of the 2007 external finance to GDP ratios of Brazil (1.366), China (1.463), and India (1.588).

## 4 Limited Commitment vs. Moral Hazard

In this section we compare the moral hazard and limited commitment regimes, and argue that the two have potentially very different implications.

### 4.1 Implications for Choices of Individuals

We first present some analytic results that characterize differences in individual savings behavior in the two regimes. These are variants of well-known results in the literature.

**Lemma 1** Let  $u(c, e) = U(c) - V(e)$ . Solutions to the optimal contracting problem under moral hazard (3) and (4), satisfy

$$U'(c_{it}) = \beta(1 + r_{t+1})\mathbb{E}_{z,t} \left( \mathbb{E}_{\varepsilon,t} \frac{1}{U'(c_{it+1})} \right)^{-1} \quad (12)$$

where  $\mathbb{E}_{z,t}$  and  $\mathbb{E}_{\varepsilon,t}$  denote the time  $t$  expectation over future values of  $z$  and  $\varepsilon$ .

This is a variant of the inverse Euler equation derived in Rogerson (1985), Ligon (1998) and Golosov, Kocherlakota and Tsyvinski (2003) among others. With a degenerate distribution for ability,  $z$ , our equation collapses to the standard inverse Euler equation. The reason our equation differs from the latter is that we have assumed that ability,  $z$ , is not insurable in the sense that asset payoffs are not contingent on the realization of  $z$  (see footnote 12). Our equation is therefore a “hybrid” of an Euler equation in an incomplete markets setting and the inverse Euler equation under moral hazard.

If the incentive compatibility constraint (4) is binding, marginal utilities are not equalized across realizations of  $\varepsilon$ . One well known implication of (12) is that in this case<sup>20</sup>

$$U'(c_{it}) < \beta(1 + r_{t+1})\mathbb{E}_{z,t}\mathbb{E}_{\varepsilon,t}U'(c_{it+1}). \quad (13)$$

With limited commitment, the Euler equation is instead<sup>21</sup>

$$U'(c_{it}) = \beta\mathbb{E}_{z,t} [U'(c_{it+1})(1 + r_{t+1}) + \nu_{it+1}\lambda]$$

where  $\nu_{it+1}$  is the Lagrange multiplier on the collateral constraint (5). If this constraint binds, then

$$U'(c_{it}) > \beta(1 + r_{t+1})\mathbb{E}_{z,t}U'(c_{it+1}). \quad (14)$$

Contrasting (13) for moral hazard and (14) for limited commitment, we can see that in the moral hazard regime individuals are *savings constrained* and in the limited commitment regime, they are instead *borrowing constrained*.<sup>22</sup> The intuition for individuals being savings constrained

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<sup>20</sup>This follows because by Jensen's inequality ( $1/U'(c_{it+1})$  is a convex function of  $U'(c_{it+1})$ )

$$\mathbb{E}_{\varepsilon,t} \frac{1}{U'(c_{it+1})} > \frac{1}{\mathbb{E}_{\varepsilon,t} U'(c_{it+1})}.$$

<sup>21</sup>Note that in contrast to (12) no expectation over  $\varepsilon$  is taken here. This is because there is perfect insurance on  $\varepsilon$ . Therefore marginal utilities are equalized across  $\varepsilon$  realizations. More formally, denote by  $c(\varepsilon, z, a)$  consumption of an individual who has experienced shocks  $\varepsilon$  and  $z$  and has wealth  $a$ . Then  $U'(c(\varepsilon, z, a)) = \psi(a, z)$  for all  $\varepsilon$ , where  $\psi(a, z)$  is the Lagrange multiplier on the budget constraint in (3). Since this is true for all  $\varepsilon$  realizations, of course also  $\mathbb{E}_{\varepsilon} U'(c(\varepsilon, z, a)) = \psi(a, z)$ .

<sup>22</sup>In the case where the corresponding constraints do not bind, both (13) and (14) collapse to the standard Euler equation under incomplete markets

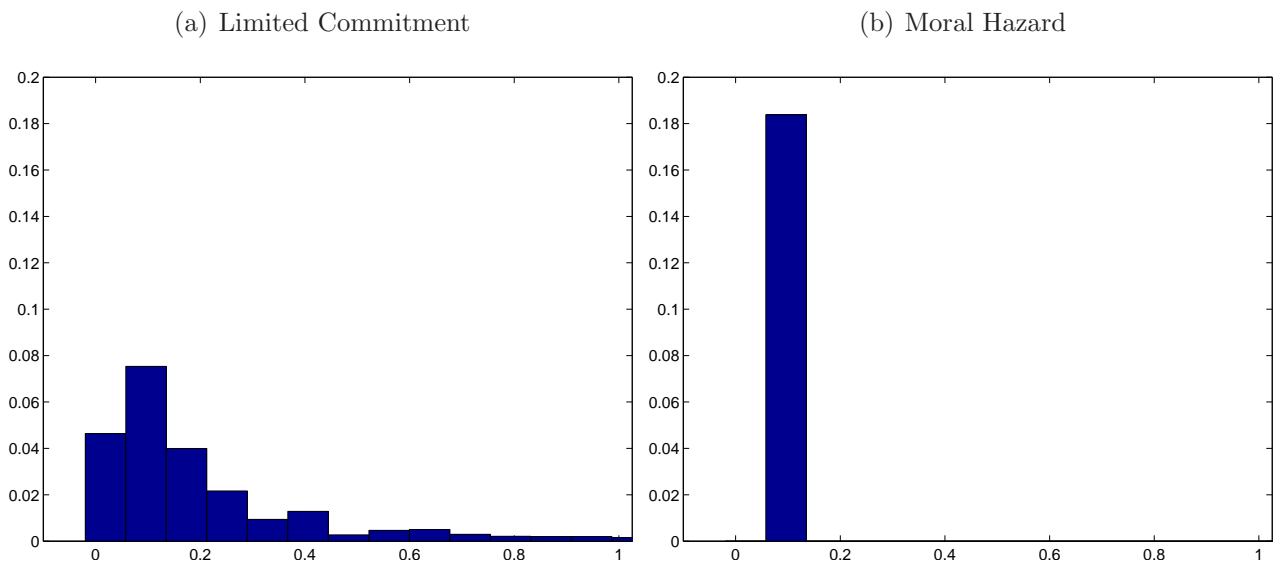
$$U'(c_{it}) = \beta(1 + r_{t+1})\mathbb{E}_{z,t}U'(c_{it+1}).$$



under moral hazard is that there is an additional marginal cost of saving an extra dollar from period  $t$  to period  $t + 1$ : in period  $t + 1$  an individual works less in response to any given compensation schedule.<sup>23</sup> Therefore the optimal contract discourages savings whenever the incentive compatibility constraint (4) binds. Finally, note that under limited commitment only the savings of entrepreneurs are distorted because only they face the collateral constraint (5). In contrast, under moral hazard the savings decision of both entrepreneurs and workers is distorted because both face the incentive compatibility constraint (4). This will be reflected in the equilibrium interest rate (see Table 2). In particular, the interest rate under moral hazard is higher than that under limited commitment. Individual savings behavior is one prediction in which the two regimes differ dramatically.

Next, we present some numerical results that illustrate further differences between the moral hazard and limited commitment regimes. Figure 2 plots the distributions of the marginal product of capital in the two regimes. In the limited commitment regime (left panel), the

Figure 2: Distribution of Marginal Products of Capital.



presence of collateral constraints (5) implies that marginal products of capital are not equalized across individual firms, that is capital is misallocated. In contrast, in the moral hazard regime marginal products of capital *are* equalized across firms so that the distribution of marginal products is degenerate (right panel). This is because in our formulation of the moral hazard problem, a change in an entrepreneur's capital stock does not change his incentive to shirk.<sup>24</sup>

<sup>23</sup>See Rogerson (1985) and Golosov, Kocherlakota and Tsyvinski (2003) for more detailed discussions of this idea.

<sup>24</sup>More precisely, the distribution of relative output obtained from two different effort levels does not depend on the level of capital. This is a result of two assumptions: that output depends on residual productivity  $\varepsilon$  in a multiplicative fashion, and that the distribution of residual productivity  $p(\varepsilon|e)$  does not depend on capital. In

Since firms do not face any other constraints that limit the amount of capital they can rent, all of them rent capital until their expected marginal product equals the user cost of capital.<sup>25</sup>

$$z\bar{\varepsilon}(e)f_k(k, \ell) = r + \delta, \quad \bar{\varepsilon}(e) \equiv \sum_{\varepsilon} \varepsilon p(\varepsilon|e). \quad (15)$$

If not in a misallocation of capital, how then will the presence of moral hazard manifest itself in our economy? Figure 3 has the answer: under moral hazard, entrepreneurs exert lower effort.<sup>26</sup> Under limited commitment (panel a), the big majority of entrepreneurs exert the highest possible effort level. In contrast, under moral hazard (panel b), a much bigger fraction of entrepreneurs chooses the lowest possible effort level or an effort level close to that. This matters because lower effort makes it more likely that entrepreneurs draw a low residual productivity realization, thereby depressing firm level TFP. In a recent paper Midrigan and Xu (forthcoming) have argued that a model with collateral constraints, when calibrated to plant level data, generates fairly small dispersion of marginal products and hence TFP losses from misallocation. As we will see in the next section, our economy with moral hazard is an example in which there are sizable TFP losses but with *no* dispersion of marginal products.

Occupational choice also differs markedly in the two economies. This is shown in Figure 4 which presents occupational choice maps, that is the occupational choice corresponding to different combinations of individual ability and wealth. Under limited commitment (panel a), selection into entrepreneurship is based on both ability and wealth. Some able but poor individuals cannot rent enough capital to make entrepreneurship attractive. And some less able individuals become entrepreneurs only because they are wealthy. In contrast, under moral hazard (panel b), selection is mainly on ability and wealthier individuals are in fact somewhat *less* likely to become entrepreneurs. Two offsetting effects are at work here: a “debt overhang”

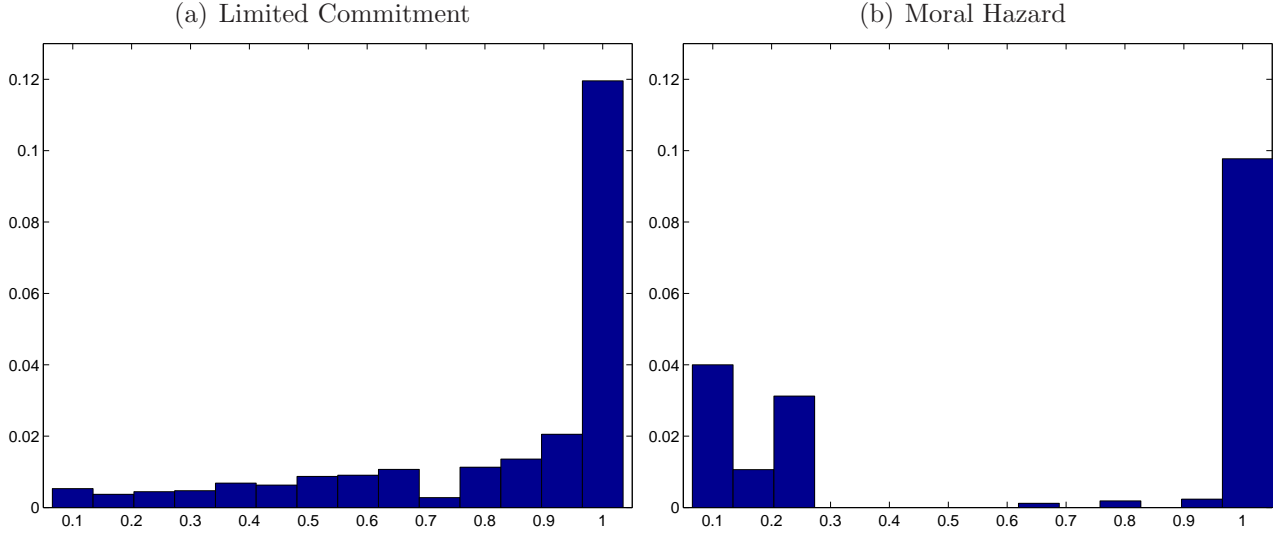
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more general formulations of the moral hazard problem, e.g. if the distribution is  $p(\varepsilon|e, k)$ , marginal products of capital would no longer be equalized.

<sup>25</sup>Similarly, entrepreneurs hire labor to equate the expected marginal product of labor to the wage,  $z\bar{\varepsilon}(e)f_\ell(k, \ell) = w$ . Hence, even though entrepreneurs bear some of the residual productivity risk,  $\varepsilon$ , under the optimal contract they behave as if they are risk neutral. This is because risk neutral intermediaries find it optimal to first maximize expected profits and to then assign  $\varepsilon$ -dependent consumption to entrepreneurs to make sure they expend the optimal amount of effort given incentive constraints. Since intermediaries pool risk over a large number of households, the expectation in (15) can be thought of as an integral over the population and not an expectation for the individual.

<sup>26</sup>The reason that individuals exert lower effort under moral hazard is entirely standard: if intermediaries offered the full information contract with full insurance against residual productivity,  $\varepsilon$ , to individuals, these would always exert low effort. To incentivize individuals, the contract gives up on full insurance and assigns them lower consumption in case of a low realization of residual productivity. But because the optimal contract delivers a given utility level to individuals at the least cost to intermediaries, it trades off providing insurance and incentivizing effort. Implementing full-information effort requires giving up too much insurance and hence having to compensate individuals in some other form. What is not entirely standard is that our analysis takes place in general equilibrium and hence also factor prices change.

Figure 3: Distribution of Entrepreneurial Effort.



effect making poorer individuals *less* likely and richer individuals *more* likely to be entrepreneurs (similar to Aghion and Bolton, 1997; Ghosh, Mookherjee and Ray, 2000; Paulson, Townsend and Karaivanov, 2006), and a standard wealth effect on effort supply making richer individuals *less* likely to be entrepreneurs. Under our parameterization, the latter effect dominates, but under alternative parameterizations this result could be overturned. In the frictionless economy in which the “debt overhang” effect is not present the negative relationship between wealth and entrepreneurship is even more pronounced.<sup>27</sup> The difference in occupational choice in the two economies, shown in Figure 4, immediately implies differences in the average entrepreneurial ability  $z$  of *active* entrepreneurs. Figure 5 displays the distributions of entrepreneurial abilities  $z$  of active entrepreneurs in the two economies. In the moral hazard economy, selection into entrepreneurship is more positive so that active entrepreneurs are more able on average. This is a force towards higher firm level TFP.

Figures 4 to 5 have shown that under moral hazard, entrepreneurs exert less effort but are more able on average. These two properties are jointly reflected in the distribution of observed

<sup>27</sup>Several remarks are in order. First, the negative wealth effect is stronger for entrepreneurs than for workers because entrepreneurs’ profits are more sensitive to effort than workers’ labor income (entrepreneur’s effort is “leveraged” so to speak). Second, the wealth effect could potentially be eliminated by a different choice of preferences than (10), for example those proposed by Greenwood, Hercowitz and Huffman (1988). However, we find separable preferences with a wealth effect more appealing, not least because they are more standard in dynamic moral hazard problems. Finally, the debt overhang effect in our dynamic model is less pronounced than that in static models like Aghion and Bolton (1997); Ghosh, Mookherjee and Ray (2000); Paulson, Townsend and Karaivanov (2006). In a static model, an entrepreneur’s repayments to the intermediary are bounded by his revenues. This gives a strong incentive to shirk to highly indebted individuals. In our dynamic setup, instead, repayments can be postponed to the future through borrowing and lending.

Figure 4: Occupational Choice and Binding Patterns of Constraints

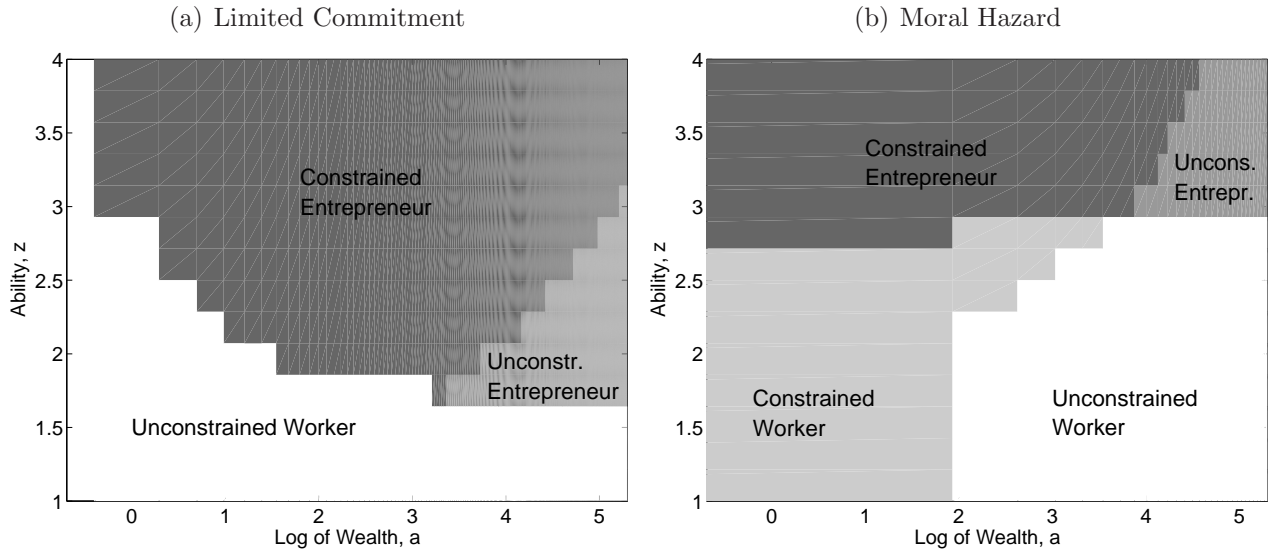
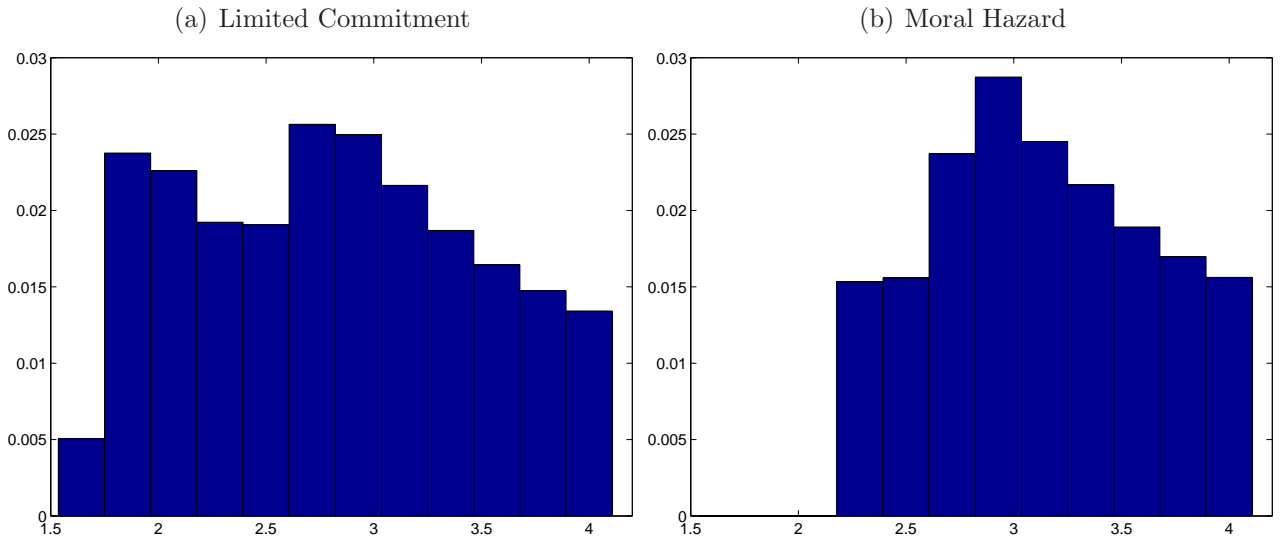
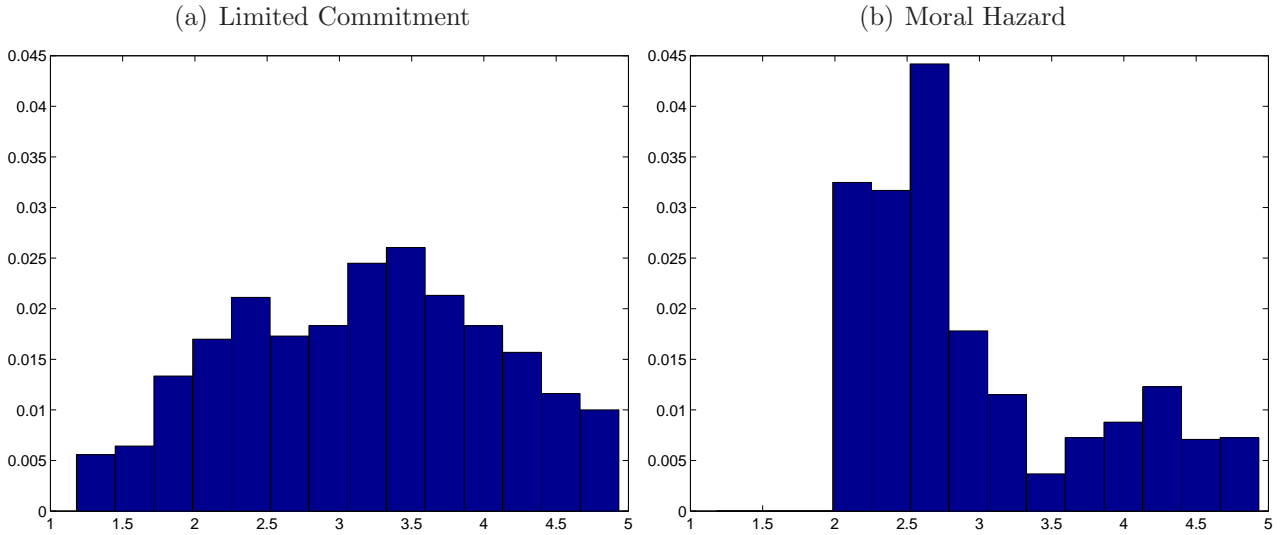


Figure 5: Distribution of Entrepreneurial Ability.



firm-level TFP graphed in Figure 6. Recall that firm-level TFP is the product of “ability” and

Figure 6: Distribution of Firm-level TFP.



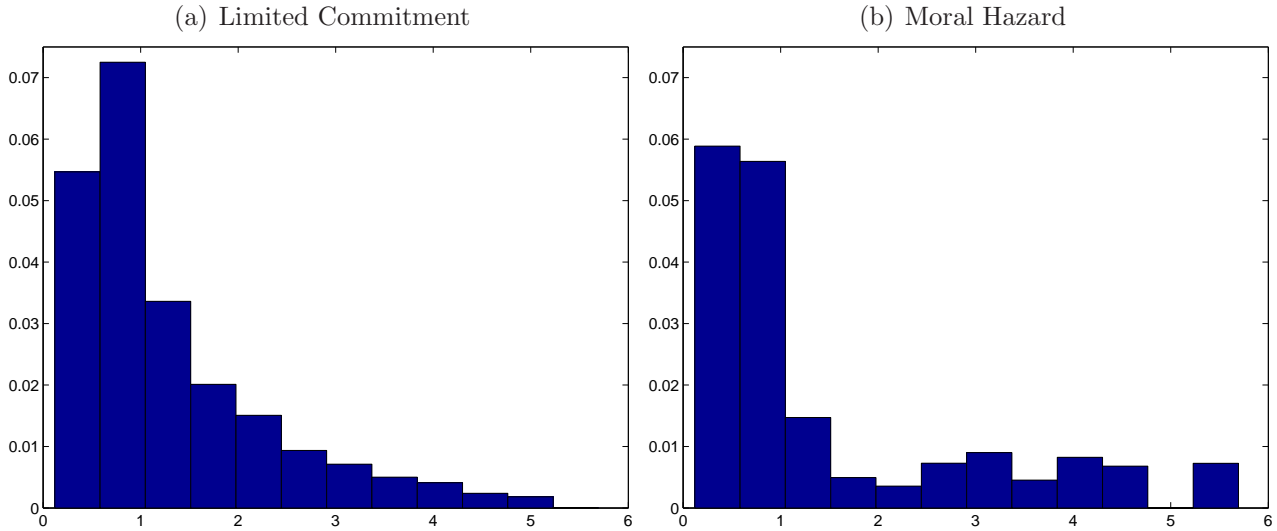
“residual productivity” and the latter depends on effort with probability distribution  $p(\varepsilon|e)$ . Ex-ante firm-level TFP is then given by  $z\bar{\varepsilon}(e)$  where  $\bar{\varepsilon}(e) \equiv \sum_{\varepsilon} \varepsilon p(\varepsilon|e)$  is expected residual productivity given an effort choice,  $e$ .<sup>28</sup> As shown in Figures 4 and 5, ability is higher in the moral hazard economy. But as shown in Figure 5, effort is lower which results in lower realizations of residual productivity. As a result of these two offsetting forces, firm-level TFP is more dispersed in the limited commitment economy. Some high ability entrepreneurs additionally exert high effort and so have very high measured productivity; but there are also some low ability entrepreneurs (Figures 4 and 5) that additionally exert low effort and are hence very unproductive.

Consistent with these findings, Figure 7 plots the distribution of firm size as measured by a firm’s number of employees. Firm size is similarly dispersed in both the moral hazard and limited commitment regimes. This is the outcome of two countervailing effects: on one hand, the productivity distribution is more dispersed under limited commitment than moral hazard which leads to more dispersion in firm size. On the other hand, a firm’s capital stock is constrained by a collateral constraint under limited commitment, leading to less dispersion in limited commitment than moral hazard.

These results have important implications for measurement. For instance, consider an econometrician examining data generated by the moral hazard economy who measures gaps

<sup>28</sup>Again, to be clear, we here assume that capital and *hired* labor are accurately measured and accounted for as inputs into production, but that entrepreneurial effort is not. This implies that low effort results in low measured firm-level TFP. That effort is not observable is a particularly natural assumption in the moral hazard regime: if effort is private information in our economy, it should also not be observable by the econometrician.

Figure 7: Firm-Size (Employee) Distribution.



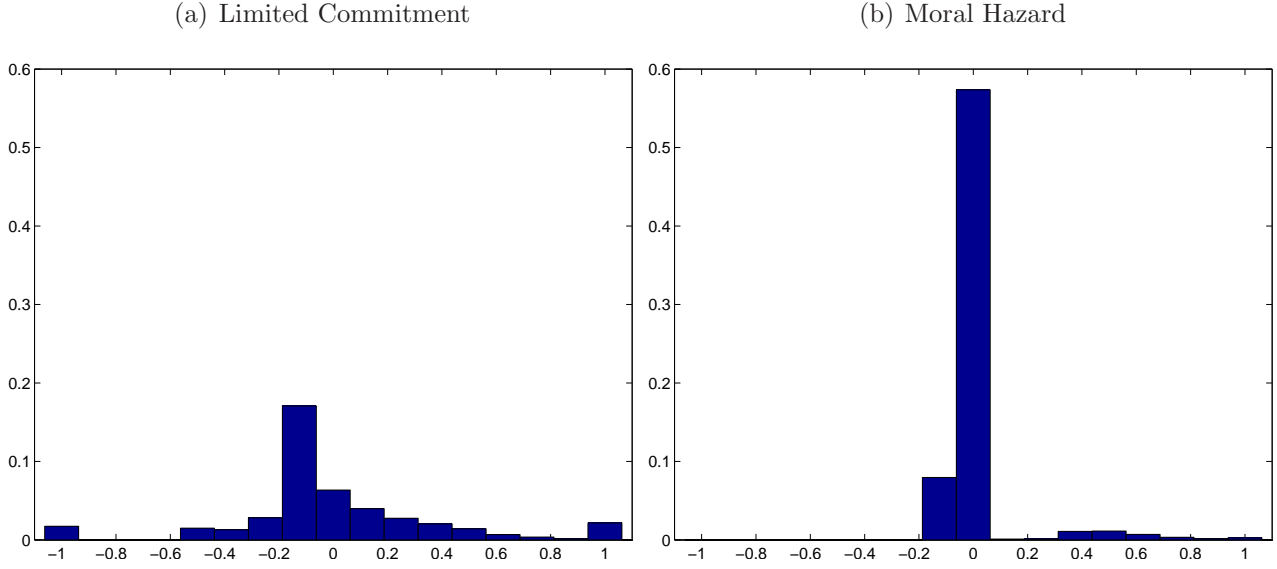
in marginal products of capital across individual firms. This econometrician would observe no capital misallocation and may therefore (erroneously) conclude that there is no friction in the capital market.

Individual savings behavior in the two economies also differs, in particular the speed of individual transitions. One convenient way of summarizing this speed of transition is to compare the eigenvalues of the transition matrix  $\Pr(a', z'|a, z)$  defined in (7) for the two economies. The eigenvalue governing the speed of convergence in the limited commitment economy is 0.9396 with a corresponding half life of  $-\log(2)/\log(0.9396) \approx 11.1$  years whereas in the moral hazard economy this eigenvalue is 0.9823 which implies a half-life of 38.8 years.<sup>29</sup> Individual transitions are therefore much slower in the moral hazard economy. This is also shown in Figure 8 which plots the distribution of wealth growth rates in the two economies. In the moral hazard economy, most wealth growth rates are close to zero. In contrast, with limited commitment wealth growth rates are much more dispersed. This is a direct consequence of the difference in the dispersion of marginal products of capital in the two regimes (Figure 2). A high marginal product of capital due to a binding borrowing constraint also implies a high return to wealth accumulation (the Lagrange multiplier in the Euler equation) and therefore leads to faster wealth accumulation. High dispersion in marginal products therefore implies high dispersion in wealth growth rates.

To further contrast individual behavior in the two regimes, Figure 9 displays sample paths of ability, wealth, effort and occupational choice for three typical individuals. The individuals start with the same level of wealth and experience the same sequence of productivity shocks. The only difference is the financial regime they operate in. Panels (c) and (d) show that

<sup>29</sup>The speed of convergence is determined by the largest eigenvalue that is less than one (see e.g. Stokey, Lucas and Prescott, 1989).

Figure 8: Distribution of Wealth Growth Rates



individuals in the limited commitment regime accumulate and decumulate wealth at a faster speed than those in the moral hazard regime (consistent with Figure 8). Panels (e) and (f) show that individuals in the moral hazard regime exert lower effort, again as expected. Finally, panels (g) and (h) show that there is more occupational mobility in the limited commitment regime. This is because under limited commitment wealth is a more important determinant of entrepreneurship (see Figure 4), and wealth moves around more (panels (c) and (d)).

Wealth and income inequality also differ in the two regimes. Figure 10 reports the wealth Lorenz curves for the two regimes. It can be seen that wealth inequality is higher in the limited commitment regime. This is a direct consequence of the bigger dispersion in marginal products of capital in Figure 2, which leads to high wealth concentration in the hands of high productivity entrepreneurs trying to save themselves out of borrowing constraints.

Similarly, Figure 11 plots the income Lorenz curves. Again, inequality is higher under limited commitment than under moral hazard.

## 4.2 Implications for Aggregates

The differences in individual behavior that we have just documented are also reflected in aggregates. Table 2 reports some aggregate statistics for the limited commitment and moral hazard economies. The first two rows report GDP and aggregate TFP for the two economies, normalized by their values in a frictionless economy.<sup>30</sup> Limited commitment (column 1) results in capital being misallocated (Figure 2). This causes TFP losses of 12.8 percent relative to the

<sup>30</sup>Aggregate TFP is computed as  $TFP = Y/(K^\nu L^{1-\nu})$  where  $Y$  is aggregate output,  $K$  is the aggregate capital stock,  $L$  is aggregate labor and  $\nu = \frac{\alpha}{\alpha+\gamma}$ .

Figure 9: Typical Histories

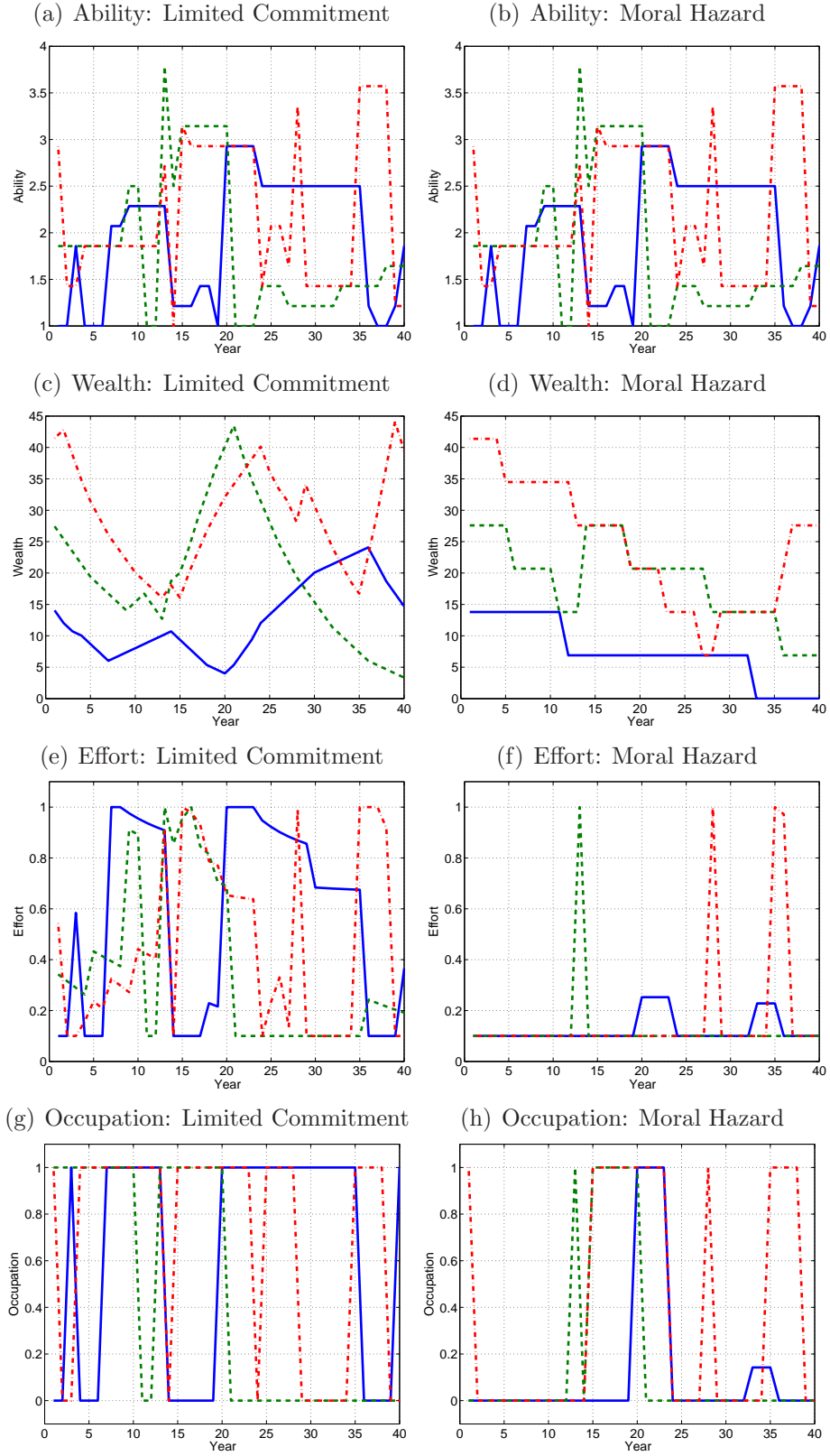




Figure 10: Wealth Lorenz Curves

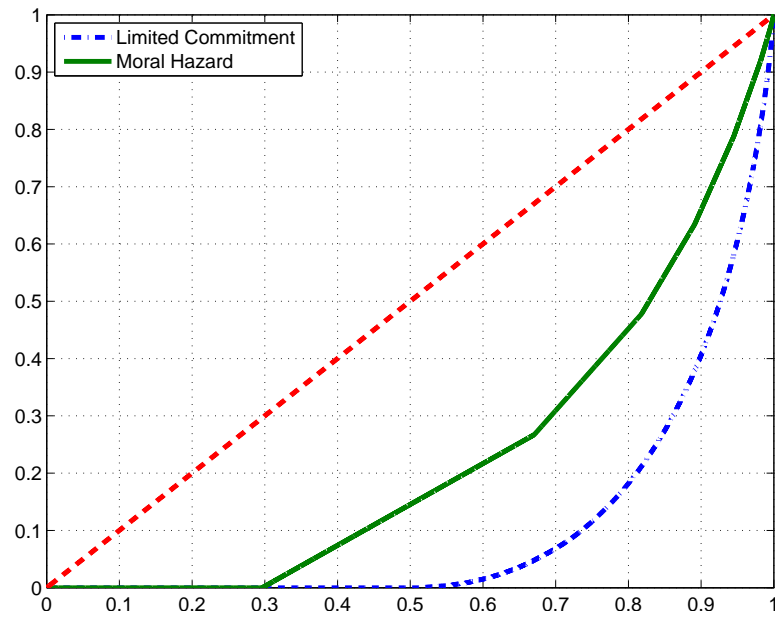


Figure 11: Income Lorenz Curves

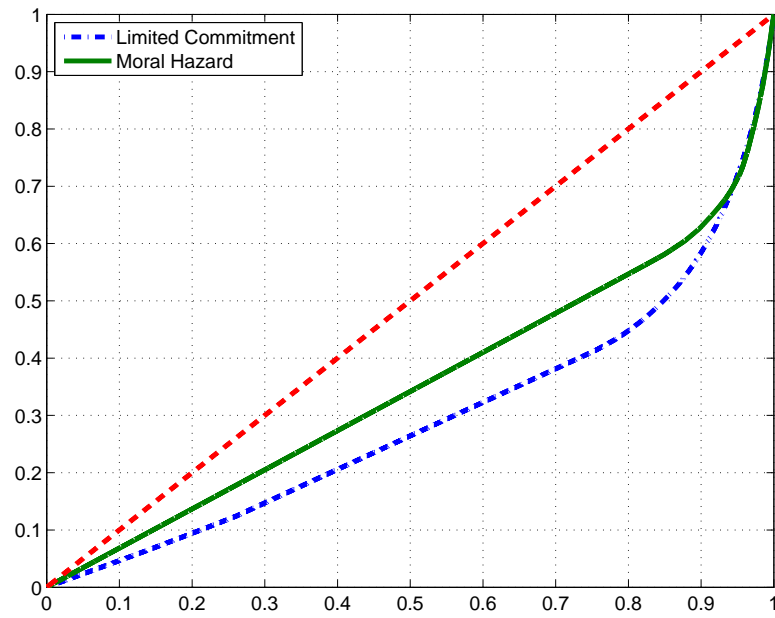


Table 2: Comparison of Different Regimes

	Limited Commitment	Moral Hazard
GDP (% of FB)	0.777	0.859
TFP (% of FB)	0.872	0.885
Capital-Output Ratio (%of FB)	0.962	1.213
Labor Supply (% of FB)	1.017	0.920
Welfare (% of FB)	0.592	0.891
Wage (%of FB)	0.764	0.931
Interest Rate	-0.041	0.010
% Entrepreneurs	0.227	0.143
External Finance/GDP	1.468	3.290

frictionless case and GDP losses of 22.3 percent. The mechanism through which these TFP losses occur is the same and their magnitude of similar order as in various previous studies (for example Buera and Shin, 2010; Buera, Kaboski and Shin, 2011). Moral hazard also results in depressed TFP and GDP, but for completely different reasons: instead of capital misallocation, this is due to entrepreneurs exerting low effort. Other aggregate statistics look more different. First, labor supply is considerably higher under limited commitment than under moral hazard. This is because the presence of moral hazard causes workers to exert lower effort than under limited commitment (analogous to its effect on entrepreneurial effort in Figure 3). Second, the equilibrium interest rate is considerably lower in the limited commitment economy than that in the moral hazard economy.<sup>31</sup> This is an implication of the different savings behavior at the micro level as described by the savings distortions in equations (13) and (14). Under limited commitment, individuals are *borrowing* constrained; in general equilibrium, the interest rate therefore adjusts downwards so as to equilibrate savings supply and demand. Under moral hazard, individuals are *savings* constrained so the opposite is true. Similarly, the ratio of external finance (total borrowing by entrepreneurs) to GDP is considerably lower in the limited commitment regime.<sup>32</sup> Again, this comes from the fact that limited commitment functions as a borrowing constraint whereas moral hazard does not place any restrictions on individual

<sup>31</sup>Some readers may wonder about its level, namely why real interest rates are negative. Interest rates are bounded below by  $-\delta$  and negative *real* interest rates due to depressed credit demand are a common feature of models with collateral constraints (Buera and Shin, 2010; Buera, Kaboski and Shin, 2011; Guerrieri and Lorenzoni, 2011). That being said, many alternative parameterizations (in particular those with lower discount factor  $\beta$ ) feature positive interest rates.

<sup>32</sup>External finance in an economy is defined as the sum of all individual borrowing  $k(a, z) - a \geq 0$ :

$$D \equiv \int_{k(a,z) \geq a} [k(a, z) - a] dG(a, z).$$

borrowing directly. Finally, we also report welfare in the two regimes.<sup>33</sup> Under our parameterization, and similar to GDP, welfare is lower under limited commitment than under moral hazard.

## 5 Mixtures of Moral Hazard and Limited Commitment

The previous section compared two economies: one in which all agents were subject to the limited commitment friction and another in which all agents were subject to the moral hazard friction. However, there is no reason why a given economy should be subject to only one imperfection. For example, Paulson, Townsend and Karaivanov (2006) find that for Thailand, moral hazard fits better in the urban areas in and around Bangkok and limited commitment better in the rural Northeast (see also Ahlin and Townsend, 2007; Karaivanov and Townsend, 2012). Therefore, we ask in this section: what happens if both frictions are present in the same economy?

### 5.1 Aggregates and Inter-Sectoral Flow of Funds in Mixture Regimes

To answer this question, we consider economies in which a fraction  $m$  of the population are subject to moral hazard and the remaining  $1 - m$  are subject to limited commitment. We then examine how aggregates vary when we vary  $m$ . In this way we can trace out all intermediate cases between the two extremes in the previous section: the pure moral hazard regime,  $m = 1$ , and the pure limited commitment regime,  $m = 0$ . We argue that such *mixture* regimes are different from simple convex combinations of the pure moral hazard and pure limited commitment economies.

As already mentioned, one possible interpretation is that different financial regimes represent different locations within an economy: moral hazard in urban and industrialized areas and limited commitment in rural and agricultural areas. The parameter  $m$  then has the interpretation of the fraction of the population living in urban areas (though our formulation allows

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<sup>33</sup>We use an egalitarian welfare measure, namely the sum across all individuals of their present discounted values of utility of consumption

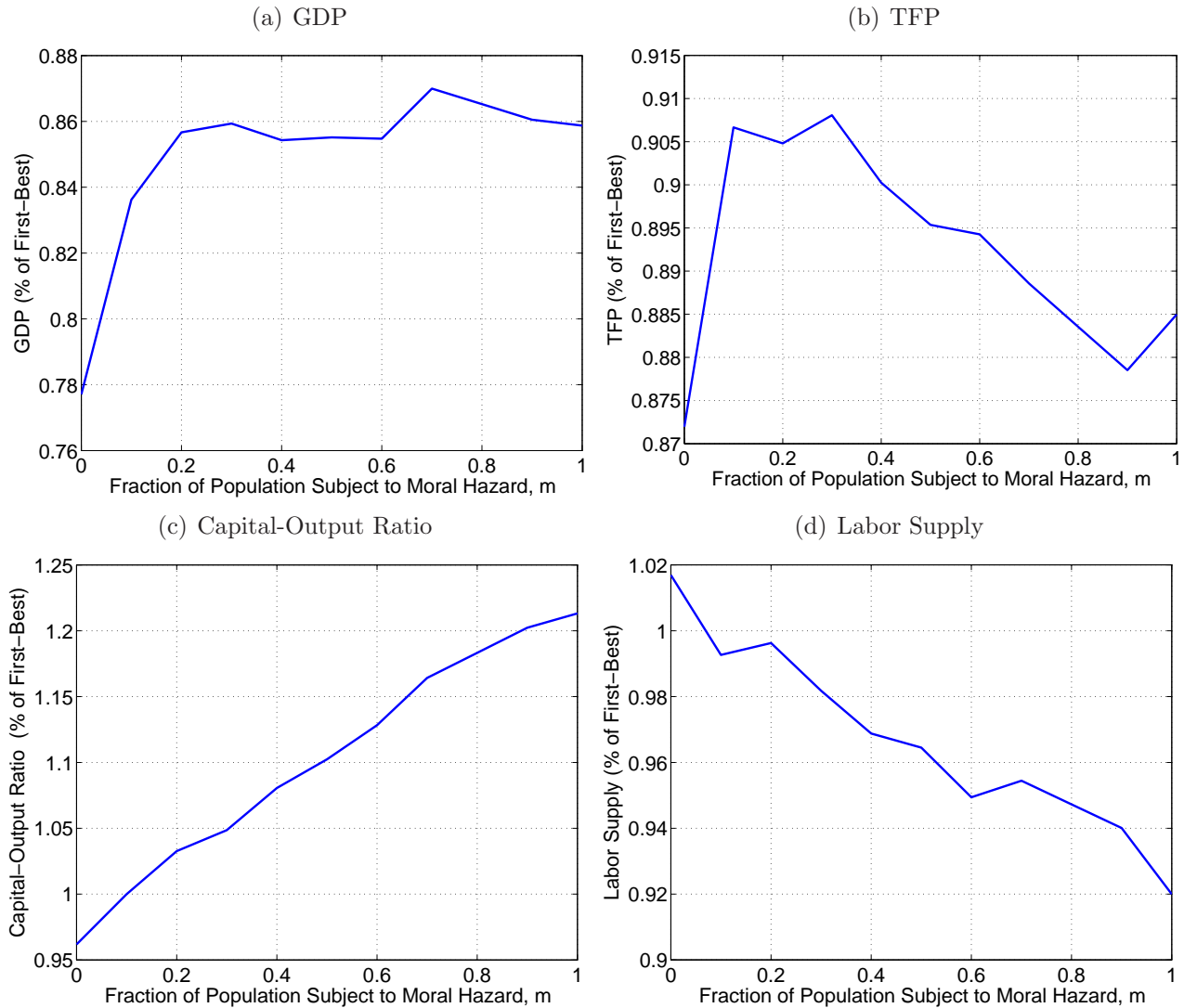
$$\mathcal{W}^j = \int v_j(a, z) dG_j(a, z),$$

where  $j \in \{LC, MH, BOTH, FB\}$  indexes the specific regime. We use this welfare measure rather than the more standard consumption equivalent measures (Lucas, 2003) because it is considerably easier to compute. In doing so, we follow Buera and Shin (2011). Note also that a possible limitation of our welfare measure is that it does not take into account transition dynamics. This is again for computational reasons; in principle transition dynamics can be easily taken into account. A technical issue arises because with CRRA utility and  $\sigma > 1$  individual value functions are negative. In Table 2, “Welfare (% of FB)” in regime  $j \in \{LC, MH, BOTH\}$  is therefore  $1 - \frac{\mathcal{W}^{FB} - \mathcal{W}^j}{|\mathcal{W}^{FB}|}$ .

workers to live in one location but to work in another, analogous to “temporary migration”).

Figures 12 and 13 plot various aggregates against the fraction of the population subject to moral hazard,  $m$ . Most aggregates in the mixed regime, for example GDP and the interest rate,

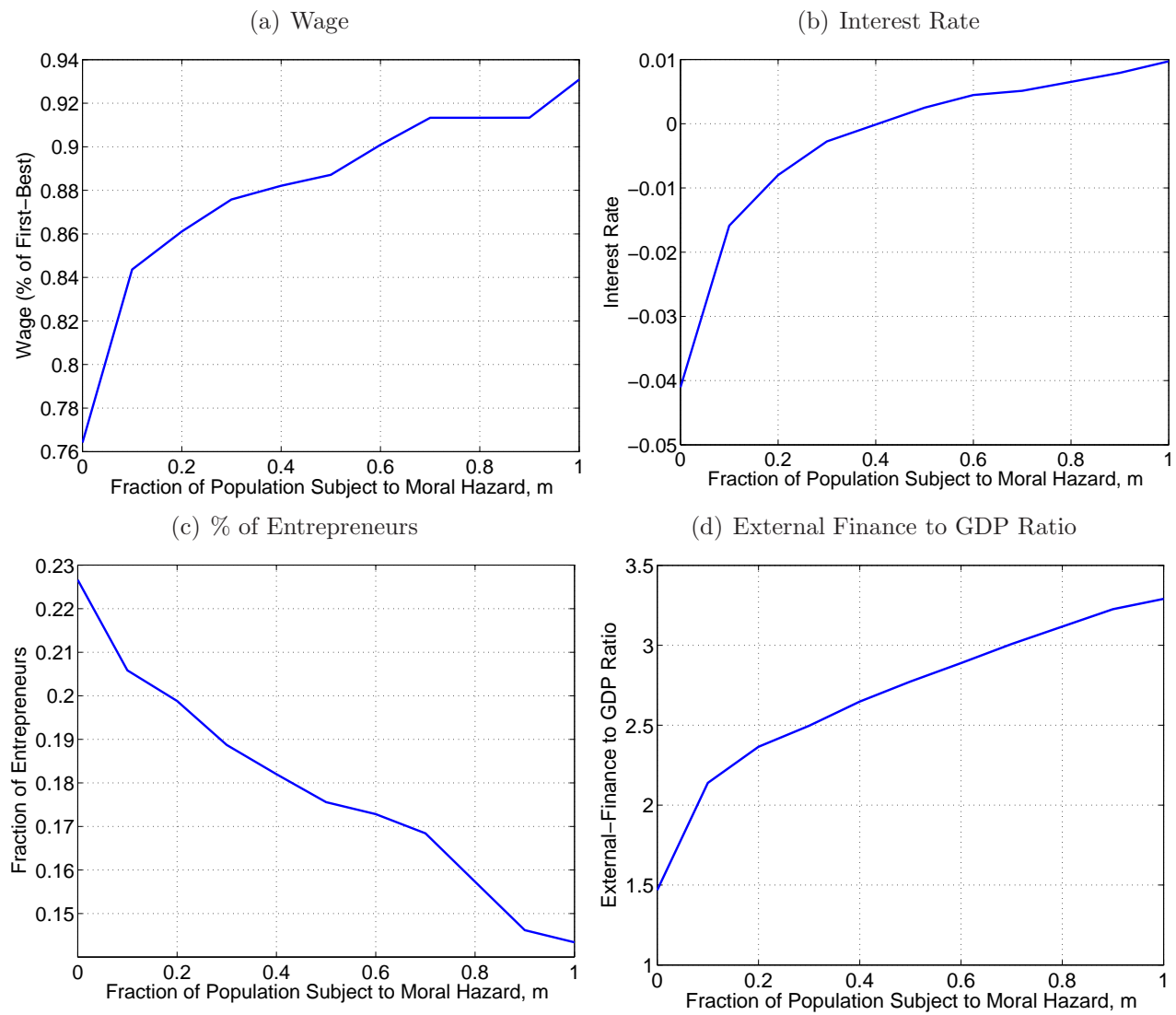
Figure 12: Aggregate Impact of Importance of Moral Hazard vs. Limited Commitment,  $m$



lie in between their values in the pure limited commitment and pure moral hazard economies. But this is not true for all variables. Notably, TFP is a non-monotone function of  $m$ . As we discuss in more detail at the end of this section, such non-monotonicities arise from general equilibrium effects and would not have been obtained in a partial equilibrium with a fixed interest rate.

To better understand these mixed regimes, we consider in more detail the economy in which fifty percent of the population are subject to moral hazard and the remaining fifty percent are subject to limited commitment, that is  $m = 0.5$ . Column 1 of Table 3 reports some aggregate

Figure 13: Aggregate Impact of Importance of Moral Hazard vs. Limited Commitment,  $m$



statistics of the economy with both regimes. Again, TFP is *higher* in the mixed regime than in either of the two pure regimes. To understand where this comes from, columns 2 and 3 of Table 3 report separate statistics for the limited commitment and moral hazard sectors of the economy. Consider first TFP. Column 2 shows that sectoral TFP in the LC sector is 109

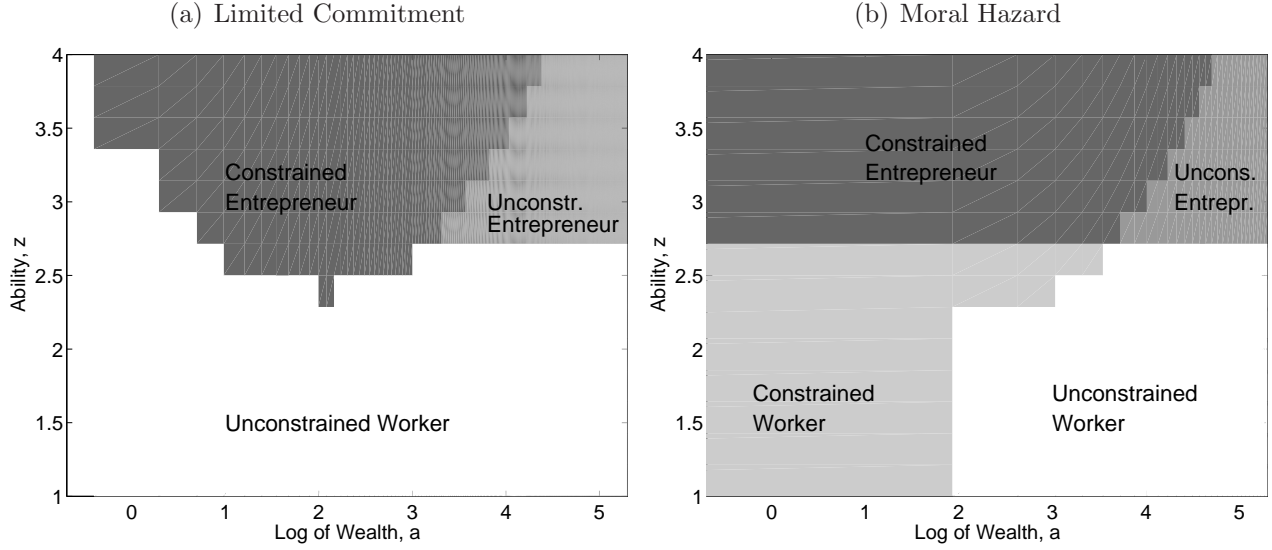
Table 3: Comparison of LC and MH Sectors in Mixed Regime

	Mixed Regime, $m=0.5$	LC sector	MH sector
	(a) National and Sectoral Aggregates		
GDP (% of FB)	0.855	0.660	1.051
TFP (% of FB)	0.895	1.092	0.819
Capital-Output Ratio (% of FB)	1.102	0.695	1.358
Labor Supply (% of FB)	0.965	0.744	1.185
Welfare (% of FB)	0.830	0.592	0.891
Wage (% of FB)	0.887	0.887	0.887
Interest Rate	0.003	0.003	0.003
% Entrepreneurs	0.176	0.175	0.176
External Finance/Sectoral GDP	2.773	1.031	3.867
	(b) Importance of Sectors in Aggregate Economy		
% Sector Contributes to GDP		0.386	0.614
% of Labor Employed in Sector		0.386	0.615
% of Capital Used in Sector		0.243	0.757
% of Labor Supplied by Sector		0.529	0.471
% of Capital Supplied by Sector		0.466	0.534
	(c) Intersectoral Capital and Labor Flows		
Net Labor Inflow (% of used)		-0.377	0.231
Net Capital Inflow (% of used)		-0.894	0.302

percent of first-best TFP, that is much higher than TFP in the pure limited commitment regime (column 1 of Table 2). To understand this, consider Figure 14 which presents the occupational choice maps for the two sectors in the mixed regime. Compare the map for limited commitment regime in panel (a) of Figure 14 to its analogue for the pure limited commitment regime in panel (a) of Figure 4. Strikingly, the LC sector in the mixed regime does not feature the very low ability entrepreneurs of the pure LC economy. This is because the relatively high interest rate in the mixed regime makes it unattractive for untalented individuals to become entrepreneurs as their revenues are too low to cover their cost of capital. This results in high sectoral and aggregate TFP. The high wage in the mixed regime is then a direct consequence of high aggregate TFP.

Panel (b) of Table 3 shows the fraction of labor and capital used and supplied by the two sectors. The MH sector uses more than three quarters of the economy's capital. This is because the interest rate in the mixed regime lies in between those in the pure limited commitment

Figure 14: Occupational Choice in LC and MH sectors of Mixed Regime



and moral hazard economies, making capital relatively cheap for the MH sector but relatively expensive for the LC sector. Finally, the MH sector supplies less than half of the economy's labor but more than half its capital. Panel (c) of Table 3 presents the same information in another way, by computing intersectoral capital and labor flows. The MH sector experiences both capital and labor inflows. For example, 30.2 percent of the capital used in the MH sector is owned by the LC sector and hence the MH sector is a net borrower (and conversely the LC sector is a net lender).

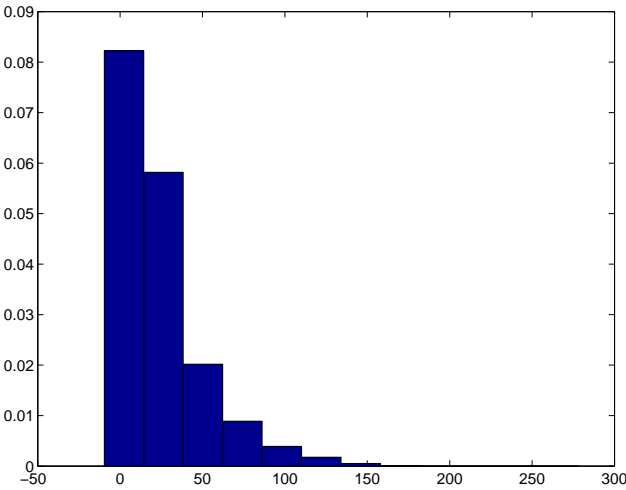
As already mentioned, Paulson, Townsend and Karaivanov (2006), Ahlin and Townsend (2007) and Karaivanov and Townsend (2012) suggest that moral hazard may be more prevalent in urban areas and limited commitment in rural areas. When we take this finding at face value and interpret the MH sector as urban and industrialized areas and the LC sector as rural and agricultural areas, our economy produces interregional patterns of aggregate income, capital and labor flows and external finance that resemble rural-urban patterns observed in the data. In particular, regional income, the aggregate capital stock and the amount of external finance are higher in urban areas, and both capital and labor flow from rural to urban areas.

As already discussed in section 4, our model also predicts that the distributions of various micro-level variables, such as firm size, differ across sectors. It is therefore natural to ask how the differences in such distributions between the LC and MH sectors in the model compare to those observed between rural and urban areas in the data. Panels (a) and (b) of Figure 15 plots the distribution of firm size as measured by a firm's productive assets (its capital) in the LC and MH sectors. Panels (c) and (d) plot the same objects using data from Thailand (Townsend Thai data).<sup>34</sup> The distributions in our model and the data share some remarkable similarity.

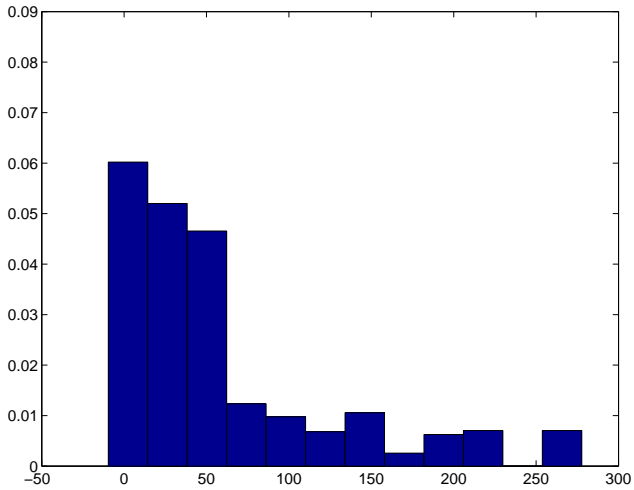
<sup>34</sup>The plots use the 2005-2011 waves of the Townsend Thai Data from four provinces (Lopburi, Chachoengsao,

Figure 15: Firm Size (Capital) Distribution in LC and MH sectors of Mixed Regime

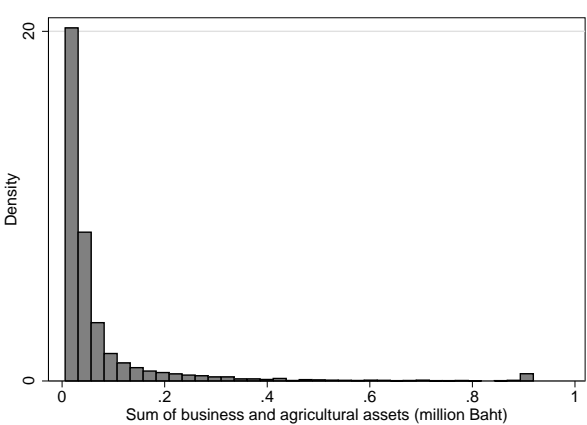
(a) Model: Limited Commitment



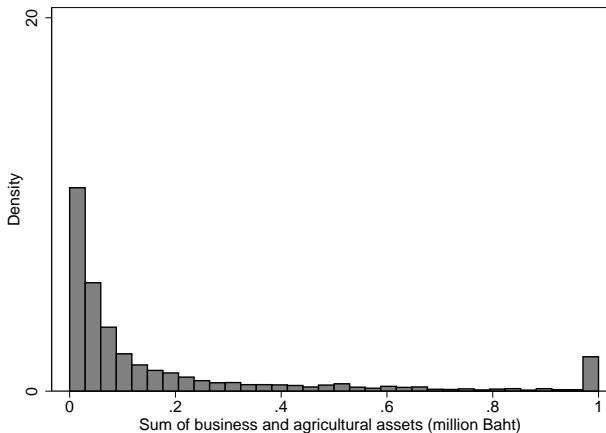
(b) Model: Moral Hazard



(c) Data: Rural



(d) Data: Urban





First, the firm size (asset) distribution is much more compressed in rural areas and in the LC sector. Second, the firm size distribution in the model’s MH sector does have a large number of small firms (the first three bins are large) but then it has a relatively fat right tail. So does the size distribution in urban areas.

Of course, in practice there are likely many other factors that distinguish cities from villages and industrialized from agricultural areas (for example, cities have better infrastructure, higher population density, regions vary in resource base etc). But we nevertheless find it noteworthy that we can generate a number of observed rural-urban patterns by letting only the financial regime differ across these regions.

## 5.2 Importance of General Equilibrium Effects

Finally, note that the non-monotonicity in TFP that we have uncovered in Figure 12 is due to general equilibrium effects. To show this, Figure 16 presents results for the same economy but for the case where the interest rate is fixed at the value of the frictionless economy.<sup>35</sup> In contrast to their counterparts in general equilibrium (Figure 12), in partial equilibrium all variables are monotonic functions of  $m$ . Similarly some of our results about capital and labor flows between the MH and LC sectors change in partial equilibrium. To this end, Table 4 replicates Table 3 but in partial equilibrium. Focussing on panel (c) and comparing it to panel (c) of Table 3 it can be seen that in partial equilibrium *both* the MH and LC sector experience capital outflows. This is because our partial equilibrium is computed at the frictionless interest rate which is strictly higher than the mixed regime interest rate in a closed economy, that is there is a “world interest rate” which is higher than the return on savings that can be obtained in either the LC or MH regimes. That being said, relative to Table 3 it remains true that the LC sector experiences the larger capital outflows than the MH sector and therefore the results are as

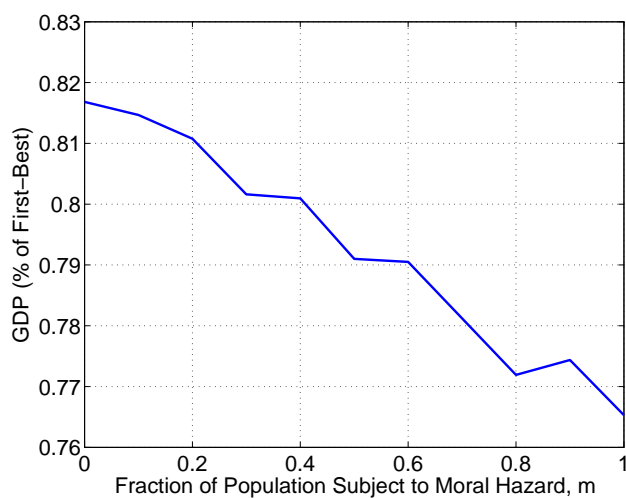
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Buriram, and Sisaket). The urban dataset covers 96 urban communities and is a stratified, clustered, random sample of 15 households in each community. The rural sample is collected over the same time period and covers four villages in each province and about forty households per village. Firm size is defined as the sum of agricultural and business assets, and we drop households who report zero holdings of either category, leaving us with 601 urban and 659 rural households. We chose assets as a measure of a firm’s size rather than employment (as is perhaps more standard), because of the prevalence of self-employed individuals (i.e. few paid employees) in the Townsend Thai data. For comparison with the rural data, the urban data are winsorized at 1 million baht.

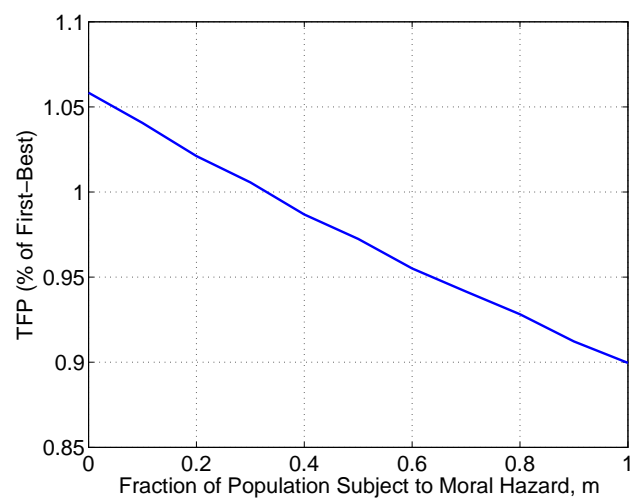
<sup>35</sup>We have also computed equilibria at both the frictionless interest rate and wage. These are somewhat hard to interpret because the wage is so elevated that hardly any of the households choose to be entrepreneurs. We therefore prefer to let the wage adjust so as to clear the labor market, and to compare an economy with only the interest rate fixed with one in which the interest rate (and the wage) are determined in equilibrium. The interest rate is also the price that is more obviously tied to differences in financial regimes because it affects borrowing and lending decisions, and the interest rate is typically taken as given in small open economy papers in the literature whereas the wage is not.

Figure 16: Aggregate Impact of Varying  $m$  in Partial Equilibrium

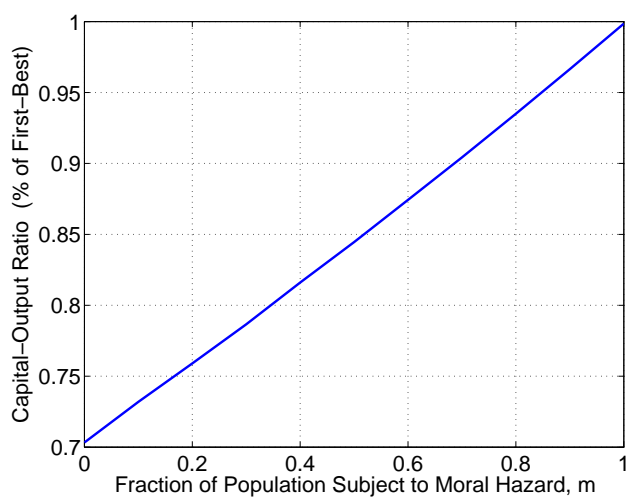
(a) GDP



(b) TFP



(c) Capital-Output Ratio



(d) Labor Supply

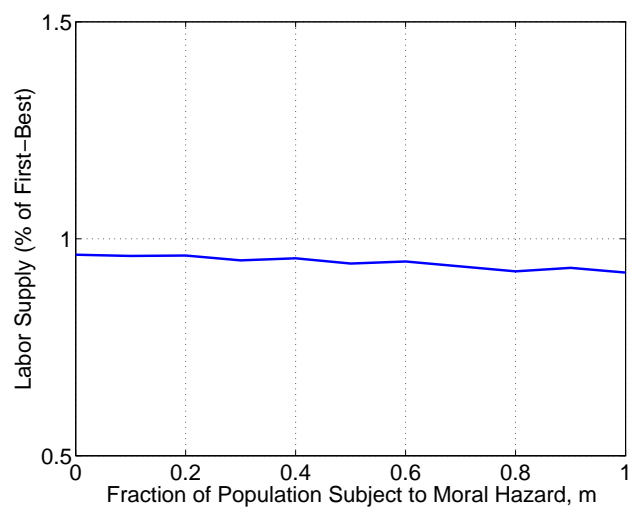


Table 4: Comparison of LC and MH Sectors in Mixed Regime in Partial Equilibrium

	Mixed Regime, $m=0.5$	LC sector	MH sector
	(a) National and Sectoral Aggregates		
GDP (% of FB)	0.791	0.841	0.741
TFP (% of FB)	0.972	1.048	0.905
Capital-Output Ratio (%of FB)	0.845	0.709	0.999
Labor Supply (% of FB)	0.943	1.003	0.883
Welfare (% of FB)	0.972	0.984	0.960
Wage (%of FB)	0.838	0.838	0.838
Interest Rate	0.025	0.025	0.025
% Entrepreneurs	0.160	0.181	0.138
External Finance/Sectoral GDP	1.575	0.993	2.236
	(b) Importance of Sectors in Aggregate Economy		
% Sector Contributes to GDP		0.531	0.469
% of Labor Employed in Sector		0.532	0.468
% of Capital Used in Sector		0.446	0.554
% of Labor Supplied by Sector		0.508	0.492
% of Capital Supplied by Sector		0.526	0.474
	(c) Intersectoral Capital and Labor Flows		
Net Labor Inflow (% of used)		0.043	-0.054
Net Capital Inflow (% of used)		-2.026	-1.193

expected. Much more surprisingly, relative to Table 3, the direction of labor flows is reversed: now labor flows from the MH sector to the LC sector (though the magnitudes are small).

## 6 Robustness of Main Results

### 6.1 Robustness to Alternative Parameterizations

The numerical results we have presented were computed with the parameter values in Table 1. In this section, we briefly discuss in how far each of our results is robust to alternative parameterizations. We have computed results under fourteen alternative parameterizations.<sup>36</sup> We here only briefly summarize these with an emphasis on differences in results, but all detailed results are available on request.

**Aggregates in moral hazard and limited commitment regimes (Table 2).** In almost all our alternative parameterizations, GDP and TFP losses are of similar magnitude (within five percentage points) as those reported in Table 2. Not surprisingly, one exception are variations in the parameter  $\lambda$  governing the tightness of collateral constraints but the differences are in line with results in the existing literature (Buera and Shin, 2010; Buera, Kaboski and Shin, 2011; Midrigan and Xu, forthcoming).<sup>37</sup> A second exception is the parameterization with lower disutility of labor  $\chi = 0.1$  which results in considerably larger GDP losses (but without changing TFP losses by much).<sup>38</sup> A third exception is TFP in the moral hazard regime when we decrease the persistence of entrepreneurial talent from  $\rho = 0.75$  all the way to  $\rho = 0$  which results in TFP losses of only two percent. The capital-to-output ratio, labor supply, welfare, the wage and the percentage of entrepreneurs are more sensitive to parameter values, which is why we do not emphasize these results as much. The equilibrium interest rate is of similar magnitude in all our alternative parameterizations and always considerably smaller under limited commitment than under moral hazard. Finally, the external finance to GDP ratio is of a similar magnitude in all our alternative parameterizations and always twice to three times higher in the MH regime than in the LC regime.

**Behavior of aggregates when varying fraction of population subject to moral hazard,  $m$  (Figures 12 and 13).** In all our alternative parameterizations, aggregates in mixture

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<sup>36</sup>We have studied variations in the parameters  $\beta, \varphi, \chi, \rho, \theta$  and  $\lambda$ .

<sup>37</sup>Decreasing  $\lambda$  from 1.8 to 1 results in higher TFP losses of 28.3 percent and increasing  $\lambda$  to 3 results in smaller TFP losses of 9 percent.

<sup>38</sup>This is because setting  $\chi = 0.1$  rather than  $\chi = 0.525$  results in much larger first-best labor supply. Therefore also first-best GDP, i.e. the denominator in calculations of GDP losses is much larger with lower disutility of labor.

regimes are different from simple convex combinations of the pure limited commit and pure moral hazard regimes (that is, the variables plotted in Figures 12 and 13 are not simply linear functions of  $m$ ). In contrast but not surprisingly, the related result that aggregate TFP is a non-monotonic function of the prevalence of moral hazard  $m$  (see panel (b) of Figure 12) is much more sensitive to parameter values. For example, if  $\lambda = 1$  instead of  $\lambda = 1.8$  as in our benchmark exercise, TFP in the pure limited commitment regime ( $m = 0$ ) is much lower. But TFP in the pure moral hazard regime ( $m = 1$ ) does not depend on  $\lambda$ . The difference between the two extremes is then so large that TFP is no longer non-monotonic for intermediate values of  $m$ .

**Inter-sectoral (regional) patterns of income, external finance, and capital and labor flows (Table 3).** These results are very robust across all our alternative parameterizations. In particular, sectoral (regional) income, the aggregate capital stock and the amount of external finance are always higher in the MH sector (urban and industrialized areas), and both capital and labor always flow from the LC sector (rural and agricultural areas) to the MH sector (urban and industrialized areas).

## 6.2 Robustness to Alternative Functional Forms

Our numerical results were also computed using the functional forms for the utility and production functions, and the talent and residual productivity distributions described in section 3. It is well-known that in moral hazard problems, the functional form of the utility function can be important, in particular whether it is separable. To explore this, we have also computed results for the case where the utility function takes the non-separable form proposed by Greenwood, Hercowitz and Huffman (1988), i.e. there is no wealth effect. This matters for some results but not for others. For example, as is well known, the inverse Euler equation (Lemma 1) does not hold anymore. Similarly, the occupational choice patterns in the MH regime in Figure 4 are now different because there is no longer a wealth effect making rich individuals less likely to exert effort and hence to be entrepreneurs. It should also be relatively easy to compute results for alternative (say CES) production functions, and talent and residual productivity distributions, but we do not have any strong reasons to believe that these would yield different results.

## 7 Conclusion

More research is needed that makes use of micro data and takes seriously the micro financial underpinnings of macro models. One likely reason for the relative scarcity of such studies is

the lack of reliable balance sheet data for firms, including smaller household-firms and household wage earners in developing countries. The Townsend Thai data used by Karaivanov and Townsend (2012) are an exception. See also Samphantharak and Townsend (2009) who construct household balance sheets by treating them in the same way accountants treat corporate firms. The collection of more such data is a very worthwhile project and there are plans to collect such data countrywide. An obvious recommendation is also for other countries to collect such balance sheet data. Some of this could be done as part of the collection of manufacturing censuses that many developing are now collecting quite effectively.

In addition to more and better data, we also need more theoretical research in macroeconomics aimed at furthering our understanding of heterogeneous agent models and the complexities these may entail, especially when more realistic micro financial underpinnings and elements from contract theory are incorporated as in the present paper. In our framework, for example, a financial reform affecting underlying obstacles in one of our financial regimes or regions will set in motion intricate transition dynamics of reallocation both across firms and across regions, and of aggregates like GDP and TFP. In ongoing work, we are currently exploring these possibilities and such transitions do seem to be computable. But much more generally, there should be high payoffs from a better theoretical understanding of heterogeneous agent models and the development of better numerical methods needed to compute them.

Our bottom line: not only does the financial sector matter for real variables, including growth and inequality, but also the details of financial contracts matter for the macro economy. This joins what have been largely two distinct literatures – macro development and micro development – into a coherent whole. The macro development literature needs to take into account the contracts we see on the ground and the micro development literature needs to take into account general equilibrium effects of interventions.

## Appendix

### A Proof of Lemma 1

The Lagrangean for (3) and (4) is

$$\begin{aligned} \mathcal{L} = & \sum_{\varepsilon} p(\varepsilon|e) \{U(c(\varepsilon)) - V(e) + \beta \mathbb{E}_{z'} v[a'(\varepsilon), z']\} \\ & + \psi \left[ (1+r)a + \sum_{\varepsilon} p(\varepsilon|e) \{x[z\varepsilon f(k, \ell) - w\ell - (r+\delta)k] + (1-x)w\varepsilon\} - \sum_{\varepsilon} p(\varepsilon|e) \{c(\varepsilon) + a'(\varepsilon)\} \right] \\ & + \sum_{e, \hat{e}, x} \mu(e, \hat{e}, x) \left[ \sum_{\varepsilon} p(\varepsilon|e) \{U(c(\varepsilon)) - V(e) + \beta \mathbb{E}_{z'} v[a'(\varepsilon), z']\} - \sum_{\varepsilon} p(\varepsilon|\hat{e}) \{U(c(\varepsilon)) - V(\hat{e}) + \beta \mathbb{E}_{z'} v[a'(\varepsilon), z']\} \right] \end{aligned}$$

The first-order conditions with respect to  $c(\varepsilon)$  and  $a'(\varepsilon)$  are

$$\psi p(\varepsilon|e) = p(\varepsilon|e)U'(c(\varepsilon)) + \sum_{e, \hat{e}, x} \mu(e, \hat{e}, x)[p(\varepsilon|e) - p(\varepsilon|\hat{e})]U'(c(\varepsilon))$$

$$\psi p(\varepsilon|e) = p(\varepsilon|e)\beta \mathbb{E}_{z'} v_a(a'(\varepsilon), z') + \sum_{e, \hat{e}, x} \mu(e, \hat{e}, x)[p(\varepsilon|e) - p(\varepsilon|\hat{e})]\beta \mathbb{E}_{z'} v_a(a'(\varepsilon), z')$$

Rearranging

$$\frac{p(\varepsilon|e)}{U'(c(\varepsilon))} = \frac{1}{\psi} \left[ p(\varepsilon|e) + \sum_{e, \hat{e}, x} \mu(e, \hat{e}, x)[p(\varepsilon|e) - p(\varepsilon|\hat{e})] \right] \quad (16)$$

$$\frac{p(\varepsilon|e)}{\beta \mathbb{E}_{z'} v_a(a'(\varepsilon), z')} = \frac{1}{\psi} \left[ p(\varepsilon|e) + \sum_{e, \hat{e}, x} \mu(e, \hat{e}, x)[p(\varepsilon|e) - p(\varepsilon|\hat{e})] \right] \quad (17)$$

Summing (16) over  $\varepsilon$ ,

$$\sum_{\varepsilon} \frac{p(\varepsilon|e)}{U'(c(\varepsilon))} = \frac{1}{\psi}$$

The envelope condition is

$$v_a(a, z) = \psi(1+r) = (1+r) \left( \sum_{\varepsilon} \frac{p(\varepsilon|e)}{U'(c(\varepsilon))} \right)^{-1} \quad (18)$$

From (16) and (17)

$$U'(c(\varepsilon)) = \beta \mathbb{E}_{z'} v_a(a'(\varepsilon), z') \quad (19)$$

Combining (18) and (19) yields (12).  $\square$

## B Capital Accumulation

The purpose of this section is to spell out in detail how capital accumulation works in our economy. We assume that there is a representative capital producing firm that holds bonds,  $B_t$ , issues dividends,  $D_t$ , invests,  $I_t$ , to accumulate capital,  $K_t$  which it rents out to households at a rental rate  $R_t$ . The budget constraint of the capital producer is then

$$B_{t+1} + I_t + D_t = R_t K_t + (1 + r_t) B_t, \quad K_{t+1} = I_t + (1 - \delta) K_t$$

The entire debt of the representative capital producer is held by intermediaries that contract with individuals and hold their wealth,  $a$ . Hence the debt market clearing condition is

$$B_t + \int a dG_t(a, z) = 0, \quad \text{all } t. \quad (20)$$

The capital producer maximizes

$$V_0 = \sum_{t=0}^{\infty} \frac{D_t}{\prod_{s=0}^t (1 + r_s)}.$$

subject to

$$K_{t+1} + B_{t+1} + D_t = (R_t + 1 - \delta)K_t + (1 + r_t)B_t \quad (21)$$

It is easy to show that this maximization implies the no arbitrage condition  $R_t = r_t + \delta$ .<sup>39</sup> Therefore the budget constraint (21) is

$$D_t = (1 + r_t)(K_t + B_t) - K_{t+1} - B_{t+1}$$

and so the present value of profits is

$$V_t = \sum_{s=0}^{\infty} \frac{D_{t+s}}{\prod_{\tau=0}^s (1 + r_{t+\tau})} = (1 + r_t)(K_t + B_t) \quad \text{all } t.$$

Zero profits implies  $K_t + B_t = 0$  for all  $t$ . Using bond market clearing (20), this implies that the economy's aggregate capital stock equals its total wealth

$$K_t = \int a dG_t(a, z), \quad \text{all } t.$$

## C Connection of Private Information Regime to Optimal Dynamic Contract

We here show how the our formulation of the contracting problem under moral hazard, (3) and (4), is related to a more familiar formulation of an optimal dynamic contracting problem under private information. In particular, we show that there is optimal insurance against residual productivity shocks,  $\varepsilon$ , (in a sense defined precisely momentarily) but no insurance against ability shocks,  $z$ . We show that for the special case in which there are only residual productivity shocks and ability is deterministic,<sup>40</sup> our formulation is equivalent to an optimal dynamic contracting problem. That is, there is optimal insurance against residual productivity shocks (subject to incentive compatibility) in this special case. The more general formulation (3) and (4) is then simply this special case with uninsurable ability shocks “added on top”.

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<sup>39</sup>Defining cash-on-hand,  $M_t = (R_t + 1 - \delta)K_t + (1 + r_t)B_t$ , the associated dynamic program is

$$V_t(M) = \max_{K', B'} M - K' - B' + (1 + r_t)^{-1} V_{t+1}[(R_{t+1} + 1 - \delta)K' + (1 + r_{t+1})B']$$

The first order conditions imply  $R_{t+1} = r_{t+1} + \delta$ .

<sup>40</sup>That is, the transition probabilities for entrepreneurial talent are degenerate,  $\mu(z'|z) = 1$  if  $z' = z$  and zero otherwise.



## C.1 Equivalence for Special Case with only Residual Productivity ( $\varepsilon$ ) but no Ability ( $z$ ) Shocks

**Standard Formulation with Promised Utility.** Consider the following problem: maximize intermediary profits (the PDV of income,  $y_t$  given by (2), minus consumption transfers to the agent,  $c_t$ )

$$\Pi_t = \mathbb{E}_t \sum_{\tau=t}^{\infty} \frac{y_{\tau} - c_{\tau}}{\prod_{s=t}^{\tau} (1 + r_s)}$$

subject to providing promised utility of at least  $W_t$  to the household

$$\mathbb{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} u(c_{\tau}, e_{\tau}) \geq W_t$$

and an incentive compatibility constraint for the household. Assume that there are only residual productivity shocks ( $\varepsilon$ ) and that entrepreneurial ability ( $z$ ) is deterministic and fixed over time. Without loss of generality, set  $z = 1$ . To simplify notation, define by  $Y(\varepsilon, e)$  an household's income given optimal choices for capital, labor and occupation

$$Y(\varepsilon, e) = \max_{x, k, \ell} \{x[\varepsilon f(k, \ell) - w\ell - (r + \delta)k] + (1 - x)w\varepsilon\}.$$

If  $W_t = W$  is promised to the household, the intermediary's value  $\Pi_t = \Pi(W_t)$  satisfies the Bellman equation

$$\begin{aligned} \Pi(W) &= \max_{e, c(\varepsilon), W'(\varepsilon)} \sum_{\varepsilon} p(\varepsilon|e) \{Y(\varepsilon, e) - c(\varepsilon) + (1 + r)^{-1} \Pi[W'(\varepsilon)]\} \quad \text{s.t.} \\ \sum_{\varepsilon} p(\varepsilon|e) \{u[c(\varepsilon), e] + \beta W'(\varepsilon)\} &\geq \sum_{\varepsilon} p(\varepsilon|\hat{e}) \{u[c(\varepsilon), \hat{e}] + \beta W'(\varepsilon)\} \quad \forall e, \hat{e} \\ \sum_{\varepsilon} p(\varepsilon|e) \{u[c(\varepsilon), e] + \beta W'(\varepsilon)\} &= W. \end{aligned} \tag{P1}$$

where we have used that the stream of household income is (2).

**Equivalence:** The joint budget constraint of a risk-sharing syndicate is

$$a_{t+1} = y_t - c_t + (1 + r_t)a_t.$$

This can be written in present-value form as

$$0 = \pi_t + a_t(1 + r), \quad \text{for all } t \quad \text{where} \quad \pi_t \equiv \mathbb{E}_t \sum_{\tau=t}^{\infty} \frac{y_{\tau} - c_{\tau}}{\prod_{s=t}^{\tau} (1 + r_s)} \tag{22}$$

are the intermediary's expected future profits. We can use (22) to establish a useful equivalence result.

**Proposition 1** *Suppose the Pareto frontier  $\Pi(W)$  is decreasing at all values of promised utility,  $W$ , that are used as continuation values at some point in time. Then the following dynamic program is equivalent to (P1)*

$$\begin{aligned} v(a) &= \max_{e, c(\varepsilon), a'(\varepsilon)} \sum_{\varepsilon} p(\varepsilon|e) \{u[c(\varepsilon), e] + \beta v[a'(\varepsilon)]\} \quad s.t. \\ \sum_{\varepsilon} p(\varepsilon|e) \{u[c(\varepsilon), e] + \beta v[a'(\varepsilon)]\} &\geq \sum_{\varepsilon} p(\varepsilon|\hat{e}) \{u[c(\varepsilon), \hat{e}] + \beta v[a'(\varepsilon)]\} \quad \forall e, \hat{e} \\ \sum_{\varepsilon} p(\varepsilon|e) \{c(\varepsilon) + a'(\varepsilon)\} &= \sum_{\varepsilon} p(\varepsilon|e) Y(\varepsilon, e) + (1+r)a \end{aligned} \quad (P2)$$

**Proof:** The proof has two steps.

**Step 1: write down dual to (P1).** Because the Pareto frontier  $\Pi(W)$  is decreasing at the  $W$  under consideration, we can write the last constraint of (P1) (promise-keeping) with a (weak) inequality rather than an inequality. This does not change the allocation chosen under the optimal contract.<sup>41</sup> The dual to (P1) is then to maximize

$$\begin{aligned} V(\pi) &= \max_{e, c(\varepsilon), \pi'(\varepsilon)} \sum_{\varepsilon} p(\varepsilon|e) \{u[c(\varepsilon), e] + \beta V[\pi'(\varepsilon)]\} \quad s.t. \\ \sum_{\varepsilon} p(\varepsilon|e) \{u[c(\varepsilon), e] + \beta V[\pi'(\varepsilon)]\} &\geq \sum_{\varepsilon} p(\varepsilon|\hat{e}) \{u[c(\varepsilon), \hat{e}] + \beta V[\pi'(\varepsilon)]\} \quad \forall e, \hat{e} \\ \sum_{\varepsilon} p(\varepsilon|e) \{Y(\varepsilon, e) - c(\varepsilon) + (1+r)^{-1}\pi'(\varepsilon)\} &\geq \pi. \end{aligned} \quad (P1')$$

where  $\pi = \Pi(W)$ . Because  $\Pi(W)$  is decreasing, its inverse  $V(\pi)$  is also decreasing. We can therefore replace the inequality in the last constraint of (P1') with an equality.

**Step 2: express dual in terms of asset position rather than profits.** Let

$$\pi = -a(1+r), \quad \pi'(\varepsilon) = -a'(\varepsilon)(1+r). \quad (23)$$

Substituting (23) into (P1') and defining  $v(a) = V[-(1+r)a]$ , yields (P2).  $\square$

The change of variables (23) simply uses the present-value budget constraint (22) to express the problem in terms of assets rather than the PDV of intermediary profits.

## C.2 General Case: Comparison of Our Formulation with Optimal Contract

**Optimal Contracting Problem.** Consider the following problem: maximize intermediary profits

$$\Pi_t = \mathbb{E}_t \sum_{\tau=t}^{\infty} \frac{y_{\tau} - c_{\tau}}{\prod_{s=t}^{\tau} (1+r_s)}$$

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<sup>41</sup>Note that this would not be the case if  $\Pi(W)$  would be increasing. In that case, replacing the equality by an inequality would change the allocation because it would deliver strictly higher welfare to both parties.

subject to providing promised utility of at least  $W_t$  to the household

$$\mathbb{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} u(c_\tau, e_\tau) \geq W_t$$

and an incentive compatibility constraint for the household. If  $W_t = W$  is promised to the household and its current ability shock is  $z_t = z$ , the intermediary's value  $\Pi_t = \Pi(W_t, z_t)$  satisfies the Bellman equation

$$\begin{aligned} \Pi(W, z) &= \max_{e, c(\varepsilon), W'(\varepsilon)} \sum_{\varepsilon} p(\varepsilon|e) \{Y(\varepsilon, z, e) - c(\varepsilon) + (1+r)^{-1} \mathbb{E}_{z'} \Pi[W'(\varepsilon), z']\} \quad \text{s.t.} \\ \sum_{\varepsilon} p(\varepsilon|e) \{u[c(\varepsilon), e] + \beta W'(\varepsilon)\} &\geq \sum_{\varepsilon} p(\varepsilon|\hat{e}) \{u[c(\varepsilon), \hat{e}] + \beta W'(\varepsilon)\} \quad \forall e, \hat{e} \\ \sum_{\varepsilon} p(\varepsilon|e) \{u[c(\varepsilon), e] + \beta W'(\varepsilon)\} &= W. \end{aligned} \tag{P3}$$

where

$$Y(\varepsilon, z, e) = \max_{x, k, \ell} \{x[z\varepsilon f(k, \ell) - w\ell - (r + \delta)k] + (1 - x)w\varepsilon\}$$

Compare this formulation to the one used in the main text, (3) and (4). Note that under the optimal contract (P3), utility  $W(\varepsilon)$  cannot depend on  $z'$ . That is, the principal absorbs all the gains or losses from  $z$  shocks. In contrast, in the formulation in the main text, (3) and (4), it is the reverse: the agent's utility varies with  $z'$  and its wealth does not. Since agent wealth is a negative scalar multiple of the principal's utility (profits) this means that the principal's welfare is made independent of  $z'$ . Exactly the reverse as in (P3). To see this even more clearly, shut down residual productivity shocks,  $\varepsilon = 1$  with probability one. Then the formulation in the main text, (3) and (4) is an income fluctuations problem, like Schechtman and Escudero (1977), Aiyagari (1994) or other Bewley models. But (P3) is just perfect insurance, with a risk neutral principal.

## D Numerical Solution: Optimal Contract with Lotteries

When solving the optimal contract under moral hazard (3) and (4) numerically, we allow for lotteries as in Phelan and Townsend (1991). This section formulates the associated dynamic program.

### D.1 Simplification

Capital, labor and occupational choice only enter the problem in (3) through the budget constraint. We can make use of this fact to reduce the number of choice variables in (3) from six  $(e, x, k, \ell, c(\varepsilon), a'(\varepsilon))$  to three  $(e, c(\varepsilon), a'(\varepsilon))$ .

Entrepreneurs solve the following profit maximization problem.

$$\bar{\Pi}(z, e; w, r) = \max_{k, \ell} \bar{\varepsilon}(e) z f(k, \ell) - (r + \delta)k - w\ell, \quad \bar{\varepsilon}(e) \equiv \sum_{\varepsilon} p(\varepsilon|e)\varepsilon.$$

Note in particular that capital  $k$  and labor  $\ell$  are chosen *before* residual productivity  $\varepsilon$  is realized (see the timeline in Figure 1). With the functional form assumption in (11), the first-order conditions are

$$\alpha z \bar{\varepsilon}(e) k^{\alpha-1} \ell^{\gamma} = r + \delta, \quad \gamma z \bar{\varepsilon}(e) k^{\alpha} \ell^{\gamma-1} = w$$

These can be solved for the optimal factor demands given effort,  $e$ , talent,  $z$  and factor prices  $w$  and  $r$ .

$$k^*(e, z; w, r) = (\bar{\varepsilon}(e) z)^{\frac{1}{1-\alpha-\gamma}} \left( \frac{\alpha}{r + \delta} \right)^{\frac{1-\gamma}{1-\alpha-\gamma}} \left( \frac{\gamma}{w} \right)^{\frac{\gamma}{1-\alpha-\gamma}}$$

$$\ell^*(e, z; w, r) = (\bar{\varepsilon}(e) z)^{\frac{1}{1-\alpha-\gamma}} \left( \frac{\alpha}{r + \delta} \right)^{\frac{\alpha}{1-\alpha-\gamma}} \left( \frac{\gamma}{w} \right)^{\frac{1-\alpha}{1-\alpha-\gamma}}$$

Realized (as opposed to expected) profits are

$$\Pi(\varepsilon, z, e; w, r) = \varepsilon z k(e, z; w, r)^{\alpha} \ell(e, z; w, r)^{\gamma} - w\ell(e, z; w, r) - (r + \delta)k(e, z; w, r)$$

Substituting back in from the factor demands, realized profits are

$$\Pi(\varepsilon, z, e; w, r) = \left( \frac{\varepsilon}{\bar{\varepsilon}(e)} - \alpha - \gamma \right) (z \bar{\varepsilon}(e))^{\frac{1}{1-\alpha-\gamma}} \left( \frac{\alpha}{r + \delta} \right)^{\frac{\alpha}{1-\alpha-\gamma}} \left( \frac{\gamma}{w} \right)^{\frac{\gamma}{1-\alpha-\gamma}} \quad (24)$$

and expected profits are

$$\bar{\Pi}(z, e; w, r) = (1 - \alpha - \gamma) (z \bar{\varepsilon}(e))^{\frac{1}{1-\alpha-\gamma}} \left( \frac{\alpha}{r + \delta} \right)^{\frac{\alpha}{1-\alpha-\gamma}} \left( \frac{\gamma}{w} \right)^{\frac{\gamma}{1-\alpha-\gamma}} \quad (25)$$

The optimal occupational choice satisfies (note that agents choose an occupation *before*  $\varepsilon$  is realized):

$$x(z, e; w, r) = \arg \max_x \{x \bar{\Pi}(z, e; w, r) + (1 - x)w\bar{\varepsilon}(e)\}$$

Given a realization of  $\varepsilon$ , those who choose to be entrepreneurs realize profits of (24) and those who choose to be workers realize a labor income of  $w\varepsilon$ . Therefore, realized (as opposed to expected) surplus is

$$S(\varepsilon, z, e; w, r) = x(z, e; w, r)\Pi(\varepsilon, z, e; w, r) + (1 - x(z, e; w, r))w\varepsilon.$$

Using these simplifications, the budget constraint in (3) can then be written as

$$\sum_{\varepsilon} p(\varepsilon|e) \{c(\varepsilon) + a'(\varepsilon)\} = \sum_{\varepsilon} p(\varepsilon|e) S(\varepsilon, z, e; w, r) + (1 + r)a. \quad (26)$$

As already noted, the advantage of this formulation is that it features three rather than six choice variables.

## D.2 Linear Programming Representation

A contract between the intermediary and a household specifies a probability distribution over the vector

$$(c, \varepsilon, e, a')$$

given  $(a, z)$ . Denote this probability distribution by  $\pi(c, \varepsilon, e, a'|a, z)$ . The associated dynamic program then is a linear programming problem where the choice variables are the probabilities  $\pi(c, \varepsilon, e, a'|a, z)$ :

$$v(a, z) = \max_{\pi(c, \varepsilon, e, a'|a, z)} \sum_{c, \varepsilon, e, a'} \pi(c, \varepsilon, e, a'|a, z) \{u(c, e) + \beta \mathbb{E}v(a', z')\} \quad \text{s.t.} \quad (27)$$

$$\sum_{c, \varepsilon, e, a'} \pi(c, \varepsilon, e, a'|a, z) \{a' + c\} = \sum_{c, \varepsilon, e, a'} \pi(c, \varepsilon, e, a'|a, z) S(\varepsilon, e, z; w, r) + (1 + r)a. \quad (28)$$

$$\sum_{c, \varepsilon, a'} \pi(c, \varepsilon, e, a'|a, z) \{u(c, e) + \beta \mathbb{E}v(a', z')\} \geq \sum_{c, \varepsilon, a'} \pi(c, \varepsilon, e, a'|a, z) \frac{p(\varepsilon|\hat{e})}{p(\varepsilon|e)} \{u(c, \hat{e}) + \beta \mathbb{E}v(a', z')\} \quad \forall e, \hat{e}$$

$$\sum_{c, a'} \pi(c, \varepsilon, e, a'|a, z) = p(\varepsilon|e) \sum_{c, \varepsilon, a'} \pi(c, \varepsilon, e, a'|a, z), \quad \forall \varepsilon, e \quad (29)$$

(28) is the analogue of (26). The set of constraints (29) are the Bayes consistency constraints.<sup>42</sup>

## D.3 Bounds on Consumption Grid

To solve the optimal contracting problem, we follow Prescott and Townsend (1984) and Phelan and Townsend (1991) and constrain all variables to lie on discrete grids. In order for the discretized dynamic programming problem to be a good approximation to our original problem, it turns out to be important to work with relatively fine grids, particularly for consumption. To achieve this with a limited number of grid points, we choose as tight an upper bound on

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<sup>42</sup>(29) is derived from the timing of the problem as follows. A lottery with probabilities  $\Pr(e)$  first determines an effort,  $e$ , for each household. Then a second lottery with probabilities  $\Pr(c, \varepsilon, a'|e)$  determines the remaining variables. Of course, nature plays a role in this second lottery since the conditional probabilities  $p(\varepsilon|e)$  are technologically determined. It is therefore required that

$$\sum_{c, a'} \Pr(c, \varepsilon, a'|e) = p(\varepsilon|e). \quad (30)$$

We have that

$$\Pr(c, \varepsilon, a'|e) = \frac{\pi(c, \varepsilon, e, a')}{\sum_{c, \varepsilon, a'} \pi(c, \varepsilon, e, a')} \quad (31)$$

Combining (30) and (31), we have

$$\frac{\sum_{c, a'} \pi(c, \varepsilon, e, a')}{\sum_{c, a', \varepsilon} \pi(c, \varepsilon, e, a')} = p(\varepsilon|e),$$

which is (29) above.

Table 5: Variable Grids

Variable	grid size	grid range
Wealth, $a$	30	$[0, 200]$
Ability, $z$	15	$[1, 4]$
Consumption, $c$	30	$[0.00001, \bar{c}(w, r)]$
Efficiency, $\varepsilon$	2	$[0, 2]$
Effort, $e$	2	$[0.1, 1]$

the consumption grid as possible and adjust it when prices change. In particular, given  $(w, r)$ , the upper bound is chosen as

$$\bar{c}(w, r) = r\bar{a} + \max\{\Pi(\varepsilon^H, \bar{z}, \bar{e}; w, r), w\varepsilon^H\},$$

for any given  $(w, r)$ , where  $\underline{a}, \bar{a}$  and so on are the lower and upper bounds on the grids for wealth and other variables, and where the profit function  $\Pi$  is defined in (24). These are the minimum and maximum levels of consumption that can be sustained if the agent were to choose  $a'(\varepsilon) = a$  in (3). Note that this bound is tighter than what is typically chosen in the literature. After solving the dynamic programming problem, we verify that consumption never hits the upper bound. Table 5 lists our choices of grids.

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